A PAPR Reduction Method Based on Modified Artificial Bee Colony Algorithm for OFDM Signals

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March 17, 2019

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Abstract-Orthogonal frequency division multiplexing (OFDM) is a very well-known technique for efficient data transmission over many carriers overlapped in frequency.However high peak to average power ratio (PAPR) is one of the major drawbacks of OFDM transmitted signal ,which increases the cost of high power amplifier(HPA) used in the system.PTS is a simple method to reduce the PAPR , but the conventional PTS transmitter transmitter has very high complexity. This paper proposed a enhanced PTS based on Artificial Bee Colony (ABC)algorithm. Without increasing the complexity of the previous ABC-PTS, the improved algorithm modified the exploration strategy for the problem of invalid search and can search the better combination of phase factors.Simulation results show that the improved ABC-PTS algorithm is an efficient method to produce a better PAPR performance .

Keywords:Orthogonal Frequency Division Multiplexing (OFDM) , peak to average power ratio (PAPR),PTS, Artificial Bee Colony (ABC),ABC-PTS

I. INTRODUCTION

OFDM[1-3] is a multicarrier modulation technology, which can effectively resist multipath fading and greatly improve the transmission rate and capacity of wireless communication system. At present, OFDM is regarded as one of the key technologies in many wireless communication system , such as wireless LAN[4], digital audio broadcasting, digital video broadcasting [5]and other fields. However the OFDM signal has high peak to average power ratio because of the accumulation properties of the IFFT transform .The high PAPR can cause large linear range and high transmitting power at the transmitter equipment.

Recently,many PAPR reduction solutions have been proposed in the literature.The most studied method for PAPR reduction named PTS[6] is a distortionless technique based on combining signal subblocks which are phase-shifted by constant phase factors.The[7]proposes a a iterative flipping algorithm for PTS to search phase factor, which has the computational complexity linearly proportional to the number of subblocks. The[8]is developed by modifying the problem into an equivalent problem of minimizing the sum of phase rotated vectors.The particle swarm algorithm and genetic algorithm are used to research on PAPR reduction in the [9] and [10] respectively,which improve the efficiency of phase factor search.The[11] propose a suboptimal phase optimization scheme based on modified artificial bee colony (ABC-PTS) algorithm.

An enhanced ABC-PTS algorithm is proposed in this paper aiming at the problem of invalidly exploring in the ABC-PTS .The algorithm modified the exploration strategy and got a better rotation factor groups without increasing the complexity of the ABC-PTS.Simulation results show that the improved ABC-PTS can achieve superior PAPR reduction performance than the ABC-PTS.

This paper is organized as follows: in Section 2, the OFDM system mode and PAPR, conventional PTS model are described.The enhanced ABC-PTS algorithm is introduced in Section 3. In Section 4, the simulation results and complexity analysis of the proposed and the other PTS schemes are presented. Conclusions are given in Section 5.

II. SYSTEM MODEL

2.1 OFDM system and PAPR

OFDM system split a high-rate data stream into N low-rate streams that are transmitted simultaneously by orthogonal subcarriers,where N is the number of subcarriers,which is modulated using PSK or QAM.The inverse discrete Fourier transform (IDFT) generates the ready-to-transmit OFDM signal.

For an OFDM symbol of the data to be transformed is denoted by $D=\{D_0,D_1,D_2,...,D_{N-1}\}$ .An IDFT operator is used as an OFDM demodulator to converted the frequency domain signal to time domain with oversampling size $LN=L\times N$. Its time domain output can be represented as

$$x(n)=\tfrac{1}{LN}\sum_{k=0}^{LN-1}D(k)e^{j2\pi\frac{kn}{LN}}\quad \forall n=0,1,...,LN-1 \tag{1}$$

Where L is the oversampling factor. It has been shown in [13]that the oversampling factor $L = 4$ is enough to provide a sufficiently accurate estimate of the PAPR of OFDM signals.The PAPR can be defined as

$$PAPR\ \{x(n)\} = 10 \log_{10} \left\{ \frac{\max\limits_{n=0,1,...,LN-1} (|x(n)|^2)}{\frac{1}{LN}\sum\limits_{n=0}^{LN-1} (|x(n)|^2)} \right\} (dB) \quad (2)$$

2.2 The traditional PTS

The principle of the traditional partial transmit sequence algorithm is to produce some alternative signal by multiplying the optimized rotation factor group to reduce the PAPR.At the probability level,PTS algorithm is proposed to reduce the probability of large PAPR..

The input data block D is equally partitioned into V disjoint sub-blocks $\{D^{(v)}, v = 1,2,...,V\}$ such that.The subblocks data symbols are subjected to IFFT operating with size LN and each data symbol $D^{(v)}$ is rotated by a phase rotated factor $b_v = e^{j\varphi_v}$,where $\varphi_v \in [0,2\pi]$.

After the PTS operation, the transmitted signal becomes $x^{'}(n) = IFFT_N(X) = IFFT_N\{\sum_{v=1}^{V} b_v D^{(v)}\}$.

In the PTS, phase vector $b = [b_1, b_2, ..., b_{V-1}]$ are optimized to find the minimum PAPR value.

III. THE IMPROVED ABC ALGORITHM FOR PAPR REDUTION

3.1 ABC algorithm

The artificial bee colony(ABC) is a recently proposed optimisation algorithm that simulates the foraging behavior of honeybee colonies[12].In the ABC algorithm,the colony of artificial bees contains three groups of bees:employed bees, onlookers and scouts.They carry out their duties and share the nectar information of the food sources (solutions) and their position information so as to find the optimized position of food source.Employed Bees response for the exploration and discovery of rich quality of food source and share the nectar information of the food sources and their position information with the onlooker bees.All onlooker bees evaluate the nectar information of each food source and chooses the one with a higher probability based on its nectar amount as a neighborhood food source .The scout bees are mainly responsible for finding new untapped food source

In the ABC, a food source position represents a possible solution to the optimisation problem and the nectar amount of a food source corresponds to the quality (fitness) of the associated solution.If a solution representing a food source cannot be improved by a predetermined number of trials, then the employed bee of an exhausted food source becomes a scout and starts to search randomly for a new food source.

3.2 The improved ABC-PTS

The ABC-PTS in[11] is applied effectively to selecting rotation factor of PTS.

However, there is drawbacks of redundant computation, which is analyzed as follows:

Due to the PTS solution space is discrete, among which candidate solutions is of a small number .Notice that the strategy of neighborhood search in[11]using(4)and(5) exists a greater probability of $b_{il}^{'} = b_{il}$, which means the new solution and current solutions are the same.In this case,the exploration failed because there is no optimization of the solution and no favorable information of better solution obtaining .

$$b_{il}' = b_{il} + \phi_{il}(b_{il} - b_{kl}) \quad (4)$$

where $l \in \{1, 2, ..., M\}$ and $k \in \{1, 2, ..., J\}$, $i \neq k$, J is the number of employed bees (the number of food sources).and ϕ_{il} is a random number between [-1,1]. Due to b_{il}' is the discrete coordinate, thus (4) is modified to the following formulas:

$$b_{il}' = \begin{cases} 1, & if\ \ \pi/4 \le b_{il}' \le 5\pi/4, \\ -1, & else, \end{cases}$$

or (5)

$$b_{il}' = \begin{cases} j, & if\ \ \pi/4 \le b_{il}' \le 3\pi/4, \\ -1, & if\ \ 3\pi/4 \le b_{il}' \le 5\pi/4, \\ -j, & if\ \ 5\pi/4 \le b_{il}' \le 7\pi/4, \\ 1, & else, \end{cases}$$

To solve this problem, an improved ABC-PTS algorithm is proposed in this paper.

The improved ABC-PTS algorithm modified the strategies of neighborhood search of the ABC-PTS.

In standard ABC algorithm[14],the neighborhood search strategy is to selection a dimension l randomly and update the value in this dimension l by (4) , which essentially means that $b_{il}^{'}$ (the value of the solution to be updated $b_i^{'}$ in the dimension l)is randomly learning from b_{kl} (the value of the learning objects b_k in the same dimension l). If $-1 \le \phi_{il} < 0$,it means that b_{il} is approaching to b_{kl} and then the results of learning is that the value of b_{il}' is between b_{il} and b_{kl} . Particularly, when $\phi_{il} = -1$,it mans that b_{kl} is completely becoming the learning object and then $b_{il}' = b_{kl}$ .If $0 < \phi_{il} \le 1$,it means that b_{il} is deviating from b_{kl} and then the results of learning is that the value of b_{il}' is between b_{il} and $2b_{il} - b_{kl}$. Particularly, when $\phi_{il} = 1$,it mans that b_{kl} is further away from the learning object b_{kl} and then $b_{il}' = 2b_{il} - b_{kl}$ .The principle of learning is shown in Figure.1.

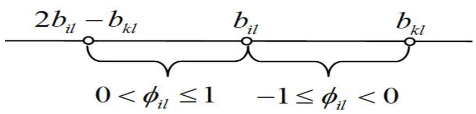

Figure.1. the principle of learning

Based on the neighborhood exploration ideas of the standard ABC algorithm and considered with the discrete solution space and solutions of a small number, the improved ABC-PTS is proposed:firstly randomly determine whether approaching to the learning object or deviating from the learning objects (hereinafter referred to as positive learning or reverse learning);then randomly choose the dimension of the solution to be updated .Details are described as follows:

A.The determination of the dimension l of the solution to be updated

Firstly,the current food source is compared with another employed bee position by each dimension then dimensions of the same value and the different value are separately recorded in set D_{same} and set D_{dif} ,which means that $D_{same} = \{d_1, d_2, ..., d_m\}$, where any element d_x of D_{same} satisfies $b_{id_x} = b_{kd_x}$; $D_{dif} = \{d_1, d_2, ..., d_n\}$, where any element d_x of D_{dif} satisfies $b_{id_x} \ne b_{kd_x}$ .Obviously $m + n = V$.

Secondly, determine the direction of learning(positive learning or reverse learning)by generating a random number a from $[0,1]$ .if $a \le 0.5$, then the direction of learning is positive,otherwise reverse.

Next,if the direction of learning is positive,then $l = RAND(D_{dif})$,which is defined as selecting a dimension l from D_{dif} randomly.if the direction of learning is reverse,then $l = RAND(D_{same})$,which is defined as selecting a dimension from D_{same} randomly.

Especially,If there is no element in D_{dif} , it is determined to reverse learning; if there is no element in D_{same} , it is determined to positive learning.

B. The strategy of updating

The new food source position $b_i^{'}$ is produced by the follow formula:

$$b_{il}^{'} = NRAND(R, b_{il}) \qquad (6)$$

where $NRAND$ is defined as selecting a solution which is not equal to b_{il} from the solution space R randomly .

The above strategies of neighborhood exploration can certainly guarantee the next generation $b_i^{'}$ is different from the current generation b_i , which avoids the problem of the new solution without updating in ABC-PTS. On the other hand,the determination on the direction of learning is random which maintains the exploration ideas of the standard ABC algorithm.

The main steps of the improved ABC-PTS algorithm are summarized as follows:

1.Initialize the value of $limit$ and the maximum iteration number G .

2.generate S randomly distributed initial solutions in solution space.

3.evaluate the fitness of the each solution using (7),and the $\frac{S}{2}$ solutions with larger fitness are assigned as employed bees.

$$fitness(b_i) = \frac{1}{1 + f(b_i)} \qquad (7)$$

4.Each employed bee selects one of the other employed bees as the learning object .Use the strategies of neighborhood search proposed in this section to determine a neighborhood solution of the present one and its fitness value is evaluated by (7). If the new fitness is higher than that of the previous solution, the employed bee is modified to the new position (solution)and forgets the old one.

5.calculate the probability value associated with each employed bee by

$$p_i = \frac{fitness(b_i)}{\sum_{i=1}^{S} fitness(b_i)} \qquad (8)$$

6.Each onlooker selects an employed bee depending on the probability value calculated in $Step5$ and become such an employed bee.Then use the proposed strategies of neighborhood search in this section to determine a neighborhood solution of the present one and its fitness value is evaluated by (7). If the new fitness is higher than that of the previous solution, the employed bee is modified to the neighborhood solution and forgets the old one.

7.Memorize the best employed bee representing the optimized solution

8.For each employed bee,abandon it if not be modified by a predetermined number $limit$, and randomly generate a new solution in solution space as this employed bee.

9.If the maximum iteration number is reached, output final solution and stop.Otherwise go to $Step4$.

C.Complexity Analysis for the improved ABC-PTS and the Existing PAPR Reduction Methods

The improved ABC-PTS has the same complexity with the ABC-PTS algorithm in [11].The calculation(here each calculation includes IFFT and PAPR) complexity of which is proportional to SG ,where S is the size of population and G is the maximal iterations. The complexity of OPTS[6] is K^{V-1} ,where K is the size of rotation factor space, V is the number of subblocks);The IPTS[14] has the computational complexity linearly proportional to the length of symbol , i.e $2N$. The complexity of the improved ABC-PTS and the ABC-PTS are similarity proportional to SG ,where S is the size of particle swarm, G is the maximal generations of ABC-PTS .

IV. SIMULATION RESULT

To evaluate the proposed improved ABC-PTS algorithm (IABC-PTS),we have carried out computer simulations. 10^4 OFDM symbols are randomly generated.In simulations, 16-QAM modulation with $N = 128$ sub-carriers is used and the phase factor $K = 2$ is chosen.and IABC-PTS and ABC-PTS have the same parameter setting,where the number of maximal iteration is $G = 30$ and $limit = 30$, the size of population is $S = 30$ .The PAPR reduction performance of OPTS and the original OFDM signal are also simulated .The simulation results are shown in figure .2.

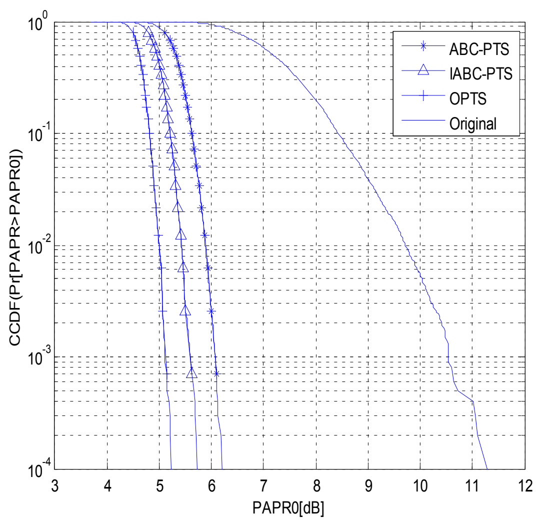

Fig. 2. Comparison of PAPR reduction among the improved ABC-PTS with the other methods, $K = 2$, $V = 16$.

When $P_r(PAPR > PAPR_0) = 10^{-3}$, the PAPR of the original OFDM is10.54dB.The PAPRs by OPTS and ABCPTS are reduced to 5.11dB and 6.07dB respectively.The PAPR by the proposed improved ABC-PTS (IABC-PTS) are reduced to5.6dB. Compared to the PAPR by ABPTS, the PAPR by the IABC-PTS wit $S = 30$ has a gap approximately0.47dB.The calculation complexity of the OPTS is $K^{V-1} = 2^{16-1} = 32768$.
But the calculation complexity of the IABC-PTS is $SG = 30 \times 30 = 900$ equal to that of the ABC-PTS.

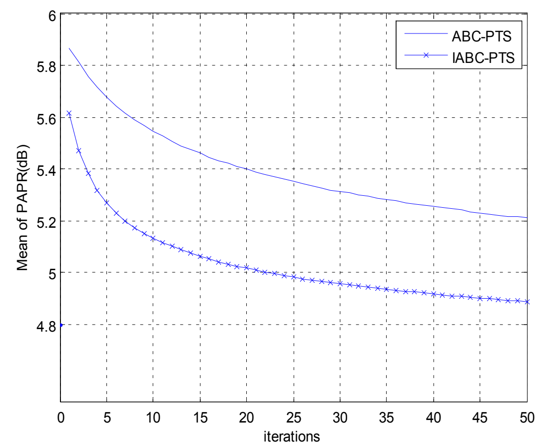

Fig.3. Comparison of mean of PAPR for IABC-PTS and ABC-PTS

For the IABC-PTS algorithm and the ABC-PTS algorithm,10000 experiments are performed to compare PAPR convergence performance for an OFDM symbol,where $S = 30$ and $G = 50$ .The simulation results is shown in Figure.3. When the iterations is 20,the mean PAPR of ABC-PTS is 5.399dB and that of the IABC-PTS is 5.018dB,reduced by0.381dB.When the iterations is 50, the mean PAPR of ABC-PTS is 5.212dB and that of the IABC-PTS is 4.889dB,reduced by 0.3823dB. Although the PAPR performance of the IABC-PTS is improved with iteration number increasing, the mean of PAPR by 20 iterations is only 0.129dB less than by 50 iterations, but the complexity is increased by 1.5 times.So 20 iteration number can be a suitable choice for our proposed IABC-PTS algorithm.

V. CONCLUSIONS

In this paper, we propose a improved ABC based PTS algorithm (IABC-PTS) to search better combination of phase factors for OFDM signals. Compared to the existing ABC-PTS algorithm ,the IABC-PTS can get better PAPR reduction without increasing the computational complexity at the same time.Moreover,The strategies of neighborhood exploration proposed in the paper can solve the problem that the solution is not up in ABC-PTS algorithm.Simulation results show that the IABC-PTS algorithm is an efficient method to produce a better PAPR performance.

ACKNOWLEDGMENT

This work is supported by the Guangdong Provincial Natural Science Foundation of China,Grant 35000-42030423.

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