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An Overview of PAPR Reduction Optimization Algorithm for MC-CDMA System

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ABSTRACT
Multicarrier Code Division Multiple Access (MC-CDMA) has attracted lot of attention from researchers as it plays an important role in wireless communication. The challenging problem of MC-CDMA is high peak to average power ratio due to large number of sub-carriers which reduces the system performance. There are many PAPR reduction techniques for MC-CDMA. This paper focus on review of different optimization methods used for PAPR reduction. To reduce PAPR the restraints are low power consumption, and low Bit Error Rate (BER).
Keywords - Ant colony optimization, MC-CDMA, ODFM, Peak to average power ratio

I INTRODUCTION

Future wireless systems such as fourth generation (4G) cellular will need tractability to provide subscribers with a variety of services such as voice, data, images and video signal. Code division multiple accesses (CDMA) have shown very successful for large scale cellular voice systems, but there is some aqnosticism about whether CDMA will be well-suited to non-voice traffic [1]. Multicarrier CDMA (MC-CDMA) has emerged as a powerful alternative to conventional direct sequence CDMA (DSCDMA) in mobile wireless communications.

Multicarrier code division multiple access (MC-CDMA) is combination of code division multiple access (CDMA) and orthogonal frequency division multiplexing (OFDM). It is a very attractive wireless communication system. The MC-CDMA has advantages of both the CDMA and OFDM systems. MC CDMA technique achieve high data rate transmission with protection against both frequency selective fading and time dispersion channel while at the same time offers a spectrum efficient multiple access strategy [2]. In Multi-Carrier CDMA, the input data streams are split into several sub-streams in parallel, and then modulate several subcarriers with each sub-stream before transmitting signals.

Despite the advantages of the MCCDMA, one of the main drawbacks is high peak-to-average power ratio (PAPR), which causes bit-error-rate (BER), performance degradation of the system. The PAPR has disadvantages such as the design complexity of Analog to Digital Converter (ADC) and Digital to Analog Converter (DAC). The high PAPR should be reduced to eliminate the non-linear distortion effect of the high-power amplifier (HPA) [3].

To reduce high PAPR, various techniques are proposed which are used for both OFDM and MC CDMA. These techniques are divided into three categories: signal distortion techniques, signal scrambling techniques and coding techniques. Signal distortion schemes include clipping, peak windowing, peak cancellation and companding. Scrambling scheme includes Selected Mapping (SLM), Partial Transmit Sequence (PTS). Coding techniques are used for signal scrambling, such as Golay complementary sequences, Shopire-Rudin sequences, and barker codes. To reduce high PAPR of MC CDMA, there are many optimization algorithm present like swarm optimization, which is basic of all other algorithms. Other algorithm are chip optimization, artificial ant colony optimization, genetic algorithm, artificial bee colony algorithm etc. In this paper we have described review of different algorithms.

This paper is organised as follow: in section 2, MC-CDMA system model, PAPR of MC CDMA are described. In section 3, various optimization algorithms such as artificial bee colony algorithm, chip interleaving and its optimization genetic algorithm, ant colony optimization are described. In section 4, the paper is concluded.

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II SYSTEM DESCRIPTION
2.1 MC-CDMA System Model

In MC-CDMA model, there are K active users and for each kth user $d^{((k))} = [d_1^{(k)}, d_2^{(K)}, ..., d_M^{(K)}]$ denotes the M modulated data symbols, where k=1,2,...,K. Modulated data symbols are converted into M parallel data streams. After this conversion each symbol is multiplexed by a user specific spreading code $c^{(k)} = [c_1^{(k)}, c_2^{(k)}, ..., c_j^{(k)}]$, where j represents the spreading factor (SF) or spreading code. Data of multiple user's can be transmitted in same frequency space and at same time as the spreading codes have property of orthogonally as shown in Fig 1. In this, we use Walsh hadamard sequences as spreading sequences. The input of K user is added and interleaved in frequency domain as $X = [X_0, X_1, ..., X_{N-1}]^T$, where N is number of sub carriers. After frequency interleaving, the interleaved symbols are input into the IFFT block of size N=M×J. The resultant baseband signal for MC-CDMA is expressed as:

$$x(t) = \frac{1}{\sqrt{N}} \sum_{m=1}^{M} \sum_{j=1}^{J} \sum_{k=1}^{K} d_m^{(k)} c_j^{(k)} e^{j2\prod\{M(j-1)+(m-1)\}t/T_S}$$

(1)

Where, T_s is symbol period of signal, in which $0 \le t \le T_s$ [4].
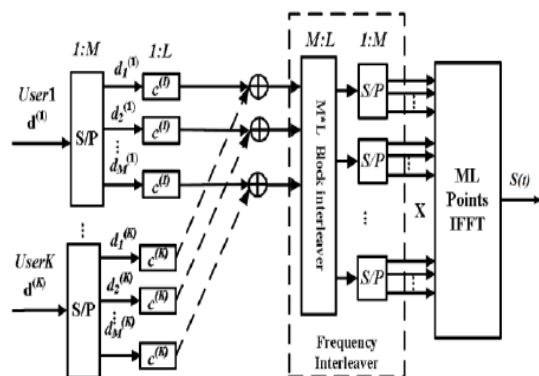

Fig 1: MC-CDMA transmitter model [4]

2.2 Peak To Average Power Ratio

Though MC-CDMA is a powerful multiple access technique but it is not problem free. The challenging problem of MC CDMA is high PAPR. In time domain, multicarrier signal is the result of addition of many narrowband signals. This addition is large at some time instances and small at other, it means that the peak value of the signal is larger than the average value [5]. MC-CDMA has large number of independently modulated sub carriers and N modulated subcarriers are added with same phase. So peak power becomes N times the power of MC-CDMA signal. High PAPR values causes a serious problem to linear power amplifier (PA) used at transmitter.

PAPR of the MC-CDMA signal is the ratio of the peak power to the average power of a multicarrier signal. It is represented as:

$$\text{PAPR} = \frac{p_{peak}}{p_{average}} = 10 \log_{10} \frac{\max \left| \left. x(t) \right|^2 \right.}{E\left[\left| x(t) \right|^2 \right]}$$

(2)

where p_{peak} is output peak power and $p_{average}$ is output average power.

III PAPR REDUCTION OPTIMIZATION ALGORITHM
3.1 Artificial Bee Colony Algorithm

The ABC algorithm is a swarm-based optimization algorithm, which simulates intelligent foraging behavior of a honeybee swarm. In this, the position of a food source gives a possible solution to the optimization problem and quantity of nectar in the food source corresponds to quality (fitness) of the associated solution. Foraging bees are classified into three phases, employed, onlookers and scouts. At initial phase, the ABC yields a randomly distributed population with employed bees. An employed bee generates a modification of position (solution) in her memory, depending on the local information (visual information), and investigates the nectar amount (fitness value) of the new source. If amount of new nectar is higher than the previous source, the bee memories the new position and forgets the old one. Otherwise, bee memories the position of the previous source in her memory.

After all employed bees finish this search process, they share the nectar information about food sources and their position information with the onlooker bees. An onlooker bee judges the nectar information taken from the employed bees and prefers the food source with probability related to its nectar amount. Like the employed bee, the onlooker bees make a modification of the position in her memory and examine the nectar amount of the potential source. If amount of nectar is higher than that of the previous source, the bee memories the new position and forgets the old one.

After the completion of searches of onlooker bees, scouts are determined. The employed bee of an exhausted source becomes a scout and begins to search randomly for a new food source. These steps are repeated through a number of cycles, called

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maximum number of cycles, or until a termination standard is satisfied. The main steps of the ABC algorithm are:

- Initialize the population
- Repeat
- Place the employed bees on their food sources
- Place the onlooker bees on the food sources depending on their nectar amounts
- Send the scouts bees to the search area for discovering new food sources
- Memories the best food source solution achieved so far
- until requirements are met [6].

3.2 Chip Interleaving and Optimization

This reduction technique is used for uplink in M-modification in MC-CDMA system. In M-modification, total number of subcarriers N_C is divided into m groups having L sub-carriers in each. For one user (uplink) every group of L subcarriers transmits one symbol spread with sequence of length L. The user transmits M parallel data symbols on all sub-carriers. Walsh sequences are used for spreading in this case and introduce some kind of redundancy to the system. For example sequence 1-1 1 will continue with -1. OFDM based systems (MC-CDMA included) are presented in time domain by addition of sinusoids. The peak value of addition of sinusoids (representing chip sequences) is reduced by changing the position of chip. When no chip interleaving is used, the first chip is on first sub-carrier, second chip on the second sub-carrier, etc. This can be symbolized by vector [1 2 3 4 5…*Nc*]. The permutation of vector, for example [3 6 9 13 …], symbolized the chip interleaving pattern where the first chip is modulated on third sub-carrier, second chip on the sixth sub-carrier and so on.

The principle of this access is to find the interleaving pattern which minimizes PAPR. The chip interleaving pattern must be same for all users in the system to keep orthogonally among them, Number of possible interleaving pattern stands with the number of sub-carriers in system which makes direct search algorithm improper for the system with more sub-carriers. So, optimum searching algorithms such as Genetic Algorithm (GA) and Ant Colony Algorithm (ACA) are used to solve this problem [7] [8].
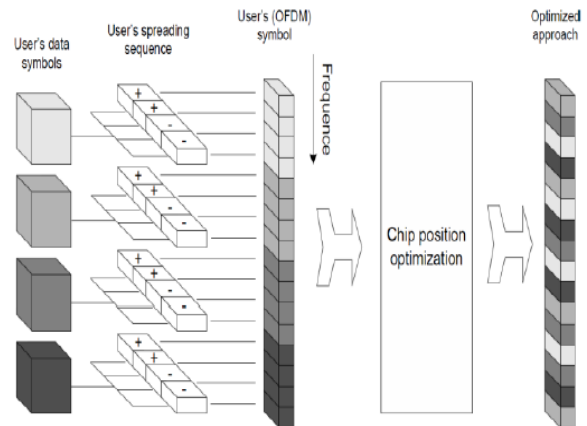

Fig 2: M- Modification of MC CDMA and its optimization [7]

3.3 Genetic Algorithm

Genetic optimization is based on the technique known as swarm intelligence, which is a part of artificial intelligence. The GA use combination of previous best solutions to obtain better one. This algorithm starts with random set of solutions called population. In every step (generation) new population is created from the old one. New individuals are made from old ones (parents). The probability for an individual becoming the parent depends upon its fitness function. The variation is introduced to prevent falling in local optimum.

Permutation encoding is used for implementing of chip spreading. In permutation encoding, each individual is represented by string of numbers (1…..48) that represents the position in a sequence. The fitness function (mean PAPR of that sequence for all possible data) is measured for each individual. The parent selection is made on random selection of 3 individuals and finds the best of them (according to fitness) which became parent. Crossover is created by one crossover point selection and permutation is copied from first parent till the crossover point and rest is from second parent. After that, the duplications of numbers must be interchanged by unused ones. The variation is made by simple swap of two numbers; one variation in one generation is presented. The best solution in the current generation is called elite and it is replicate in the next generation without differences (until better one is founded) [9]. Fig. 3 describes the value of fitness function in particular generations.
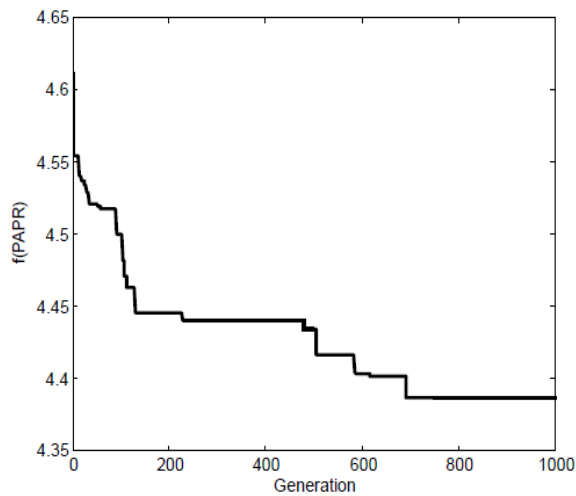
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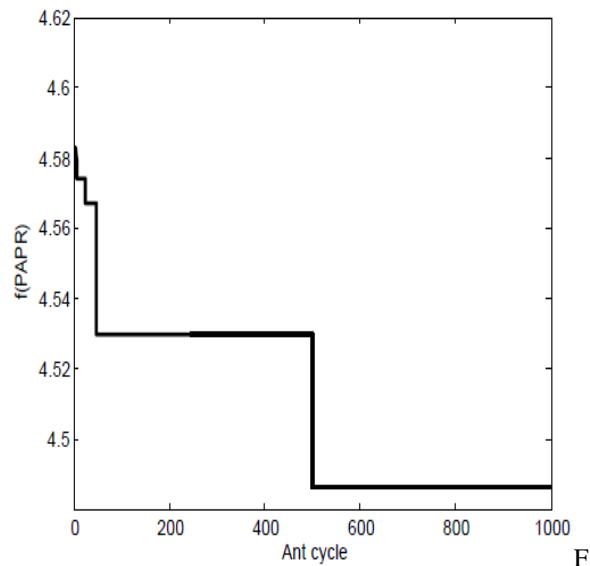*(AET- 29th March 2014)*

Fig 3: GA optimization process [9]

3.4 Ant Colony Optimization

Ant Colony Optimization (ACO) is a metaheuristic approach for solving hard combinatorial optimization problems [10]. This technique represents distributed solution of difficult problems by lots of locally interacting simple agents called ants. They travel by sections called towns to make complete way with all towns. Each ant left trail on its way. The intensity of trail depends upon PAPR of sequence built by the ant. The ant makes decision which town will be visited next depending on trial laid on the way to towns. This makes the positive feedback in the algorithm. The pheromone trail act as communication medium between real ants. The pheromone trails in ACO service as distributed, numerical information which the ants use to probabilistically make solutions to the problem being solved. The PAPR of sequence is evaluated only after complete tour of ants, so trial is computed only ones in complete cycle.

The trail intensity is updated after complete cycle according to:

$$T_{ij}(t+1) = Q.T_{IJ}(t) + \Delta T_{ij} \qquad (3)$$

where Q is coefficient such that $(1 - Q)$ represents evaporation of trail. The ΔT_{ij} is tray intensity increment on edge (i, j) (between towns i and j) obtained as:

$$\Delta T_{ij} = \sum_{k=1}^{m} \Delta T_{ij}^{k} \qquad (4)$$

Where ΔT_{ij} is the quantity of trail substance [9].
The running of algorithms is visualized as function of best solution (elite) according to Cycle in Fig.4.

Fig 4: ACO Process [9]

IV CONCLUSION

In this paper, we have presented different optimization algorithm for PAPR reduction which is challenging problem in MC CDMA. Although Chip interleaving has advantages of low complexity, no performance degradation, no side information but worst case of PAPR is still present. ABC algorithm has low computational complexity and less computational time. GA is slightly better and has less computation time. ACO is better among all as it reduces the probability of having PAPR value. Besides this, ACO has small complexity and no side information.

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