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Study of Various Algorithms on PAPR Reduction in OFDM System

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Abstract

Artificial Bee Colony algorithm (ABC) is a swarm intelligence algorithm proposed by Karaboga in 2005, which is inspired by the behavior of honey bees. In this paper we make use of this algorithm to reduce PAPR in OFDM .Orthogonal frequency division multiplexing (OFDM) is an attractive technique for wireless high-rate data transmission as it minimizes effect due to frequency- selective fading channels. However, OFDM has some drawbacks in the transmission system. One of the major problems of the OFDM system is that OFDM signal has higher peak to-average-power ratio (PAPR) than single carrier signal because OFDM signal is the sum of many narrowband signals in the time domain. The high PAPR can cause inter-modulation and out-of-band radiation due to power amplifier nonlinearity. Therefore, it is highly desirable to reduce the PAPR of an OFDM signal. Many methods have been proposed including Partial Transmit Sequence (PTS) , Selective Level Mapping (SLM) and some more. Here a newly suboptimal method based on artificial bee colony (ABC-PTS) algorithm is proposed to search the better combination of phase factors.

Keywords: *OFDM block, PAPR SLM, PTS, PTS-ABC.*

INTRODUCTION

Orthogonal frequency division multiplexing (OFDM) is a widely used modulation and multiplexing technology, which has become the basis of many tele-communication fields. OFDM is a “Multi-Carrier Transmission Scheme” which is a good solution for high speed digital communications. In this the data to be transmitted is spread over a large number of orthogonal carriers, each being modulated at a low rate. The carriers can be made orthogonal by appropriately choosing the frequency spacing between them. Therefore, OFDM is an advanced modulation technique which is suitable for high-speed data transmission due to its advantages in dealing with the multipath propagation problem, high data rate and bandwidth efficiency. OFDM has several attractive features which make it more advantageous for high speed data transmission over other data transmission techniques. These features include High Spectral Efficiency, Robustness to channel fading, Immunity to impulse interferences, Flexibility, Easy equalization. But in-spite of these benefits there are some obstacles in using OFDM like OFDM signal exhibits very high Peak to Average Power Ratio (PAPR), very sensitive to frequency errors (Tx. & Rx. offset), Inter Carrier Interference (ICI) between subcarriers.

To reduce PAPR, there are several techniques like Selective Level Mapping, Partial Transmit Sequence, PTS-ABC and some more.

SPECTRAL EFFICIENCY OF OFDM

OFDM is a special case of FDM (Frequency Division Multiplexing). In FDM, the given bandwidth is subdivided among a set of carriers. There is no relationship between the carrier frequencies in FDM. For example, as shown in Figure 1, consider that the given bandwidth has to be divided among 5 carriers (say a, b, c, d, e). There is no relationship between the subcarriers; a, b, c, d and e and we can transmit anything within the given bandwidth. If the carriers are harmonics, say (b=2a, c=3a, d=4a, d=5a , integral multiple of fundamental component a) then they become orthogonal. This is a special case of FDM, which is called OFDM (as implied by the word – ‘orthogonal’ in OFDM). Figure 2 shows a typical OFDM transmitter.

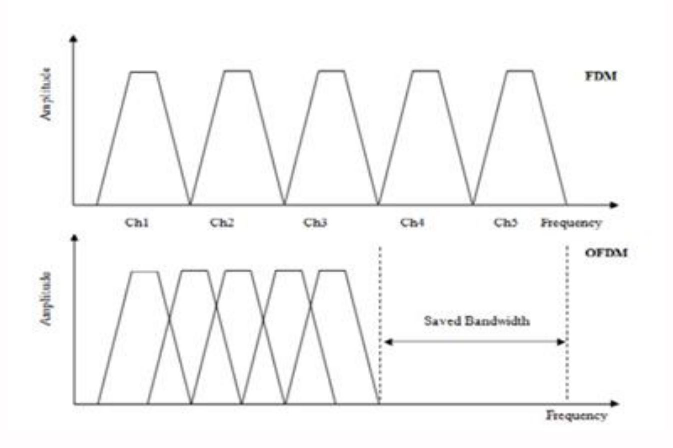

Figure 1. Comparing OFDM with FDM

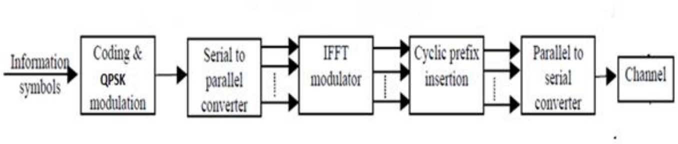

Figure 2. OFDM Transmitter block diagram

PAPR Problem

One of the new problems emerging in OFDM systems is the so-called Peak to Average Power Ratio (PAPR) problem. The input symbol stream of the IFFT should possess a uniform power spectrum, but the output of the IFFT may result in a non-uniform or spiky power spectrum. Most of transmission energy would be allocated for a few instead of the majority subcarriers. This problem can be quantified as the PAPR measure. It causes many problems in the OFDM system at the transmitting end.

The PAPR is the relation between the maximum power of a sample in a given OFDM transmit symbol divided by the average power of that OFDM symbol. PAPR occurs when in a multicarrier system the different sub-carriers are out of phase with each other. At each instant, they are different with respect to each other at different phase values. When all the points achieve the maximum value simultaneously; this will cause the output envelope to suddenly shoot up which causes a 'peak' in the output envelope. Due to presence of large number of independently modulated subcarriers in an OFDM system, the peak value of the system can be very high as compared to the average of the whole system. This ratio of the peak to average power value is termed as Peak-to -Average Power Ratio. An OFDM signal consists of a number of independently modulated sub-carriers which can give a large PAPR when added up coherently. When N signals are added with the same phase they produce a peak power that is N times the average power of the signal. So OFDM signal has a very large PAPR, which is very sensitive to nonlinearity of the high-power amplifier.

EFFECT OF PAPR

A major obstacle is that the OFDM signal exhibits a very high Peak to Average Power Ratio (PAPR).Therefore, RF power amplifiers should be operated in a very large linear region. Otherwise, the signal peaks get into non-linear region of the power amplifier causing signal distortion. This signal distortion introduces inter-modulation among the subcarriers and out of band radiation. Thus, the power amplifiers should be operated with large power back-offs. On the other hand, this leads to very inefficient amplification and expensive transmitters. Thus, it is highly desirable to reduce the PAPR. These large peaks cause saturation in power amplifiers, leading to inter-modulation products among the subcarriers and disturbing out of band energy. Therefore, it is desirable to reduce the PAPR.

SIGNAL SCRAMBLING TECHNIQUES

The fundamental principle of these techniques is to scramble each OFDM signal with different scrambling sequences and select one which has the smallest PAPR value for transmission. Apparently, this technique does not guarantee reduction of PAPR value below a certain threshold, but it can reduce the probability of high PAPR to a great extent. This type of approach includes: Selective Mapping (SLM) and Partial Transmit Sequences (PTS).

SELECTIVE LEVEL MAPPING(SLM)

In the SLM, the input data sequences are multiplied by each of the phase sequences to generate alternative input symbol sequences. Each of these alternative input data sequences is made the IFFT operation, and then the one with the lowest PAPR is selected for transmission.

In selection mapping method, firstly M statistically independent sequences which represent the same information are generated, and next, the resulting M statistically independent data blocks for m=1,2,..M are

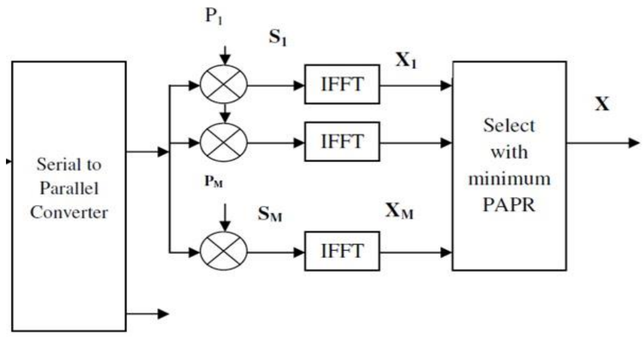

Figure 3. Block Diagram Of SLM

then forwarded into IFFT operation simultaneously. The discrete time-domain sequences are acquired and then the PAPR of these M vectors are calculated separately. Eventually, the sequences Xd with the smallest PAPR is selected for final serial transmission.

Partial Transmit Sequence

Partial Transmit Sequence is one of the most important technique for reducing PAPR in OFDM systems. Main idea of PTS is data blocks are divided into non-overlapping sub-block with independent rotation factor. The fundamental idea of this technique is sub-dividing the original OFDM symbol data into sub-data which is transmitted through the sub-blocks which are then multiplied by the weighing value which were differed by the phase rotation factor until choosing the optimum value which has low PAPR.

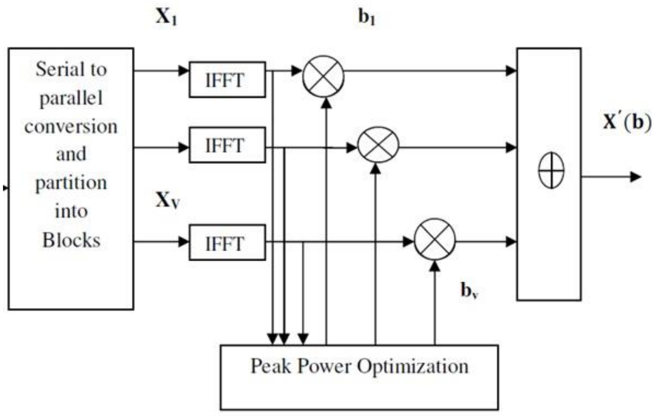

Figure 4. Block Diagram of PTS

The data sequence X in frequency domain is sub-divided into Vsub-sequence which were transmitted in sub-blocks without overlapping and having equal size of N which contains N/V non-zero values in each sub-block. The signal with optimum PAPR is selected and then transmitted. The drawbacks of the technique are high computational complexity. The computational complexity increases as the number of subcarriers increases, due to this the complexity to find out the best phase factor increase in order to minimize the PAPR. The input signal of the OFDM signal with minimum PAPR is transmitted and the probability of occurrence of high PAPR is reduced.

PARTIAL TRANSMIT SEQUENCE - ARTIFICIAL BEE COLONY

The ABC is a recently proposed optimization algorithm that simulates the foraging behavior of honeybee colonies. In the ABC algorithm, the position of a food source represents a possible solution to the optimization problem and the amount of nectar in the food source corresponds to the quality (fitness) of the associated solution. The ABC algorithm consists of three main phases, which are the phases of employed bees, onlooker bees and scout bees. At the first phase, the ABC generates a randomly distributed initial population with employed bees. An employed bee produces a modification of the position (solution) in her memory, depending on the local information (visual information), and tests the nectar amount (fitness value) of the new source. If the new nectar amount is higher than that of the previous source, the bee memorizes the new position and forgets the old one. Otherwise, she keeps the position of the previous source in her memory. After all employed bees complete the search process, they share the nectar information of the food sources and their position information with the onlooker bees.

An onlooker bee evaluates the nectar information taken from the employed bees and chooses the food source with a probability related to its nectar amount. As in the case of the employed bee, the onlooker bee produces a modification of the position in her memory and checks the nectar amount of the potential source. Provided that its nectar is higher than that of the previous source, the bee memorizes the new position and forgets the old one. After the onlooker bees complete their searches, scouts are determined. The employed bee of an exhausted source becomes a scout and starts to search randomly for a new food source. These steps are repeated through a predetermined number of cycles, called maximum number of cycles, or until a termination criterion is satisfied.

PTS BASED ABC

The main steps of ABC-PTS are as follows:

1. Initialize the phase vector b_i randomly and determine the MCN(max cycle no).
2. Evaluate the fitness of each phase vector.
3. Repeat
4. Employed bees search the new food sources within the neighbor-hood of the b_i. Then calculate the fitness of each new source b'_i .
5. Onlooker bees select food sources.
6. Onlooker bees look for new food sources and evaluate the fitness of the each b'_i
7. If a Limit Value is reached, go to step 6. Otherwise, continue
8. Send out scout bees to randomly find new phase vector
9. Memorize the best food source
10. Until cycle ¼ maximum cycle number.

SIMULATION RESULTS AND DISCUSSIONS

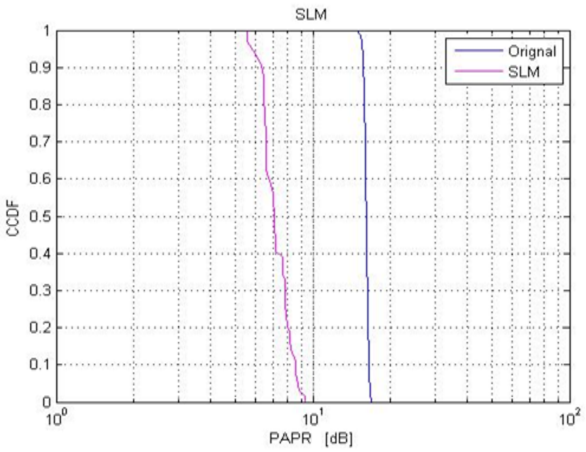

Figure 5. SLM with 64 Sub-carriers

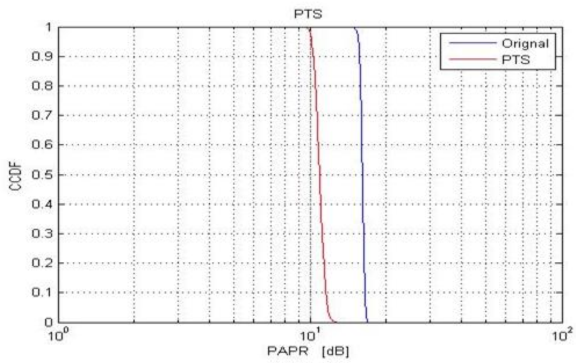

Figure 6. PTS with 64 Sub-carriers

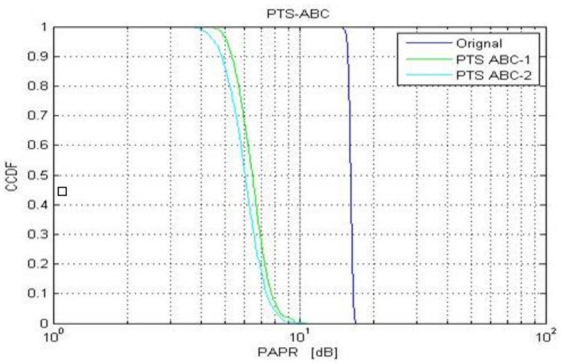

Figure 7. PTS-ABC with 64 Sub-carriers

The complementary cumulative distribution function (CCDF) of the PAPR is the most commonly used performance measure for PAPR reduction techniques. CCDF is the probability how much the instantaneous PAPR exceeds the Average PAPR. Plots for PTS-ABC-1 and PTS-ABC-2 correspond to the number of sub-blocks 2 and 4 respectively. The improvement in performance of PAPR reduction is obtained when the number of sub-blocks are increased. But, when we increase the number of sub blocks the searching complexity of optimal phase factor also increases.

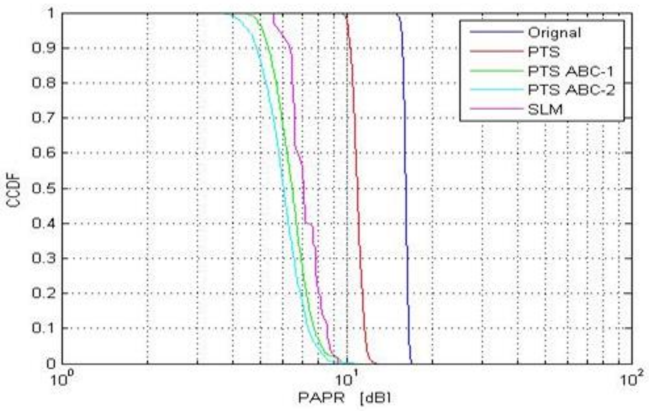

Figure 8. Comparison Plot of different algorithms for PAPR reduction

Also, as the number of sub-carriers increase, there is an increase in the PAPR. SLM, PTS and PTS-ABC algorithms show appreciable reduction in PAPR which can be understood from the table given below.

Table 1: PAPR for different algorithms

Number of Subcarriers	Original PAPR In dB	PAPR of PTS in dB	PAPR of SLM in dB	PAPR of PTS-ABC in dB
8	7.1162	3.5468	4.4788	3.6571
16	10.1235	5.8058	5.4013	4.4735
32	13.1229	8.3082	6.3704	5.2959
64	16.1327	10.986	7.2599	4.929
128	19.1521	13.728	8.0569	6.7485
256	22.1654	16.558	8.6381	6.5143
512	25.1783	19.443	9.224	7.812
1024	28.1845	22.369	9.7697	8.3497

CONCLUSION

Thus, here PAPR reduction techniques (SLM, PTS, PTS-ABC) in OFDM system are analyzed and found that the PTS-ABC has shown better performance and at the same time requires far less computational complexity as compared to other techniques. SLM and PTS are important probabilistic schemes for PAPR reduction, SLM can produce independent multiple frequency domain OFDM signals, whereas the alternative OFDM signals generated by PTS are independent. PTS divides the frequency vector into some sub-blocks before applying the phase transformation. Therefore, some of the complexity of several full IFFT operations can be avoided in PTS, so it is more advantageous than SLM if amount of computational complexity is limited. PTS method is special case of SLM method. For PTS method, the number of rotation factors may be limited in certain range. A suboptimal phase optimization scheme based on artificial bee colony (ABC-PTS) algorithm, has shown efficient PAPR reduction in OFDM system with less complexity when compared with others.

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