Review of PTS based Algorithms for PAPR Reduction Techniques in OFDM System

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***Abstract*—In recent year, Orthogonal Frequency Division Multiplexing technique plays an important role in wireless digital communication system. OFDM is a multi-carrier modulation technology which enables high capacity of data transmission over a single path. But the major problem in OFDM is the high peak-to-average power ratio due to independent subcarrier. A large PAPR distorts the signal if the transmitter contains non-linear components, which can increase the complexity and reduces the efficiency of power amplifier. Various techniques are surveyed to reduce the PAPR level and complexity. Partial Transmit Sequence is also one of the distortions less technique that improves PAPR performance. However, the high computational complexity is the major disadvantage of PTS due to many IFFT operations. This paper presents various algorithms to reduce the computational complexity.**

Keywords— Orthogonal Frequency Division Multiplexing (OFDM); Peak-to-average power ratio (PAPR); Partial transmits Sequence (PTS).

I. INTRODUCTION

A. *ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING (OFDM)*

OFDM (Orthogonal Frequency Division Multiplexing) is a widely used in wireless & mobile communication system. An OFDM is a part of family of multicarrier modulation technology, which can many signals transmitted at the same time over a single transmission path. The basic concept of OFDM system, a high bit rate is transmitted into a lower bit rate of carriers. Each carriers are orthogonal maintained. Thus, an OFDM signal is produce a complex signal by multiplexing [3].

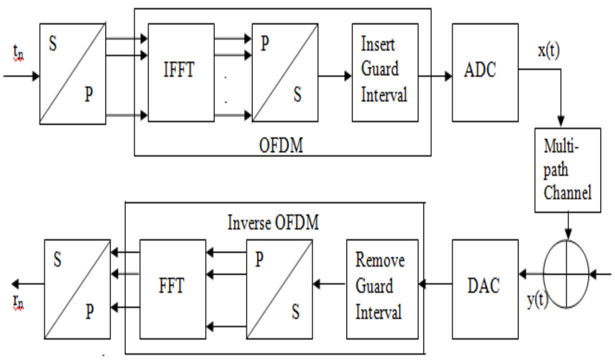

Fig. 1 OFDM transceiver structure [14]

The OFDM data is generate by taking input data to serial to parallel converter. The Inverse Fast Fourier Transform (IFFT) can bring the required spectrum to time domain and provide the carrier are orthogonal. The Fast Fourier Transform (FFT) is the reverse process of IFFT. The FFT can convert the time domain signal to frequency spectrum and the function of FFT to find the original transmission waveform. The block diagram of OFDM Transmitter and Receiver is shown in Figure 1 [14].

OFDM has a number of attractive features like strengthens to channel fading, flexibility, easy equalization, resistance to impulse interference and capacity to handle strong echoes. OFDM is one of the very efficient techniques used in high speed digital broadband systems like Digital Television Broadcasting (DTB), Digital Audio Broadcasting (DAB) and Digital Video Broadcasting (DVB). OFDM is a most popular technology of communication system, which has many important applications like Wireless Local Area Networks (WLAN), European Telecommunication Standard Institute (ETSI) and High Performance Radio Local Area Network (HIPERLAN) [14].

II. PEAK TO AVERAGE POWER RATIO (PAPR)

OFDM signal show very high Peak to average power ratio. A high PAPR can cause the complexity increased of the analog to digital converter (A/D) and digital to analog converter (D/A). Therefore, Radio frequency amplifier (RF) can decrease the efficiency and it can operate in non-linear region which damaging the performance of communication system. In OFDM system, an input data block of length N can be written as $X = [X_0, X_1 \ldots\ldots, X_{N-1}]^T$, and each symbol modulating one of a set of subcarrier, $\{ f_n, n = 0,1,\ldots\ldots\ldots, N-1\}$. The N subcarriers are selected to be orthogonal. The data block of the OFDM symbol is given by [1]:

$$x(t) = \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} X_n , e^{j2\pi n \Delta f t}, \qquad 0 \leq t \leq NT,$$

PAPR of the OFDM signal is defined as the ratio between the maximum power and the average power during the OFDM signal [12]. Then the Peak to Average Power Ratio is expressed as [1]:

$$PAPR = \frac{\max_{0\le t\le NT} |x(t)|^2}{1/NT \int_0^{NT} |x(t)|^2 dt}$$

The large PAPR can be reduced as the value of *max|x(t)|* decreased [1]. OFDM signal with large Peak to Average Power Ratio is given in figure 2. The PAPR problems are arising by calculation of four sinusoidal signals with different frequency and phase shift logically [12].

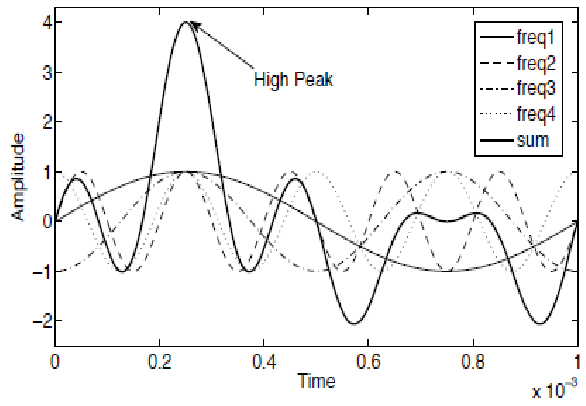

Fig. 2 High Peaks in OFDM signal [12]

Another factor used in PAPR is the Complementary Cumulative Distribution Function (CCDF), which is used to measure efficiency of PAPR technique [1]. The Crest Factor (CF) is defined as the square root of PAPR [14].

$$Crest\ Factor = \sqrt{PAPR}$$

The CCDF expression of the PAPR of OFDM signals can be written as [7]:

$$CCDF = max_{0\le t\le NT} \frac{|x(t)|}{E[|x(t)|]}$$

E[|x(t)|] is the average power. In several cases, the large PAPR can be decreased by reducing the value of maximum signal power for the reason that the large value of average power causes interference [7]. There are several techniques to reduced PAPR, which are basically divided into two groups such as signal scrambling techniques and signal distortion techniques. These can be further subdivided into many techniques such as clipping, peak windowing and peak cancellation. Another technique of signal scrambling are block coding, sub-block, selected mapping (SLM) and partial transmit sequence (PTS) [3].

III. PARTIAL TRANSMIT SEQUENCE (PTS)

Partial Transmit Sequence is a distortion less technique based on scrambling rotations to group of subcarriers. PTS is based on the same principle as Selected Mapping (SLM), but gives better performance than SLM. The basic concept of PTS technique is the input data block is portioned into disjoint sub-blocks. The sub-carriers which are transmitted through the sub-blocks are multiplied by weighing value of the phase rotation vector for those sub-blocks. The phase rotation vector is chosen such that the PAPR value is minimized. The block diagram of PTS technique is shown in Fig. 3 [10]. In this, the serial data X is divided into sub sequence by using serial to parallel converter and transmitted in sub blocks and each sub-blocks include N/V non-zero value [10].

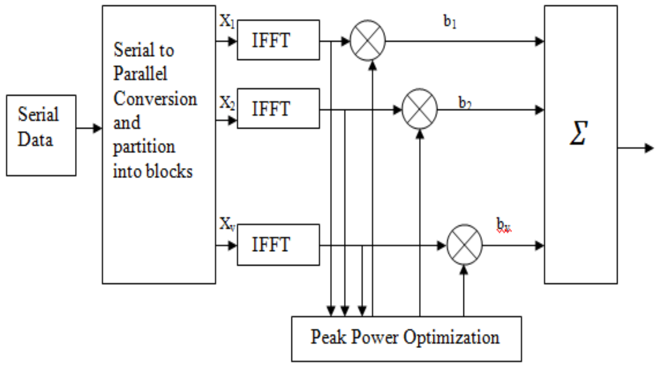

Fig. 3 Conventional OFDM Diagram employing PTS [10]

The Partial Transmit Sequence needed several inverse fast Fourier/wavelet transform (IFFT/IDWT) which produce in large computationally complexity. To decrease its complexity, different algorithms are proposed which are based on PTS [13]:

A. Particle Swarm Optimization (PSO)

PSO is a population-based global optimization technique which supported the social manners of bird flocking looking for food. The particle is called the population members which are mass-less and volume-less. All particles represent an explanation of high-dimensional space, its current position and its best position create by its region. The velocity update and position value has two primary operators of PSO technique. In the iteration, each particle repairs its position and velocity as follows [4]:

$$x^i_{k+1} = x^i_k + v^i_{k+1}$$

$$v^i_{k+1} = v^i_k + c_1 r_1(p^i_k - x^i_k) + c_2 r_2(p^g_k - x^i_k)$$

Where, x^i_k stand for Particle position

v^i_k correspond to Particle velocity

p^i_k represents Best "remembered" position

c_1, c_2 stand for acceleration constants

r_1, r_2 are random numbers between 0 and 1

The areas of application of PSO are edge detection in noisy images, signature verification, color image segment and QOS adhoc multicast [4].

B. Artificial Bee Colony (ABC)

Artificial Bee Colony is the most successful swarm algorithm based on the behavior of the bees in nature. ABC algorithm is categorized into foraging and mating behavior. The employed bees, onlookers and scouts are three groups in the artificial bee colony to find the optimization problem [4]. In ABC algorithm, a food source position is corresponding to phase vector $b_i = [b_{i1}, b_{i2}, \ldots, b_{i(v-1)}]$, i= 1,.....,SN, where S denotes the size of randomly distributed population size. For each employed bee, the new phase vector is expressed by [9]:

$$b_i' = b_i + \phi_i(b_i - b_k)$$

Where ϕ_i is a random number between [-1, 1], b_k is a solution of the region of b_i .

The fitness value of a solution b_i in the population is expressed as [9]:

$$fit(b_i) = \begin{cases} \frac{1}{1+fit(b_i)} & if \quad fit(b_i)\geq 0 \\ 1 + abs(fit(b_i)) & if\ fit(b_i)<0 \end{cases}$$

Where, $fit(b_i)$ stand for the PAPR value and is preferred to be at a smallest amount [9].

C. Genetic Algorithm (GA)

- GA is an Evolutionary Algorithm which is based on stochastic optimization algorithm.[4] GA initiate with random set of solution called population and which a population of strings can solution of optimization problems. GA involves three principles:

- Selection
- Crossover
- Mutation

GA is valuable and well-organized when the search space is huge multipart, no mathematical investigation is obtainable and conventional investigate method be unsuccessful. But genetic algorithm has some weakness such as it is difficult to working on active data sets and not fit for explaining the restriction optimization problems [4]. GA provides one more solution to reduce the complexity of PTS. It can useful with highly nonlinear problems and non-differentiable function. GA agrees to find the numerical solution to complex problems [8].

D. Differential Evolution (DE)

Differential Evolution is a population-based stochastic parallel swarm evolutionary algorithm. It is used to look for an optimal solution and reducing non linear, non differential and maintain space function. The differential evolution method usually four stages: initialization of the parameter vectors, mutation and difference vectors, crossover and selection [5].

- The differential method starts with an initial solution set, searches for a global optimum point from the feasible region.
- After initialization, the mutation operation of differential evolution creates donor vector to each population member. While doing the mutation, it uses three vectors. The first represents the local best, the second global best which are adaptive in nature and the third selected randomly.
- Once the mutation is complete, the crossover comes into play after generating the donor vectors. The function of crossover that it generates the final offspring vector. Crossover be a symbol of a characteristic case of "gene" replace.
- The next step of the algorithm is selection, which determines the population of next generation. It is the best solution of determine the new generation and thus cost function decrease with number of generation [5].

It is similar to Genetic Algorithm, but there will be one difference. The genetic algorithm, mutation is result of small perturbations while differential evolution, mutation is result of arithmetic combination. DE has many benefits like simple to implement, reliable, accurate, robust and high-speed optimization. DE has used to discover the optimal solution but this process has a time consuming [4].

E. Ant Colony Optimization (ACO)

ACO is based on Swarm Intelligence of meta-heuristic motivated by the foraging manners of ants in the natural. The inspiring source of ACO is the pheromone trail laying which resembles the behavior of ant colony for search shortest path. It means that if the pheromone trail is high then searching the food source also increases. Ant colony optimization has advantage to digital image processing and avoiding the convergence to optimal solution. ACO is prearranged into three major purposes as given [4]:

Ant Solutions Construct - achieves the solution construction process.

Pheromone Update – achieves pheromone trail updates

Daemon Actions –achieves extra updates from a global viewpoint [4].

Ant colony optimization is used to reduce the PAPR. In PTS based ACO method can be implemented by approximately changing the ant location. The modified Ant colony optimization is proposed to discover the optimal angle which helps to reduce the PAPR. The ant colony optimization has compensation of avoid the meeting to a nearby optimal solution [6].

F. Firefly Algorithm (FF)

Firefly algorithm is an alternative of swarm-based heuristic algorithm for constrained optimization [4], which is supported of the variation in light intensity. It facilitates the fireflies to travel towards brighter and further attractive position in arrange to achieve optimal solutions [2]. The flashing light is associated with the objective function to be optimized, and formulate new optimization. We can idealize some of the essential flashing properties of suitable fireflies. The firefly algorithm has the following idealized rules [4], [2].

- Every fireflies are unisex and they will travel towards further attractive and brighter.
- The quantity of attractiveness of firefly is comparative to its brightness, thus if there is not a brighter or more attractive firefly then it will travel randomly.
- The light intensity of a firefly is finding out by the objective function.

The firefly algorithm has many advantages which make it very efficient for solving the optimization problems [4]. The proposed FF-PTS system supplies approximately the equal PAPR information as that of the optimal exhaustive PTS, while preserve a low computational load [2].

G. Bacterial Foraging Optimization (BFO)

BFO algorithm is a novel evolutionary computation algorithm based on the phenomenon of a bacterial colony. The BFO algorithm is a biologically inspired computing technique which introduced by Passino in 2002. BFO algorithm consist of three most important mechanism namely, chemo-taxis, reproduction and elimination-dispersal [4]. Chemo-taxis are the primary step for a bacterium, which create a cell to cell communication system. The main goal of bacterium is to optimize the best food position in pre-defined iteration. In reproduction, bacteria are set in downward order and divide into two, only the best healthiest bacteria tend to survive and placed in the same food location. In elimination-dispersal, only some bacteria are uninvolved and a few of the bacteria are located in random situation in the environment. BFO based PTS algorithm is a improved arrangement of phase factors for searching OFDM signals. The BFO-PTS algorithm can superior for PAPR reduction, for the reason that the BFO-PTS algorithm has just three control factors which can be effortless used [11].

IV. CONCLUSION

OFDM is a type of multicarrier modulation techniques, which offer high spectral efficiency, low realization complexity and less vulnerability to echoes. OFDM is infinitely used in different communication method. A most important weakness of OFDM is the Peak to Average Power Ratio (PAPR) which distorts the OFDM signal. To recover the PAPR reduction in OFDM systems, different Partial Transmit Sequence supported algorithms are created in this paper. PTS is a non distortion technique which has need of little quantity of redundancy for the recovery of PAPR. But in the PTS technique, the computational complexity raises exponentially with increase in sub-blocks. Partial Transmit Sequence and its based algorithms are analysis in this paper to reduce the complexity of phase factor.

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