



STUDY OF VARIOUS PTS BASED ALGORITHMS FOR PAPR REDUCTION IN OFDM SYSTEMS

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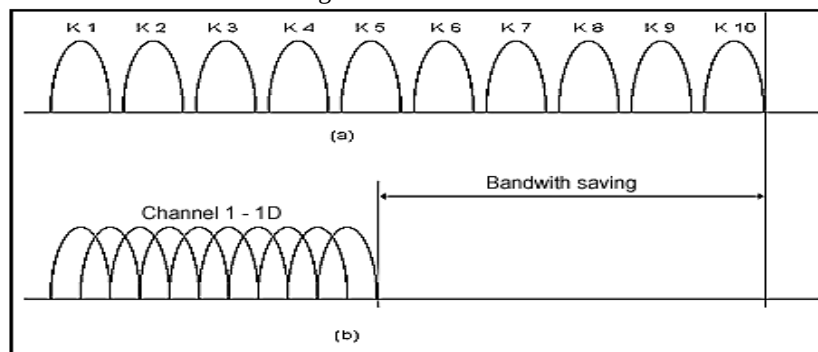
Abstract: Orthogonal Frequency Division Multiplexing is a special form of multicarrier modulation technique and has found its way to the high-speed wireless and mobile communications world. This technique does not require extensive equalization and has excellent immunity against fading and inter-symbol interference but its major drawback is the large Peak-to-Average power Ratio (PAPR) of the transmitted signal. These high peak signals when passed through power amplifiers cause the non-linear distortion of the signals. Also they increase the dynamic range of amplifiers. Partial transmit sequences (PTS) is a distortion less phase optimization technique that significantly improves peak-to average power ratio (PAPR) performance with a small amount of redundancy for orthogonal frequency division multiplexing (OFDM) systems. However, the computational complexity in conventional PTS increases exponentially with the number of sub blocks. Various algorithms are designed to reduce complexity of PTS and these are studied in this paper.

Keywords: PAPR, OFDM, PTS

I. Introduction

A. OFDM THEORY

Orthogonal frequency division multiplexing (OFDM) is a widely used wireless communication system that requires a high bit rate and high capacity transmission. It is a special form of multicarrier modulation technique which is particularly suited for transmission over a dispersive channel. In OFDM a high rate data stream is divided into many low data streams and these streams are then multiplied by corresponding carrier frequency signals that are orthogonal to each other. A composite signal so formed by multiplexing these modulated signals is called the OFDM signal. It is advancement over traditional Frequency Division Multiplexing (FDM) technique which is used to carry only one signal over one path. Here the different carriers are orthogonal to each other, that is, they are totally independent of one another. This is achieved by placing the carrier exactly at the nulls in the modulation spectra of each other as shown in figure 1.



Fig(1). OFDM spectrum

The condition for orthogonality means that two periodic signals are said to be orthogonal when the integral of their product over one period is equal to zero.

$$\text{For the case of continuous time: } \int_0^T \cos(2\pi nft) \cos(2\pi mt) dt = 0 \quad (1)$$

$$\text{For the case of discrete time: } \sum_{k=0}^{N-1} \cos\left(\frac{2\pi km}{N}\right) \cos\left(\frac{2\pi kn}{N}\right) dt = 0 \quad (2)$$

Where $m \neq n$ in both cases. OFDM system has advantages of less inter symbol interference due to increase in symbol duration. Also conversion of the channel into many narrowly spaced orthogonal sub-carriers makes it

immune to frequency selective fading. Orthogonally placing the sub-carriers lead to high spectral efficiency. These systems can be efficiently implemented using IFFT. Main drawback of OFDM systems is peak to average power ratio which is caused by presence of a large number of sub – carriers with varying amplitude, which in turn reduce the efficiency of the amplifier.

II. Peak to average power ratio

One of the biggest disadvantages of OFDM system is high Peak to Average Power Ratio. It is one of the major practical complications of the uncoded OFDM signals. Figure (2) shows OFDM signal with PAPR problem.

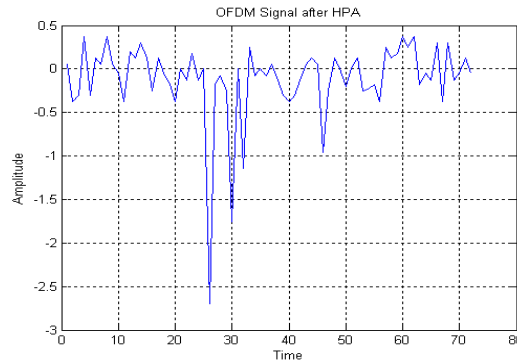


Fig 2: Amplitude of OFDM symbol showing large peak

When the N sinusoidal signals after modulation by their carriers, adds mostly constructively the peak envelop power is as much as N times the mean power. As a result the amplitude of such a signal can have very large values. PAPR is defined as the ratio between the instantaneous power of the peaks and the average power of the signal. Mathematically,

$$\text{PAPR} = \frac{\max [x(t)]^2}{E\{[x(t)]^2\}} \quad (3)$$

Where $E \{.\}$ is the expectation operator and $x(t)$ is transmitted signal.

Also, The Crest factor CF is the square root of PAPR. The high value of CF causes problems when the signal is applied to a non-linear device such as a power amplifier because it results in in-band distortion and spectral spreading.

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

PAPR is usually analysed by using statistical parameter called complementary cumulative distribution function (CCDF). CCDF shows the probability that PAPR is above a threshold level[7]. CCDF is defined as

$$P(\text{PAPR} \geq z) = 1 - ((1 - \exp(-z))^N)^N \quad (4)$$

From equation (3), it can be seen that the value of PAPR can be reduced either by reducing the maximum signal power or by increasing the average power. In reality, reducing the maximum signal power is used in most cases because increasing the average power causes more interference. Peak to average power ratio cause many problems in OFDM systems. When high-peak power signals pass through power amplifiers, Analog to Digital (A/D) and Digital to Analog (D/A) converters, peaks are distorted non-linearly because of amplifier and converters imperfection thus, the output signal will suffer from intermodulation distortion resulting in energy being generated at frequencies outside the allocated bandwidth. It also has an adverse effect on dynamic range of system elements. An increase peak to average power ratio value cause the increase in linearity range of the analog circuitry used in the system. This inturn causes higher power consumption, lower efficiency and increase in cost of system elements. [2]. There are many PAPR reduction techniques and these are broadly classified into two categories as distortion type and non-distortion type methods. Distortion type techniques reduce the PAPR by reducing the higher peaks in the signal and thereby distorting the signal. Example: clipping, peak windowing, peak cancellation etc. Non-distortion type techniques include coding and data scrambling methods. These methods do not introduce any distortion, but they also do not ensure reduced PAPR. Example: peak reduction carrier, selective level mapping (SLM), partial transmit sequence (PTS) and block coding [3].

III. PAPR reduction algorithms based on PTS

Partial transmit sequence is considered as efficient technique as compare to other non distortion type techniques. The main disadvantage of partial transmit sequence is its complexity as it require many IFFT operations thus resulting in high computational complexity in practical systems. So various algorithms are designed based on PTS in order to reduce its complexity.

Particle swarm optimization algorithm: PSO algorithm is a population based search algorithm based on the simulation of the social behavior of birds within a flock. In PSO, individuals are referred to as particles. In PSO, initially each potential solution is assigned a randomized velocity and is flown through the problem space. Each particle adjusts its flying according to its own flying experience and its companion flying experience. New

velocity value for each particle is calculated based on its current velocity, the distance from its previous best position and the distance from the global best position given by

$$v_i^{t+1} = w.v_i^t + c1.[pbest_i^t -] + c2[gbest -] \quad (5)$$

$$x_i^{t+1} = x_i^t + v_i^t \quad (6)$$

Where;

v_i^t is velocity of ith particle at iteration t,

w is weight inertia.

c1, c2 is Acceleration Constants.

r1, r2 is random number between 0 and 1.

x_i^t is current position of ith particle at iteration t,

pbest_i is personal best of ith particle.

The new velocity value is then used to calculate the next new position of the particle in the search space. PSO is a simple PAPR reduction technique which may be easily implemented in hardware. PSO does not require proper threshold value and PAPR reduction using PSO gave good result as compared of simple and clipping technique.[2]

Artificial bee colony (ABC): PTS based on an artificial bee colony (ABC) algorithm (ABC-PTS) is an intelligent swarm optimization algorithm which simulates the intelligent foraging behavior of a honey bee swarm. In the ABC algorithm, employed bees, onlooker bees, and scout bees are tasked with finding optimum food sources, and first the food source positions are generated randomly. In the PAPR reduction problem, a food source position is equivalent to phase vector $b_i = [b_{i1}, b_{i2}, \dots, b_{i(V-1)}]$ where $i = 1, 2, \dots, SN$ where SN denotes the population size. The employed bees look for a new food source within the neighborhood of the previous source. In the ABC-PTS, the new phase vector (the new food source) is expressed by

$$b_i = b_i + \phi_i(b_i - b_k) \quad (7)$$

Where b_k is a solution within the neighborhood of b_i , and ϕ_i is a random number in the range of $[-1, 1]$. The fitness of a solution is expressed as

$$fit(b_i) = \begin{cases} \frac{1}{1 + f(b_i)}, & f(b_i) \geq 0 \\ 1 + abs(f(b_i)), & f(b_i) < 0 \end{cases} \quad (8)$$

Where $f(b_i)$ represents the PAPR value of the signal. Employed bees share the fitness of the food sources with onlooker bees. The onlooker bees then move to a food source depending on its fitness values whose probability is given as

$$p_i = \frac{fit(b_i)}{\sum_{i=1}^{SN} fit(b_i)} \quad (9)$$

After the employed bees and onlooker bees complete their searches for food source and if the fitness values of the food sources do not improve with a number of iterations then employed bees become the scout bees. The scout bees look for new food sources randomly by

$$b_i = \min(b_i) + rand(0, 1) * (\max(b_i) - \min(b_i)) \quad (10)$$

Where $\min(b_i)$ and $\max(b_i)$ are the lower and upper bounds of the phase vector.

The above steps are repeated within in a cycle, called the maximum number of cycles (MCN) to produce to find the optimum phase vector. Simulation results showed that the ABC-PTS with 1024 searches and the Random search-PTS with 4096 searches had nearly the same PAPR performances. Therefore, the computational complexity of the ABC-PTS is less than 4 times that of the random search-PTS. [1]

Immune evolutionary algorithm (IEA): It utilizes the local information to intervene in the globally parallel process and avoid repetitive and useless work during the procedure, so as to overcome the blindness in action of the mutation. During the actual operation, immune algorithm stops the degenerative phenomena arising from the evolutionary process, thus making the fitness of population increase steadily. The idea of immunity is mainly realized through two steps based on reasonably selecting vaccines, i.e., an immune selection and a vaccination. Immune selection is used for preventing the useless work and vaccination is for raising fitness. Immune evolutionary algorithm (IEA) has achieved significant PAPR reduction while maintaining low complexity. [4]

Genetic algorithm (GA): Genetic algorithm based numerical solution provide one more solution to reduce the computational burden of PTS. GA is implemented as a computers simulation in which a population of abstract representations (chromosomes) of candidate solutions (genes) to an optimization problem evolves toward better solutions. It usually starts from a population of randomly generated chromosomes and happens in generations. In each generation, the fitness of every chromosome in the population is evaluated, multiple chromosomes are randomly selected from the current population (based on their fitness), and modified (mutated or recombined) to form a new population. The new population is then used in the next iteration of the algorithm. GA can deal with highly nonlinear problems and non-differentiable functions as well as functions with multiple local optima. [5]

Differential evolution (DE): Differential evolution is an efficient and powerful population-based stochastic search technique the applied to search the optimal phase weight factor for the PTS technique in order to reduce the PAPR. The DE method starts with an initial solution set, and an attraction-repulsion mechanism is then used iteratively to move those particles towards optimality. The DE method usually has three main procedures: initialization, mutation operation, crossover operation, and selection operation. Initialization is used to sampling K points randomly form the feasible region. The mutation operation of DE applies the vector differentials between the existing population members. Once the mutation phase is complete, the crossover process is activated. The crossover operator is applied to the primary and secondary parents, resulting in the offspring vector. The population for the next generation is selected from the individual in current population and its corresponding vector according to the select rule. It is widely applied to high data rate multicarrier modulation systems. DE method obtained the desirable PAPR reduction with low computational complexity when compared with the various stochastic search techniques. [6]

IV. References

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