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Peak-to-Average Power Ratio Reduction using ABC & PTS Algorithm in Wavelet Packet Modulation

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***Abstract*— Wavelet Packet Modulation (WPM) is a new scheme of choosing modulation scheme for transmission of multicarrier signal on wireless channel which helps in orthogonal wavelet base in place of sine functions. Though this modulation is over all similar to that of Multi-carrier code-division multiple access (MC-CDMA), it provides interesting additional features. Large Peak to Average Power Ratio (PAPR) of transmitted signal is the major drawbacks of the wavelet packet modulation (WPM) scheme. Utilizing the advantage of concentrating the energy to certain subspaces of the discrete wavelet transform, the performance of three methods to reduce PAPR in WPM is investigated. In general, the partial transmit sequence (PTS) technique is used to reduce PAPR. In this paper, we use the artificial bee colony (ABC) algorithm to reduce the PAPR value of the PTS for WPM signals. The accomplishment of the artificial bee colony (ABC) algorithm for Daubechies wavelets was compared with the primary WPM for different Daubechies wavelets, arbitrary search PTS for Daubechies wavelets and optimum PTS by computer simulations.**

***Index Terms*— Artificial bee colony (ABC) algorithm, partial transmit sequence (PTS), peak-to-average power ratio (PAPR), wavelet packet modulation, particle swarm optimization (PSO).**

I. INTRODUCTION

A multiplexing method avail a WPM (Wavelet Packet Modulation) where data containing bits regulate a place of orthogonal wavelet packet waveforms that are then consolidated into a single compound signal. WPM is a promising alternative to the popular Fast Fourier Transform (FFT) based Multi-carrier code-division multiple access (MC-CDMA). However, high peak to average power ratio (PAPR) that affects MC-CDMA is also a problem in WPM.

MC-CDMA may stand for Multi-carrier code division multiple accesses, a multiple access technology used in telecommunication systems based on OFDM. The large peaks increase the amount of inters modulation distortion resulting in an increase in the error rate. The average signal power must therefore be kept low to ensure that the transmitter amplifier operates in the linear region [7]. The survey of PAPR reduction in WPM can be summarized as follows: a multi-pass pruning method to reduce PAPR was proposed by Baro [8]. Zhang [9] suggested a threshold based method to reduce PAPR. Le et. al [10] derived upper bounds for the maximum PAPR for WPM transmission and based on these results wavelets that minimize PAPR are obtained. A novel adaptive companying transform scheme was prospective by Rostamzadeh to effectually declining the PAPR of OFDM and WPM signals [11]. Torun et. al [12] prospective a method to reduce the Peak-to-Average Power Ratio (PAPR) in the developmental Wavelet Packet Multi-carrier Modulation (WPM) system. A method works on the principle that the PAPR of a multicarrier system can be adjusted by varying the phase-shifts of the subcarriers. Hence different PAPR values for the same information can be obtained by randomly altering the phases of the sub-carriers used to modulate the data. The WPM frame with the least PAPR is then identified and transmitted.

In this paper, we use the artificial bee colony (ABC) algorithm to reduce the PAPR value of the PTS for WPM signals. The ABC algorithm [13]-[15] is an intelligent swarm optimization algorithm based on intelligent foraging behaviour of a honey bee swarm. In the proposed (ABC-PTS) scheme, each food source equals a phase factor vector and honey bees goal to find the optimum food source which gives the maximum PAPR reduction.

The paper is organized as follows: In Section II, the System model is described. In Section III, the wavelet packet modulation (WPM) and PAPR reduction of the WPC signals are described. In Section IV Classic PTS and PSO-PTS are introduced. In Section V, proposed ABC algorithm for PTS is given, it use for better PAPR reduction. In Section VI, the simulation results are presented. In Section VII, conclusions are given.

II. PRELIMINARIES

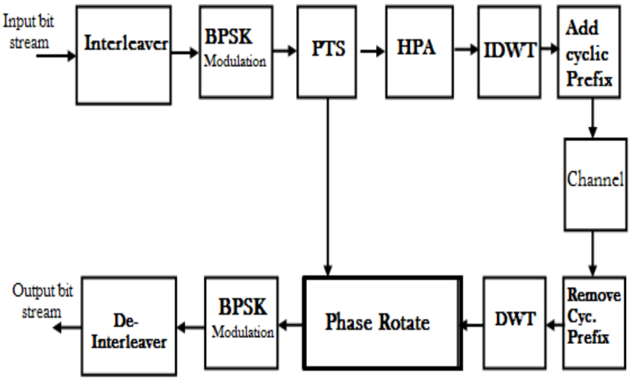

Figure 1: System Model

Figure 1 shows the system model that is used for the simulations. Firstly, we take input bit streams from the users are interleaved to eliminate burst error caused by the communication channel. Interpolate signals are epitomized with BPSK, and then PTS is adapted for PAPR diminution. The PTS requires side information, which has to be transmitted to get the original WPM signal in the system receiver. The cycle adjunct is then interpolated in the signal, that is intensify by the HPA to terminate the intersymbol interference (ISI) imitative from the communication channel. The cycle prefix is removed from the transmitted signal in the receiver. After the fast Fourier transforms (FFT), phase

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rotation is applied to get the phase of the original MC-CDMA signal from the side information. Then BPSK demodulation is performed. Finally, each BPSK demodulated symbol is carried to the original place in the bit stream by the deinterleaver [6].

III. WAVELET PACKET MODULATION

In multi-carrier modulation we use a wavelet packet modulation (WPM) as a new type of intonation having high bandwidth utilization, unique convenience in the proficiency of anti-disturbing and multi-rate transmission. It is considered as a tough contender to Multi-carrier code-division multiple accesses (MC-CDMA).

IMPLEMENTATION OF WPM

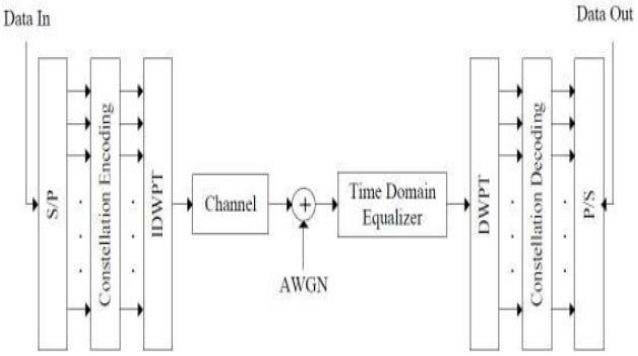

Figure 2: Block Diagram of WPM

The simplified block diagram of the multicarrier communication system using wavelet packet transform is as shown in figure 2. The input data stream is divided into parallel lower data substreams by a serial to parallel (S/P) converter i.e. the data symbols design a block of N subcarriers that are first converted from serial to parallel to decrease symbol rate by a factor of N that is equal to the no. of sub-carriers. The signal transmitted on the channel is in the discrete domain, x[n], and is composed of successive modulated symbols, and each of this is constructed as the sum of M waveforms m[n] individually amplitude modulated with the constellation encoded symbol. So it can be expressed in the discrete domain as:

$$x[n] = \sum_{s} \sum_{m=0}^{M-1} a_{s,m} \varphi[n - sM]$$

Where $a_{s,m}$ is a intent encoded s^{th} data symbol regulate m^{th} the waveform T is denoting the sampling period, $\varphi_m[k]$ is non-null only in the interval [0, LT − 1] for any m{0..M − 1}. In an AWGN channel, the waveforms $\varphi_m[k]$ should be cooperatively orthogonal to accomplish the lowest probability of defective symbol accommodation i.e. = δ[m − n] where represents a convolution operation and δ[j] = 1 if j = 0, and 0 otherwise. In MC-CDMA, the discrete functions $\varphi_m[k]$ are the well-known M complex basis functions w[t]exp (j2π (m/M)kT) limited in the time domain by w[t] which is window function. These basis functions are sine-shaped waveforms that are equally spaced in the frequency domain, each having a bandwidth of 2π/M and are grouped in pairs of identical centric frequency and sometimes modulated by a complicated BPSK encoded symbol. In WPM, the subcarrier waveforms are attaining by applying the WPT. As in MC-CDMA, the inverse transform is apply to build the transmitted symbol although the leading transform acquiesce recapture the data symbol transmitted. Since wavelet theory has part of its origin in filter bank theory, the processing of a signal into wavelet packet coefficients through WPT is usually referred as dissolution while the reverse operation is termed as fusion or reformation (i.e. from wavelet packet coefficients). The essential trait of the WPT is that the waveforms are elongated than the transform length. Consequently, WPM inhere a group of overlay transforms. As they overlay in time domain the starting of a later symbol is transmitted before the previous one(s) ends. The inter-symbol orthogonality is maintained as the waveforms are M-shifted orthogonally despite the overlap of consecutive symbols. Increased frequency domain localization can be made use provided by longer waveforms while the loss in system capacity is avoided that normally results from time domain spreading.

PEAK AVERAGE POWER RATIO (PAPR) REDUCTION OF WPM

The PAPR of the base band transmitted signal x(t) is defined as the ratio of maximum power of the transmitted signal over the average power. The PAPR of MC-CDMA signal in analog domain can be represented as [5]:

$$PAPR = \frac{max_{0\le tT_s}|X(t)|^2}{E(|X(t)|^2)}$$

Non-aligned distortion in HPA occurs in the analog domain, but the most of the signal processing operation for PAPR reduction occur in the digital domain. The PAPR of discrete time signal is given as [6]:

$$PAPR = \frac{max_n(|x(n)|^2)}{E(|x(n)|^2)}$$

Where, E (.) denotes ensemble average calculated over the duration of WPDM symbols. The Complementary Cumulative Distribution Function (CCDF) of the PAPR is one of the most frequently used performance measures for PAPR reduction techniques. The CCDF of the PAPR denotes the probability that the PAPR of data block exceeds a given certain value, and is expressed as follows [2]:

$$CCDF\ (PAPR0) = \Pr\{PAPR > PAPR0\}$$

From the central limit theorem it follows that for a large value of subcarriers N, the real and imaginary component of the multicarrier signal are modeled as a zero mean Gaussian distribution random variable with varianceσ^2. The amplitude of the MC-CDMA signal therefore has a Rayleigh distribution and its power distribution becomes a central chi-square distribution with two degrees of freedom and zero mean [6]. The CCDF of the PAPR can be calculated as:

$$\Pr(PAPR \le PAPR0) = 1 - (1 - e^{-PAPR0})^N$$

The distribution obtained by the conventional analysis, however, does not fit those of the PAPR of the MC-CDMA signals obtained by computer simulations, even for very large N. In [8], Van Nee and Prasad gave an empirical approximation:

$$CCDF(PAPR0) = 1 - (1 - e^{-PAPR0})^{\alpha N}$$

IV. CLASSIC PTS AND PSO-PTS

PSO is called a population-based search algorithm that influenced by the performance of organic commonality that displayed both individual and social behavior; vis a vis of these communities are schools of fishes, flocks of birds, and swarms of bees. Members of such community chunk familiar ambition (e.g., finding food) that are realized by exploring its environment while interacting among them.

A basic PSO Algorithm

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for every particle $i$ = 1,2 ..., $S$ do
   Initialize the particle's position with a uniformly distributed random vector: $\mathbf{x}_i \sim U(\mathbf{b}_{lo}, \mathbf{b}_{up})$
   Initialize the particle's best known position to its initial position: $\mathbf{p}_i \leftarrow \mathbf{x}_i$
   if $f(\mathbf{p}_i) < f(\mathbf{g})$ then
       update the swarm's most appropriate  position: $\mathbf{g} \leftarrow \mathbf{p}_i$
   Initialize the particle's velocity: $\mathbf{v}_i \sim U(-|\mathbf{b}_{up}-\mathbf{b}_{lo}|, |\mathbf{b}_{up}-\mathbf{b}_{lo}|)$
while a termination criterion is not met do:
   for each particle $i$ = 1, ..., $S$ do
      for each dimension $d$ = 1, ..., $n$
do Pick random numbers: $r_p, r_g \sim U(0,1)$
         Update the particle's velocity: $\mathbf{v}_{i,d} \leftarrow \omega\ \mathbf{v}_{i,d} + \varphi_p\ r_p\ (\mathbf{p}_{i,d}-\mathbf{x}_{i,d}) + \varphi_g\ r_g\ (\mathbf{g}_d-\mathbf{x}_{i,d})$
      Update the particle's position: $\mathbf{x}_i \leftarrow \mathbf{x}_i + \mathbf{v}_i$
      if $f(\mathbf{x}_i) < f(\mathbf{p}_i)$ then
         Update the particle's best known position: $\mathbf{p}_i \leftarrow \mathbf{x}_i$
         if $f(\mathbf{p}_i) < f(\mathbf{g})$ then
            Update the swarm's most appropriate position: $\mathbf{g} \leftarrow \mathbf{p}_i$
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The values b_{lo} and b_{up} are respectively the lower and upper boundaries of the search-space. The termination criterion can be the number of iterations performed, or a solution where the adequate objective function value is found [16]. The parameters ω, φp, and φg are chosen by the professional and control the behaviour and adequacy of the PSO technique.

PSO-PTS

PSO as an optimizer is used to solve the phase factor problem, which is shown as PSO process block in Fig 3 below. In PSO algorithm solution space of the problem is called particles, which is φ_k in the PTS based PSO scheme [17]. By moving the particles around in the search-space, the optimal solution of the phase problem will be reached. During the movement of the particles, each particle is characterized by two parameters: position and velocity [18]. The PSO algorithm evaluates particles with fitness value, which is PAPR the objective function. A solution space is randomly generated, which is a matrix of size S×K where S is the number of particles and K is the number of disjoint sub-block [19]. In other words, the solution space is a matrix its rows are $\varphi_1, \varphi_2, \ldots\ldots, \varphi_k$.

Since the PSO is an iterative algorithm, in the i^{th} iteration each particle can be described by its position vector $Y_{SK}^t = y_{S1}^t, y_{S2}^t, \ldots\ldots, y_{SK}^t$ and velocity vector is given as, $V_{SK}^t = v_{S1}^t, v_{S2}^t, \ldots\ldots, v_{SK}^t$ where $S\epsilon[1,S]$ and $Y_{SK}^t \epsilon R$ where R denotes the domain of the objective function. The PSO algorithm searches the solution space for the optimum solution by using iteration process. Each particle updates itself in every iteration by tracking two best positions. These are called the local best position, which is the best solution this particle achieved $p_{sk} = p_{s1}, p_{s2}, p_{s3}, \ldots. p_{sk}$ and the global best position can be given as $\mathrm{p}_{\mathrm{sk}}^{\mathrm{g}} = \mathrm{p}_{s1}^{\mathrm{g}}, \mathrm{p}_{s2}^{\mathrm{g}}, \mathrm{p}_{s3}^{\mathrm{g}}, \ldots \ldots, \mathrm{p}_{\mathrm{sk}}^{\mathrm{g}}$ which the best position is obtained so far by any particle in the whole swarm. The updating process of the position and velocity of each particle can be expressed as

$$V_{SK}^{t+1} = wV_{SK}^t + C_1 r_1 (p_{sk}^t - Y_{SK}^t) + c_1 r_1 ((p_{sk}^t)^g - Y_{SK}^t)$$
$$Y_{SK}^{t+1} = Y_{SK}^t + V_{SK}^t$$

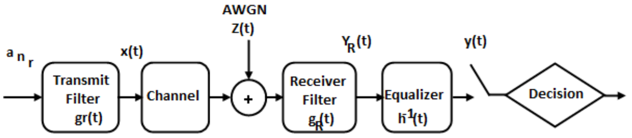

Figure 3: PAPR reduction techniques by using PSO based PTS weighing factor

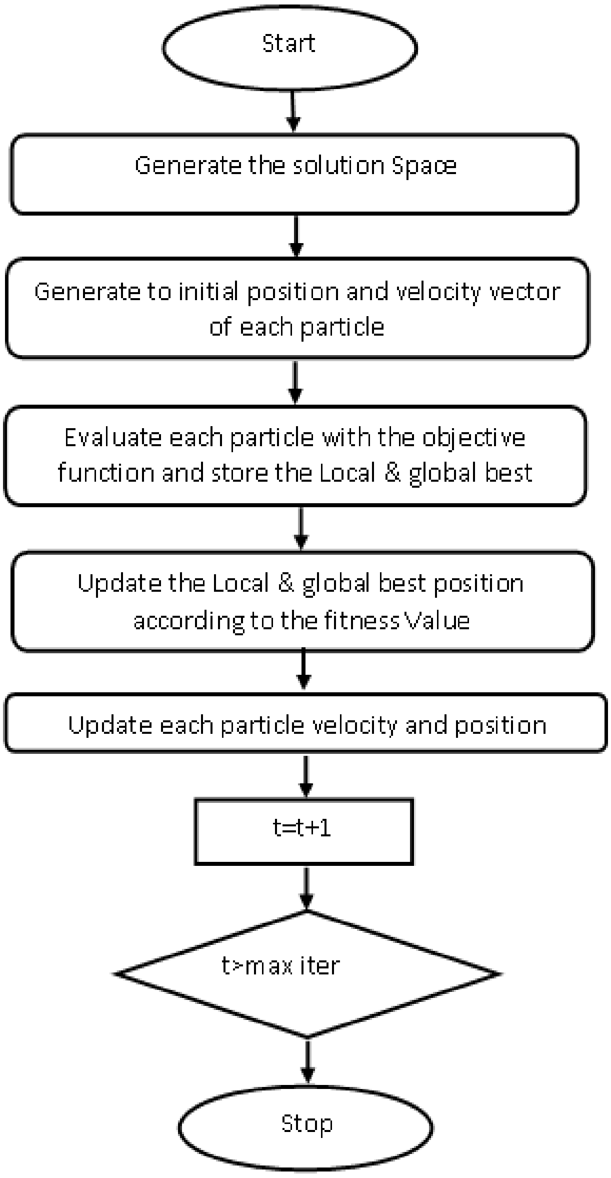

Figure 4: PSO-PTS Algorithm

Where, c_1 and c_2 are the acceleration terms [20]. The constant r_1 and r_2 are uniform distribution random numbers in the range of [0, 1]; w is the inertia factor.

V. PROPOSED ALGORITHM

The artificial bee colony (ABC) algorithm, which simulates the foraging behavior of honey bee colonies, was recently proposed by Karaboga [5]. 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. If the PAPR reduction problem arises, then a food source position and phase vector $\mathrm{b_i} = [\mathrm{b_{i1}}, \mathrm{b_{i2}}, \ldots., \mathrm{b_{i(v-1)}}], \mathrm{i} = 1, \ldots., \mathrm{SN}$, both are equivalent, where SN denotes the size of population, which is composed of the employed bees or the onlooker bees. The employed bees look for a new food source within the neighborhood of the previous source**.** If the nectar amount of the latest source is greater than the previous one, the new source is remind as a possible optimum explanation. In the ABC-PTS, the new phase vector (the new food source) is expressed by

$$b_i' = b_i + \emptyset_i(b_i - b_k) \qquad (1)$$

Where, b_k is a solution within the neighborhood of b_i, and $\emptyset_i$ is a random number in the range of [−1, 1]. The nectar amount of the food source determines the quality or fitness of the solution. The fitness of a solution is expressed as

$$fit(b_i) = f(x) = \begin{cases} \frac{1}{1+f(b_i)}, & iff(b_i) \geq 0 \\ 1 + abs(f(b_i)), & if\ f(b_i) < 0 \end{cases} \qquad (2)$$

Where, f (bi) represents the PAPR value of the signal and is desired to be at a minimum. Employed bees share the fitness of the food sources with onlooker bees in the hive. The onlooker bees then move to a food source depending on its fitness value. The probability of an onlooker bee selecting a food source is calculated as

$$p_i = \frac{fit(b_i)}{\sum_{i=1}^{sn} fit(b_i)} \qquad (3)$$

After an onlooker bee reaches a food source, it looks for a new source within the neighborhood of the previous one and memorizes the food sources according to their fitness. After the employed bees and onlooker bees complete their searches, if the fitness values of the food sources do not improve with a number of iterations that is called the “limit” value, employed bees become the scout bees. The scout bees look for new food sources randomly by

$$b_i = \min(b_i) + rand(0,1) * (\max(b_i) - \min(b_i)) \quad (4)$$

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). In a cycle, possible SN solutions are produced. In the ABC-PTS algorithm, MCN * SN possible solutions are produced to find the optimum phase vector.

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

Step 1: Initialize the phase vector $\mathbf{b}_i$

Step 2: Randomly.

Step 3: Evaluate the fitness of the each phase vector using equation (2).

Step 4: Repeat.

Step 5: New phase vector $\mathbf{b}_i$ is produced within the neighborhood of $\mathbf{b}_i$ by the employed bees using equation (1) and evaluating the fitness of each $\mathbf{b}_i$ using equation (2).

Step 6: Onlooker bees select food sources using equation (3).

Step 7: Onlooker bees look for new phase vectors using equation (1) and evaluate the fitness of the each $\mathbf{b}_\mathbf{i}$ using equation (2).

Step 8: If the limit value is not reached, go to step 6. Otherwise, continue.

Step 9: Send the scout bees randomly to find new phase vectors using equation (4).

Step 10: Memorize the solution of the best phase vector.

Step 11: Until cycle = maximum cycle number (*MCN*).

VI. RESULTS

In the simulations, WPM system has *N*=256 subcarriers and BPSK modulation was used. HPA is used with IBO=0,3,6 dB and *p*= 0.5, 2. Oversampling factor of the transmitted signal is *L*=4. In the simulations, the signal is transmitted over AWGN channel. WPM signals are randomly partitioned into *V*= 16 subblocks. The number of the phase factor is selected as *W*=2. In fig 5 shows CCDF vs PAPR using PSO-PTS for 8 user.

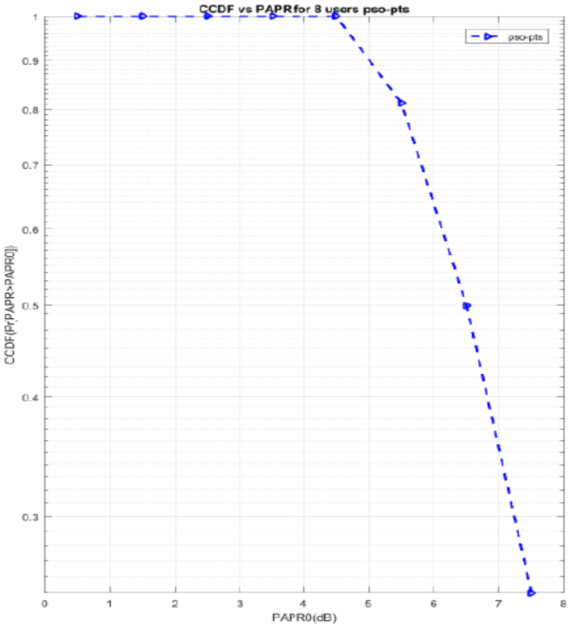

Figure 5: CCDF vs PAPR using PSO-PTS

In fig 6 shows BER vs SNR using PSO-PTS for 8 users.

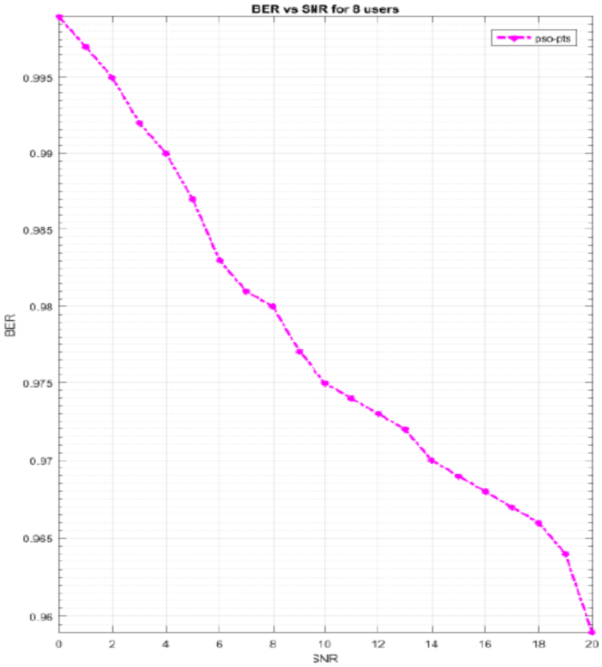

Figure 6: BER vs SNR using PSO-PTS

In fig 7 shows CCDF vs PAPR using ABC-PTS for 8 users.

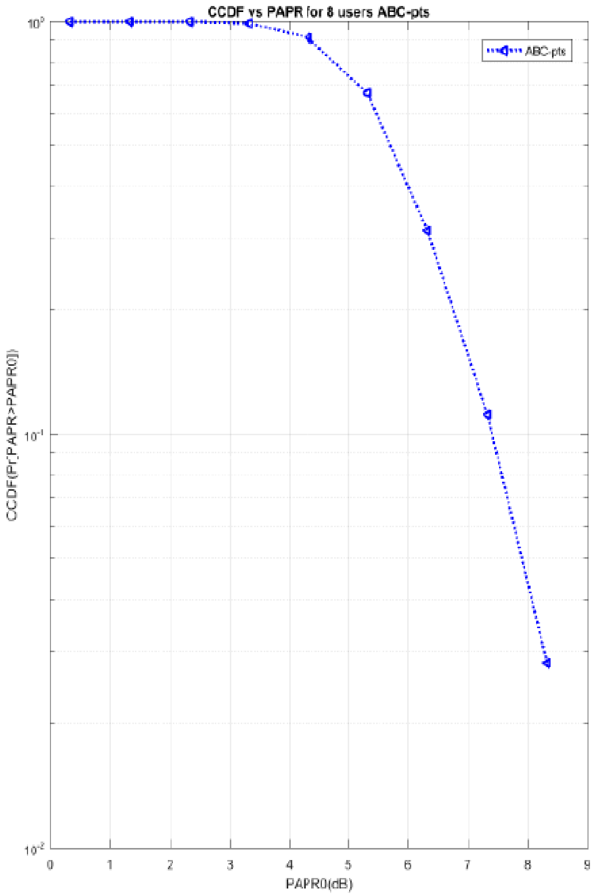

Figure 8: CCDF vs PAPR using ABC-PTS

In fig 8 shows BER vs SNR using ABC-PTS for 8 users.

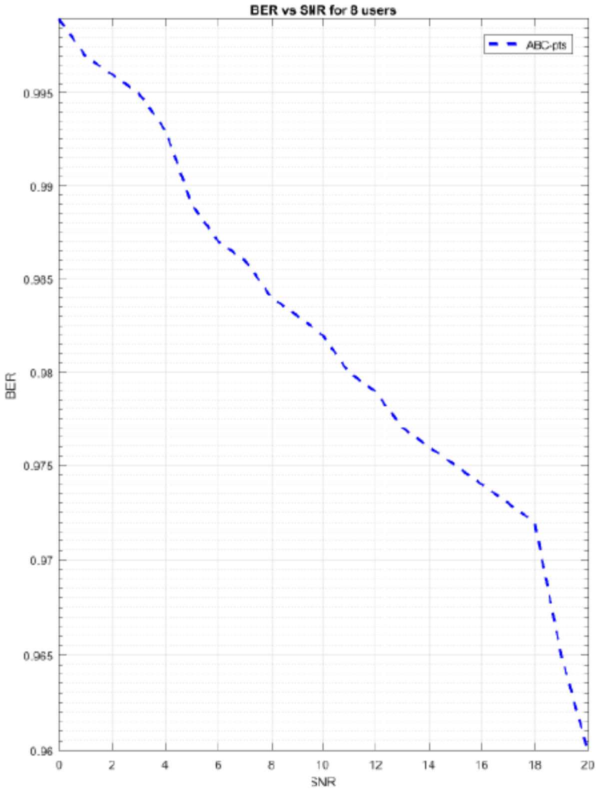

Figure 8: BER vs SNR using ABC-PTS

In fig 9 representation the performance of BER vs SNR using ABC-PTS, PSO-PTS, PTS.

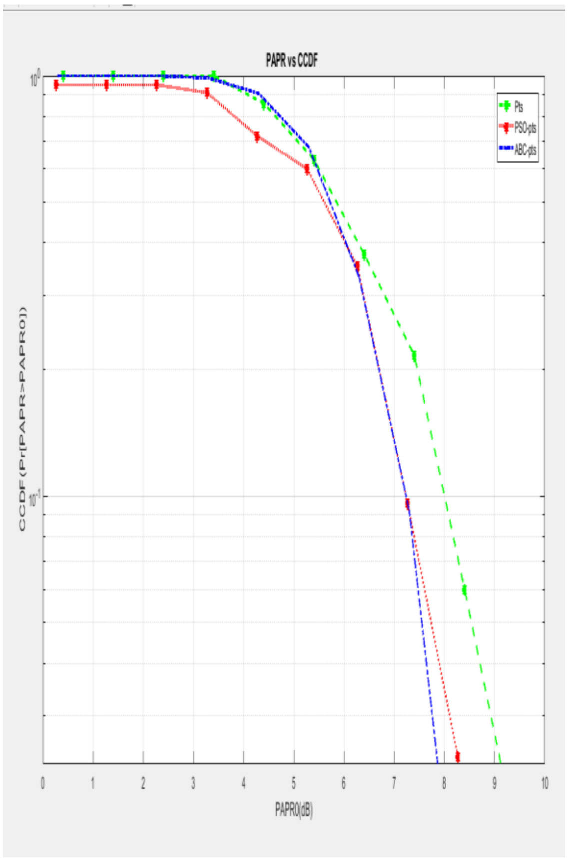

Figure 9: Performance comparison of PAPR vs CCDF

In fig 10 representation the performance of BER vs SNR using ABC-PTS, PSO-PTS, PTS.

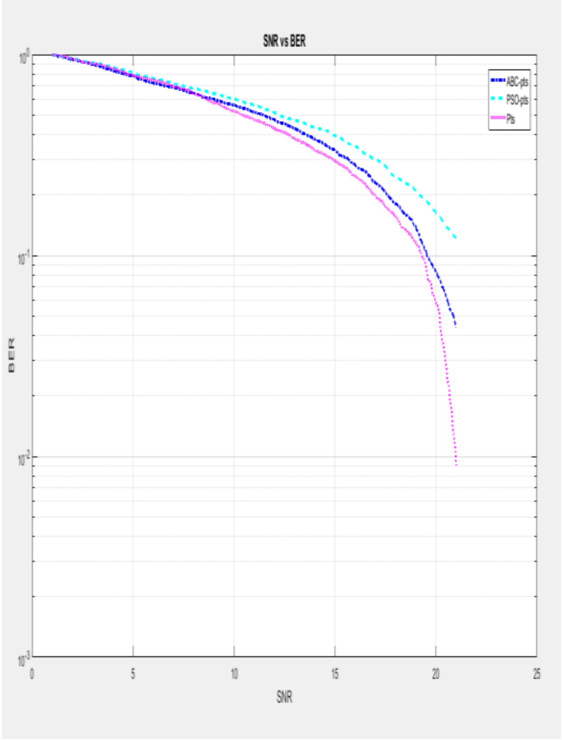

Figure 10: Performance comparison of SNR vs BER

VII. CONCLUSION

The achievement of results, WPM starts us to wind up that this new modulation scheme is a feasible substitute to MC-CDMA to be considered for today's communication systems. WPM is kind of more perceptive than MC-CDMA to commonly find types of distortion due to non-ideal elements of the system. The main concern of WPM nevertheless resides in its skill to fulfill the wide range of fulfillment of tomorrow's ubiquitous wireless communications. PAPR reduction using artificial bee colony (ABC) algorithm for PTS is proposed for wavelet packet modulation. In the result section we calculate CCDF vs PAPR using ABC-PTS, PSO-PTS and BER vs SNR using ABC-PTS, PSO-PTS. Performance comparison also show in result section using ABC-PTS, PSO-PTS, PTS by plotting graph in single figure.

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