Global Journal of Computer Science and Technology: E
Network, Web & Security
Volume 15 Issue 8 Version 1.0 Year 2015
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 0975-4172 & Print ISSN: 0975-4350

PAPR Reduction using PTS-PSO Technique for 16×16 MIMO-OFDM Systems with 16-QAM

By Jayati Das & Rajesh Bansode

Mumbai University, India

Abstract- In this paper, it is proposed that a particle swarm optimization (PSO) based partial transmit sequence (PTS) technique is used so that least Peak-to-Average Power Ratio(PAPR) is achieved in Multiple Input Multiple Output- Orthogonal Frequency Division Multiplexin gsystems (MIMO-OFDM). Our approach is to apply PSO based PTS on each antenna of the system helping to find the optimal phase factors, which is a straightforward method to achieve minimum PAPR in this system. PSO based PTS algorithm when applied to MIMO-OFDM systems with a wide range of phase factors, results in high performance after simulation. The results PAPR achieved for 16X16 MIMO-OFDM systems without PTS using 16-QAM is 15.8dB whereas with PTS the PAPR achieved is 7.1 dB therefore overall reductions PAPR with and without PTS is 8.7 dB. Similarly PAPR achieved for 16X16 MIMO-OFDM systems without PTS-PSO using 16-QAM is 15.8 dB whereas with PTS-PSO the PAPR achieved is 3.6 dB therefore overall reductions PAPR with and without PTS is 12.2 dB. The final reduction in PAPR resulted as 8.7 dB and 12.2 dB respectively.

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GJCST-E Classification : C.2.1

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Abstract- In this paper, it is proposed that a particle swarm optimization (PSO) based partial transmit sequence (PTS) technique is used so that least Peak-to-Average Power Ratio(PAPR) is achieved in Multiple Input Multiple Output-Orthogonal Frequency Division Multiplexin gsystems (MIMO-OFDM). Our approach is to apply PSO based PTS on each antenna of the system helping to find the optimal phase factors, which is a straightforward method to achieve minimum PAPR in this system. PSO based PTS algorithm when applied to MIMO-OFDM systems with a wide range of phase factors, results in high performance after simulation. The results PAPR achieved for 16X16 MIMO-OFDM systems without PTS using 16-QAM is 15.8dB whereas with PTS the PAPR achieved is 7.1 dB therefore overall reductions PAPR with and without PTS is 8.7 dB. Similarly PAPR achieved for 16X16 MIMO-OFDM systems without PTS-PSO using 16-QAM is 15.8 dB whereas with PTS-PSO the PAPR achieved is 3.6 dB therefore overall reductions PAPR with and without PTS is 12.2 dB. The final reduction in PAPR resulted as 8.7 dB and 12.2 dB respectively.

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I. Introduction

Multiple antennas used at the transmitter and receiver in the wireless communication system known as MIMO These schemes are highly considered to improve the range and performance of an overall system. Therefore, the use of multiple antenna permits to transmit and receive simultaneously by eliminating the multipath effect. MIMO allows higher throughput, diversity gain having increased spectral efficiency and interference reduction [1]. It offers high data rateandimproved link reliability due to antenna diversity gain through spatial multiplexing gain. Orthogonal frequency division multiplexing (OFDM) is a multicarrier modulation technique, which decreases the effect of the noise and interferences, MIMO technique can be used in conjunction with OFDM to increase the diversity gain and/or the system capacity by exploiting spatial domain [2].

The best feature of MIMO- OFDM is to provide high data rate for wireless communications. However, fortransmitted signal high peak-to average power ratio (PAPR) is a major drawback of the OFDM scheme [3]. Since MIMO-OFDM system is based on OFDM, it also faces the same issue. The high power amplifier (HPA) causes this high PAPR which is sensitive to nonlinear distortion. The nonlinear distortion generates inter-symbol interference (ISI) and inter-modulation, which increases the bit error rate.

Many techniques have been proposed in the literature to effectively address the high PAPR in OFDM systems. These approaches include the clipping techniques (that employ clipping or nonlinear saturation around the peaks to reduce PAPR) [4], coding techniques, and probabilistic (scrambling) techniques. Particle swarm optimization (PSO) is effective in optimizing difficult multidimensional discontinuous problems in a variety of fields. Main goal of PSO is to find in the field the location with the highest density of particles. Without any knowledge of the field a priori, the search begins in random locations with random velocities looking for particles. While a fundamental to use PTS is data blocks are divided into non overlapping sub-block with independent rotation factor. With lowest amplitude this rotation factor generates time domain data. The fundamental idea of this technique is sub-dividing the original OFDM symbol data into sub-data being transmitted through the sub-blocks which are then multiplied by the weighing value which has been differed by the phase rotation factor until choosing the optimum value which has low PAPR.

In this paper, a thorough study of PAPR Reduction in MIMO-OFDM using PTS is done. There by applying a straight forward technique this is implemented by applying PTS algorithm on each of the system's antennas [5]. This technique is called Independent PTS (IPTS).

The rest of this paper is organized as follows. In section II, describesproposed system architecture which is subdivided as Peak to Average power Ratio, Partial Transmit Sequence, Particle swarm optimization and PSO based PTS algorithm. The simulation results of the PSO based PTS MIMO-OFDM algorithm are presented and discussed in section III. Hence concluding the paper,

II. System Architecture

In day to day increasing need of high-speed wireless communication, OFDM can be applied to transform frequency selective MIMO channel into parallel MIMO channels, in multipath fading environment

Author α: Masters in Electronics and Telecommunication subject. Area of interest is Wireless Communication.
e-mail: dasjayatid@gmail.com
Author σ: is currently an Associate Professor pursuing Ph.D. in wireless Communication.
e-mail: rajesh.bansode1977@gmail.com

by reducing the complexity of the receiver also high data rate robust transmission can be achieved. At the transmitting end, a number of transmission antennas are used. To space-time coding an input data bit stream is supplied, then modulated by OFDM and finally fed to antennas for sending out radiation.Before recovery of the original signal is made at the receiving end, in-coming signals from transmitting end are fed into a signal detector and processed MIMO system with a transmit array of $M_T$antennas and a receive array of $M_R$antennas [6].

Problem of high PAPR a disadvantage in OFDM is discussed along with in depth knowledge of PAPR, how it causes problem in existing OFDM along with its outcome. For reduction of this problem at first OFDM is generated by choosing the spectrum requisite based on the input data, and modulation scheme used. Same data is assigned to transmit for each carrier to be produced. The required phase and amplitude of them are calculated based on the modulation scheme [7]. Using an Inverse Fourier Transform (IFT) requisite spectrum is achieved and then converted back to its time domain signal. The peak value of the system is very high as compared to the average of the complete system due to presence of large number of modulatedsub- carriers in an OFDM. This ratio of the peak to average power value is termed as Peak-to Average Power Ratio.

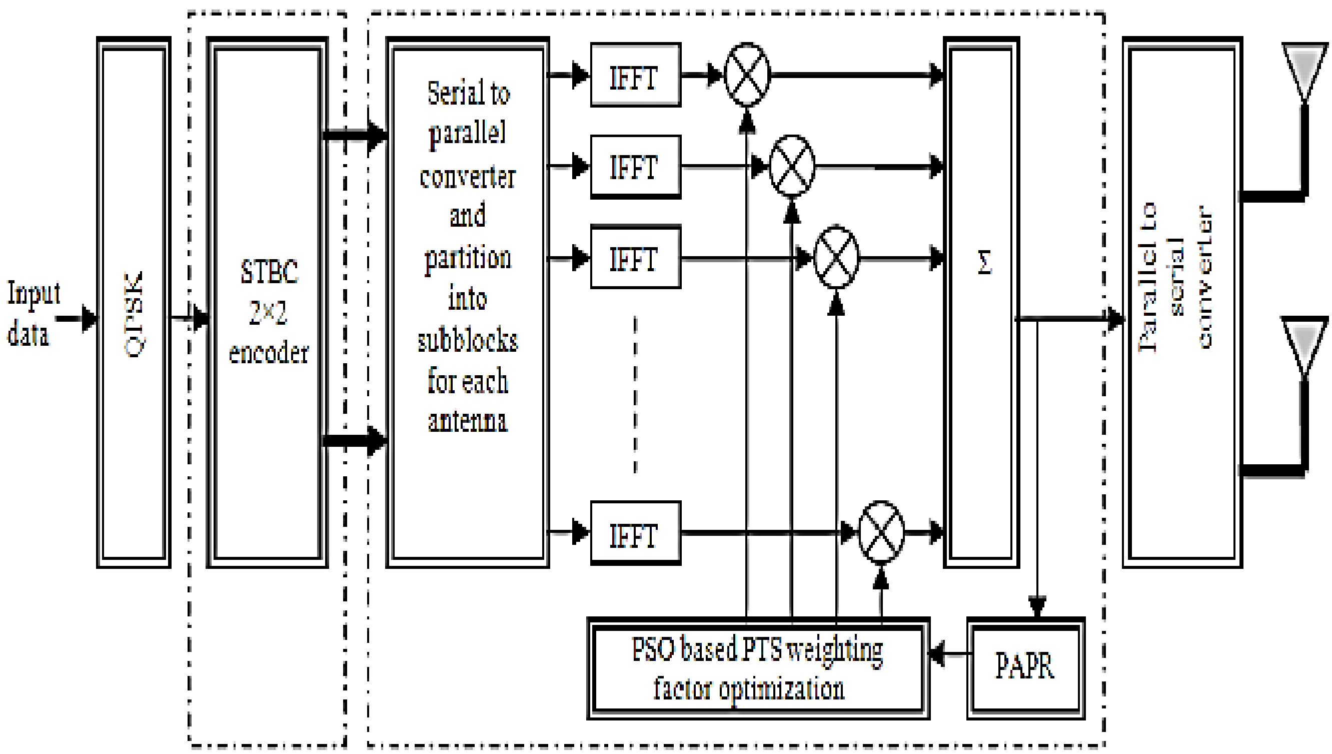

Fig.1: PAPR reduction technique by using PSO based PTS weighing factor

a) Peak to Average Power Ratio

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 $\mathrm{X} = [\mathrm{X}_0, \mathrm{X}_1 \ldots\ldots, \mathrm{X}_{N-1}]_\mathrm{T}$,and each symbol modulating one of a set of subcarrier$\{f_n, n = 0,1,\ldots\ldots.., N-1\}$. The N subcarriers are selected to be orthogonal. The datablock of the OFDM symbol is given by

$$x(n) = \frac{1}{\sqrt{N}} \sum_{i=0}^{N-1} X_i e^{\frac{j2\pi ni}{N}}, \qquad 0 \le n \le N-1 \qquad (1)$$

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

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

The large PAPR is reduced as value of$max|x(t)|$ decreased. The PAPR problems are arising by calculation of four sinusoidal signals with different frequency and phase shift logically.

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

$$Crest\ Factor\ =\ \sqrt{PAPR} \qquad (3)$$

The CCDF expression of the PAPR of OFDM signals can be written as

$$CCDF\ =\ max_{0\leq T\leq NT}\frac{|x(t)|}{E[|x(t)|]} \qquad (4)$$

$E[|x(t)|]$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. There are several techniques to reduced PAPR, and is subdivided into two groups as signal scrambling techniques and signal distortion techniques. These can be further subdivided into many techniques such as clipping, peak windowing and peak cancellation.

b) Partial Transmit Sequence

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 [8]. The phase rotation vector is very carefully chosen such that the PAPR value is minimized. PTS is highly successful in PAPR reduction and efficient redundancy utilization; on other hand a considerable computational complexity is required to search with respect to high-dimensional vector space along with necessary transmission of side information (SI) to the receiver are challenges for a practical implementation. The complexity issue has been formulated such that the search problem of PTS is a combinatorial optimization (CO) problem

c) Particle Swarm Optimization

PSO is a population-based globalised 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. The language used to discuss the PSO follows from the analogy of particles in a swarm.

d) Particle Swarm optimization based PTS Algorithm

PSO as an optimizer is used to solve the phase factor problem, which is shown as PSO process block in Fig below. In PSO algorithm solution space of the problem is called particles, which is φ_k in the PTS based PSO scheme [9]. 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 [10]. 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$S \times K$where S is the number of particles and K is the number of disjoint sub-block [11]. In other words, the solution space is a matrix its rows are$\varphi_1, \varphi_2, \varphi_3 \ldots\ldots\ldots. \varphi_k$.

Since the PSO is an iterative algorithm, in the i^{th}iteration each particle can be described by its positionvector $Y_{SK}^t = y_{S1}^t, y_{S2}^t, y_{S3}^t, \ldots\ldots\ldots y_{Sk}^t$ and velocityvector is given as$V_{SK}^t = v_{S1}^t, v_{S2}^t, v_{S3}^t, \ldots\ldots\ldots v_{Sk}^t$, where $s \in [1, S]$ and $Y_{SK}^t \in R$ where Rdenotes 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$p_{sk} = p_{s1}, p_{s2}, p_{s3}, p_{s4}, \ldots. p_{sk}$ and the global best position can be given as

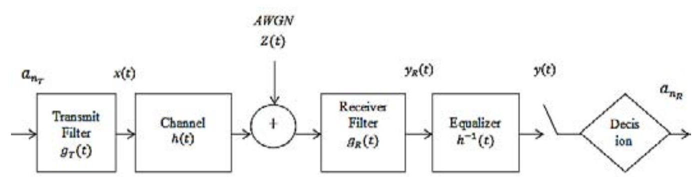

Fig. 2 : PAPR reduction technique by using PSO based PTS weighing factor

$p_{sk}^g = p_{s1}^g, p_{s2}^g, p_{s3}^g, p_{s4}^g, \ldots\ldots p_{sk}^g$ 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

$$V_{SK}^{t+1} = wV_{SK}^t + c_1r_1(p_{sk}^t - Y_{SK}^t) + c_1r_1((p_{sk}^t)^g - Y_{SK}^t)$$

$$\boldsymbol{Y}_{SK}^{t+1} = \boldsymbol{Y}_{SK}^t + \boldsymbol{V}_{SK}^t \qquad (5)$$

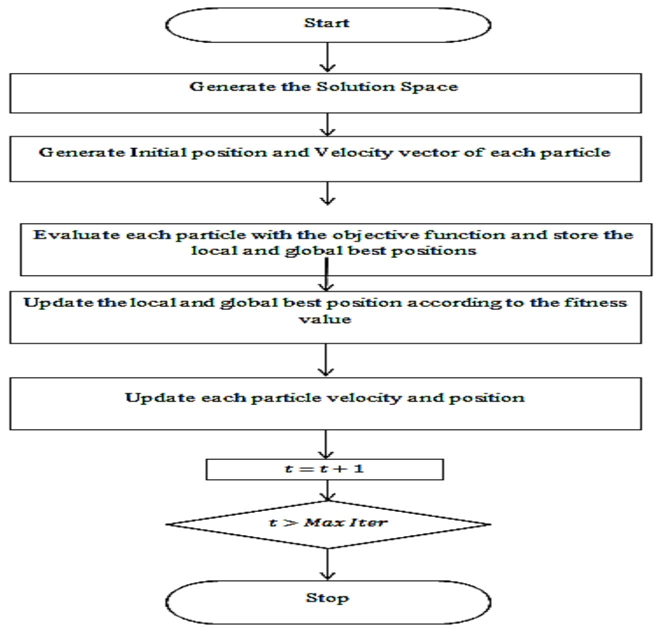

Fig. 3 : PSO-PTS Algorithm

Where c_1 and c_2 are the acceleration terms [12]. The constant r_1 and r_2 are uniform distribution random numbers in the range of [0, 1]; **w** is the inertia factor.

III. Simulation ResultAnd Discussion

Complementary Cumulative Distribution Function (CCDF) of PAPR is calculated by generating 2000 random OFDM frames. The constant acceleration $c_1 = c_2 = 2$and the inertia factor w is calculated by using

$$w = (w_{max} - w_{min}) \times \frac{Itr_{max} - Itr_{min}}{Itr_{max}} + w_{min} \qquad (6)$$

Fig.4. below shows CCDF of PAPR for PSO-PTS MIMO-OFDM (16×16) is compared with the original PAPR MIMO-OFDM. The PAPR of PSO-PTS MIMO-OFDM signal exceeds 3.6 dB is 10^{-6} while with the same PAPR of the PTS MIMO-OFDM system exceeds 7.1 dB and the PAPR of the original MIMO-OFDM system exceeds 15.8 dB The further study gives us the knowledge of reduction in PAPR is calculated as difference of MIMO-OFDM PAPR value without PTS to that of PAPR value of MIMO-OFDM with PTS.

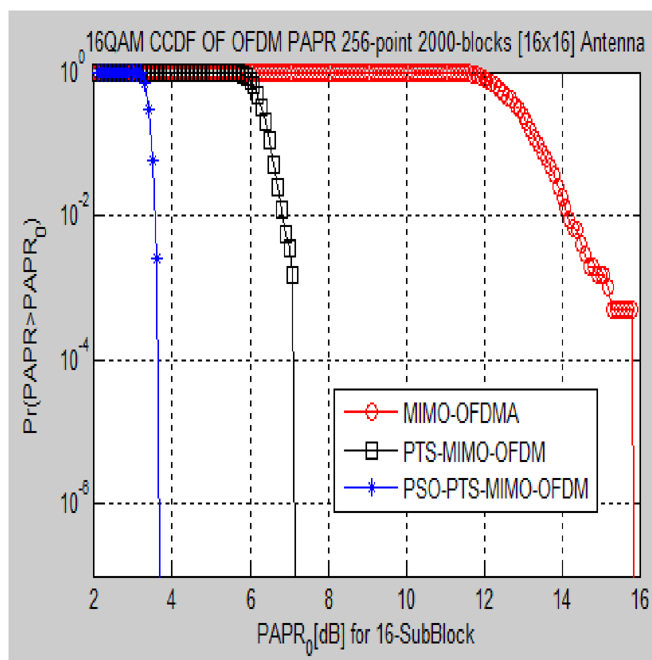

Fig. 4 : CCDF vs. PAPR for PSO-PTS MIMO (16×16)

Table 1: CCDF vs. PAPR for PSO-PTS MIMO

Condition	PAPR(dB)	CCDF	Parameter
MIMO-OFDM	15.8	10^{-6}	2000blocks, 16×16, 16 QAM, 256 Carrier
PTS MIMO-OFDM	7.1		
PTS-PSO MIMO-OFDM	3.6		

For simplicity adjacent portioning technique is used. By increasing the number of sub-blocks of PTS-PSO MIMO-OFDM system, the performance of the system is enhanced. The CCDF of PAPR exceeds the PTS-PSO MIMO- OFDM when K = {4, 8, 16} is shown in Fig.5. PAPR of 3.6 dB is achieved for CCDF 10^{-6} when K = 16; PAPR of 3.8 dB is achieved for CCDF 10^{-6} when K = 8, and PAPR OF 4.4 dB is achieved for CCDF 10^{-6} when K = 4

Table 2 : CCDF vs. PAPR (Sub Blocks)

Sub-Blocks	PAPR(dB)	CCDF	Parameter
K=16	3.6	10^{-6}	2000blocks,16 × 16,16 QAM,256 Carrier
K=8	3.8		
K=4	4.4		

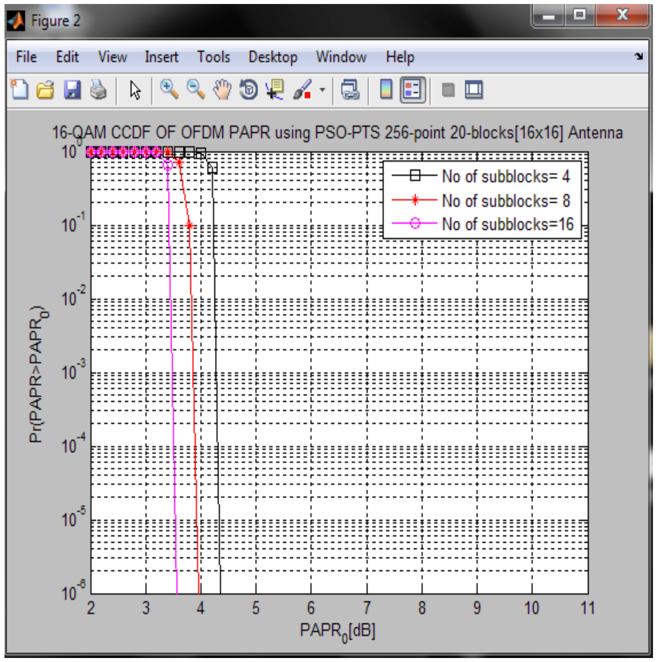

Fig. 5 : CCDF vs. PAPR for PSO-PTS MIMO (Sub-Blocks) (16×16)

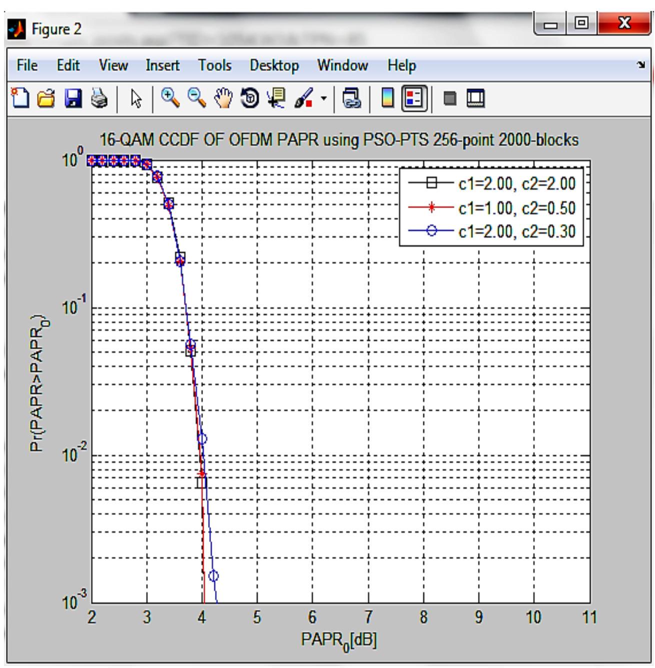

*Fig.6.*CCDF vs. PAPR for PSO-PTS MIMO (Acceleration Constant) (16×16)

The performance of PSO-PTS is analyzed for different constants accelerations are used. The probability that the PAPR exceeds 3.4 dB is 0.01 when $c_1 = c_2 = 2$ and exceeds 3.435dB is 0.0099 when $c_1 = c_2 =$

0.3. It can be noted from the graph that $c_1 = c_2 = 2$ is slightly better performance than other combinations.

Table. 3 : CCDF vs. PAPR (Acceleration Constant)

Sub Carrier	Acceleration Constant	PAPR (dB)	Probability	Parameter
256	$c_1 = c_2 = 2$	3.4	0.01	2000blocks(2k bits),16×16,16 QAM,256 Carrier
	$c_1 = c_2 = 0.3$	3.435	0.0099	

IV. Conclusion

In this paper, the PAPR of MIMO-OFDM systems using PSO algorithm is studied. The performance of the system is evaluated by calculating the CCDF. Applying PSO-PTS algorithm on MIMO-OFDM PAPR achieved for 16X16 MIMO-OFDM systems without PTS using 16-QAM is 15.8dB whereas with PTS the PAPR achieved is 7 dB hence reductions PAPR with and without PTS is 8.7 dB. Similarly PAPR achieved for 16X16 MIMO-OFDM systems without PTS-PSO using 16-QAM is 15.8 dB whereas with PTS-PSO the PAPR achieved is 3.6 dB therefore reductions PAPR with and without PTS is 12.2 dBby choosing the phase factors with high degrees of freedom the number of needed particles is low and the performance of PSO algorithm is enhanced. Performance of PSO-PTS had been analyzed for various Sub-Block and best PAPR is found for Sub-Block K=16 and is 3.6dB. And for acceleration constant the probability calculation is best found for $c_1 = c_2 = 2$ with PAPR exceeding 3.4dB at probability of 0.01. The complexity of the search is low since the number of particles is also kept low. The system modeled had 16 Transmitting and Receiver antenna.

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