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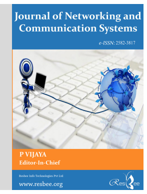

MCGA: Modified Compact Genetic Algorithm for PAPR Reduction in MIMO-OFDM System

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Abstract: Reduction of PAPR is the main objective of designing the ORPD with superior operation. Still, it remains as the challenging point due to the increased computational complexity. In this paper, we proposed the Modified Compact Genetic Algorithm (MCGA) based- scrambling in order to reduce the peak to-average-power ratio (PAPR) and Bit Error Rate (BER). Further, the experimental result of the proposed MCGA algorithm is compared with the standard scrambling. The analysis is performed based on the examination of the PAPR and BER rate. Hence, it shows that the proposed MCGA algorithm superiority than the standard scrambling technique for reducing the PAPR and BER.

Keywords: OFDM, scrambling, PAPR, BER, MCGA algorithm

1. Introduction

Recently in wireless communication, the Spatial Frequency Block Coded –Multicarrier modulated communication are achieving more attention [4] [8]. The main advantage of this modulation system is obtaining the high spectral efficiency and high adaptability against the frequency selective fading and multipath delay. Instead of these advantages, this system may suffer from the high range of Peak-to-Average Power Ratio (PAPR). Further, when the signal enters the High Power Amplifier (HPA) the high PAPR makes the undesired distortion in the transmitted signal [10] [9] [30]. PAPR is deduced to maintain the power saving capability of the system. Hence, various researchers have worked towards the approach to make the reduction in PAPR.

A number of methods such as Signal Pre-distortion and Signal Scrambling have developed to reduce the PAPR. In case of scrambling approaches, it includes Selective mapping (SLM) [2] [1], phase optimization [3] and Partial Transmission system (PTS) [13] where as the pre-distortion of signal includes the clipping methodologies. Both the methods such as SLM and PTS have the ability to reduce the PAPR with reduced Bit Error Rate (BER) which make the reliable signal transmission.

The researchers have used the same methods such as SLM [3], SLM with mapping signal sequences [6], sub optimum detection approach; PTS have also been applied to the SFBC-coded MIMO-OFDM system. On comparing the PTS scheme with SLM [21], it has been stated that, PTS have less computational complexity. Despite several approaches such as for PAPR reduction, Type-I PTS and Type-II PTS have been implemented in [5], and have obtained the result with less PAPR with reduced cost of computation. Generally, PTS method divides the input pclock into number of sub-blocks with no overlapping [20] [23]. However when the number of sub- blocks increases, there is an increment in the phase weighting factors, which leads to raise the computational complexity [14] [15]. This limitation has reduced by implementing the intelligent techniques such as Particle Swarm Optimization (PSO), Quantum-Inspired Evolutionary Algorithm (QEA), electromagnetism-based (EM-based) algorithm etc. Further, with the use of crossover, mutation and adaptation of parameter modified Differential Evolution (DE) algorithm have been applied in [22] which have overcome the limitations of DE and PSO [25] [26]. So it is essential to implement best algorithm for ORPS system with reduced computational complexity.

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2. Literature Review

2.1 Related Works

In 2014, Luo Renze *et al*. [24] have developed the two improved SLM techniques such as ED-SLM and SLM to reduce the PAPR in the OFDM system. In the first ED-SLM, the signals have transmitted with the absence of side information (SI), and further it has scrambled with the specified phase sequences. The Euclidean phase distance detection (EPD) have used in the receiver side to retain the SI with perfect demodulation. In the second SLM approach, Hadamard matrix has used to transmit the signals with less PAPR. The experimental results have analyses and stated that the proposed method provides less PAPR and BER when compared with the conventional methods.

In 2014, Sheng-Ju Ku [5] have implemented the low- complexity PTS schemes in order to obtain the signal transmission in OFDM with less PAPR and to overcome the computational complexity occurred in the conventional algorithms. Here, the computational complexity is reduced by sample powers of sub-blocks that produce the cost functions for choosing the samples. The comparative analysis with other methods has shown that the proposed method obtains the less PAPR and BER with reduced computational cost.

In 2015, Elavarasan *et al*. [11] have suggested the modified PTS scheme which uses Group Phase Weighting Factor (GPW) and Recursive Phase Weighting Factor (RPW) in combination with All Pass Filtering, in order to provide the decrement of PAPR of OFDM system. This methodology has reached the improvement by generating the multiple phase shifts and selecting the most favourable one. In addition, it has produced the optimal phase shift and protection of magnitude response. A comparison between the proposed algorithm and the original PTS scheme has resulted in the superiority of the proposed algorithm in reducing PAPR.

In 2015, Necmi Tas¸pınar and Mahmut Yıldırım [7] have adopted the Parallel Artificial Bee Colony Algorithm (P-ABC) which is based on the new search strategy. The performance of the P-ABC were tested in both OFDM and multiple input multiple-output (MIMO)-OFDM systems. Further, ABC/best/1 and modified ABC/best/1have also proposed to reduce the PAPR. The experimental results of the proposed method have proved that it maintains the OFDM system with less PAPR and BER.

In 2015, Arafat et al [26] have suggested the novel technique to improve the robustness in the SFBC base-OFDM system. In this approach, it maps the channel matrix of the frequency selective- fading channels into piecewise fading. This method has provided the superiority over the normal SFBC, since the channel parameters are similar over the parameters of the channel. The interference caused due to the channel variation acts only as additive noise, and has provided superior performance with less computational cost.

2.2 Review

The selection of optimal signal sequences of OFDM have remained as the challenging point under the Class III - SLM [19] scheme. The other stochastic searching procedures such as MCCSFLA [12], Greedy algorithm [18] and Parallel ABC [7] with the scrambling techniques have also been successfully reported in the literature. However, lots of improvement has to be subjected to handle the challenges yet. Absence of variability in including parallelism [7], numerous conditions for choosing the better candidate [16] [17], difficulty in designing and conformation phase of the search process [18] is some of the challenges arising in the ORPD system. Hence, the review reveals that the state-of-the-art scrambling techniques need improvement in the OFDM system to reduce PAPR.

3. Design of SFBC-MIMO-OFDM

Consider, SFBC-MIMO-OFDM comprises T transmit antennas and R receiver antennas. That contains N number of subcarriers. Between transmit and receive antennas, the frequency selective fading channel may arise which may contains L_i independent paths and identical power delay profile. The channel impulse response between the transmit antenna and receive antenna is represented in eqn. (1) where T_l represents the delay of the l^{th} path, $\tau_{i,j}(l)$ denotes the complex amplitude of the l^{th} path. $\tau_{i,j}(l)$ is considered as the zero-mean, complex Gaussian random variables with unit variance as in eq. (2), where E denotes the expectation.

$$h_{m,n}(r) = \sum_{l=0}^{L_i \quad 1} \tau_{i,j}(l)(T \quad T_l) \tag{1}$$

$$E\left(\tau_{i,j}(l)\right)^2 = \delta_l^2 \tag{2}$$

From eqn. (1), the frequency response of the channel is expressed in eq. (3) where $j = \sqrt{-1}$ is the imaginary unit.

$$H_{m,n}(f) = \sum_{l=0}^{L_i - 1} \tau_{m,n}(l) e^{-j2\pi f r_1} \tag{3}$$

The MIMO channel is assumed to be spatially uncorrelated as the channel taps $\tau_{m,n}(l)$ is independent for various indices (m,n). The code words of the SF code block are represented as matrix $N \times T$ that contains the transmitted bit streams as in eq. (4), where $cb_m(n)$ represents the channel symbol that is transmitted over the transmit antenna n.

$$Cb = \begin{bmatrix} cb_1(0) & cb_2(0) & \cdots & cb_T(0) \\ cb_1(1) & cb_2(1) & \cdots & cb_T(1) \\ \vdots & \vdots & \ddots & \vdots \\ cb_1(N-1) & cb_2(N-1) & \cdots & cb_T(N-1) \end{bmatrix} \tag{4}$$

The energy constraints of SFBC is expressed as,

$$E\|Cb\|_F^2 = NT \tag{5}$$

At the n^{th} receive antenna, FFT is applied at the i^{th} subcarrier is represented as,

$$S_f(n) = \sqrt{\frac{\rho}{M_t}} \sum_{m=1}^{T} cb_m(j) H_{m,n}(n) + z(n) \tag{6}$$

In eq. (6), $H_{m,n}(n)$ represents the channel frequency response at the i^{th} subcarrier between the transmit antenna m and the receive antenna n and $S_f(n)$ is the received signal. The frequency deviation is given as, $\Delta f = 1/T$, where T is the OFDM symbol period.

The channel frequency response between the transmit antenna m and receive antenna n is represented in eq. (7) and the corresponding impulse response can also be expressed as another form using the term $u = e^{-j2\pi\Delta f}$ in eq. (8).

$$H_{m,n} = \left[H_{m,n}(0) \quad H_{m,n}(1) \quad \cdots \quad H_{m,n}(N-1)\right]^T \tag{7}$$

$$H_{i,j} = R_d . P_{m,n} \tag{8}$$

The delay distribution R_d is represented in eq. (10) and the power distribution of the channel impulse response $P_{m,n}$ is represented in eq. (11) as,

$$R_d = \begin{bmatrix} 1 & 1 & \cdots & 1 \\ u^{T_0} & u^{T_1} & \cdots & u^{T_{L_i - 1}} \\ \vdots & \vdots & \vdots & \vdots \\ u^{(N-1)T_0} & u^{(N-1)T_1} & \cdots & u^{(N-1)T_{L_i - 1}} \end{bmatrix}_{N \times L_i} \tag{9}$$

$$P_{m,n} = \left[a_{m,n}(0) \quad a_{m,n}(1) \quad \cdots \quad a_{m,n}(L_i - 1)\right]^T \tag{10}$$

4. PAPR reduction in SFBC-OFDM using Genetic Algorithm

An easy and adaptable method to reduce the PAPR in OFDM is SLM which is based on scrambling. This technique is used to transmit the information with low PAPR. With the utilization of the selected signal, this method is carried out. The block diagram of SFBC-OFDM is shown in fig. 1. The information transmitted from the transmitter to the receiver side suffers from complexity if the error occurred between the transmissions.

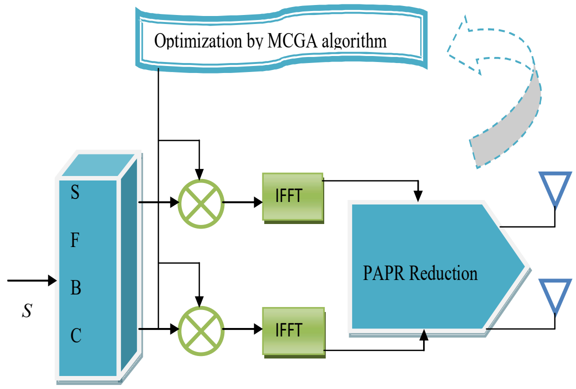

Fig. 1. *Block diagram of proposed MCGA base-scrambling approach.*

This complexity arises when the number of sub carriers increases. The frequency-domain symbols with multiple antennas is expressed as

$$S = [S(0), S(1), ...S(N \quad 1)] \tag{11}$$

Assume, the IFFT operation is applied to the two vectors like S_1 and S_2. Further, the time-domain samples are generated as $t_1(n)$ and $t_2(n)$, $0 \le n \le N \quad 1$. The orthogonality of the matrix at the receiver side is of the form, where I_n is $n \times n$ identity matrix.

$$C_{ortho} = (|(S(2v)|^2 + |(S(2v+1)|^2) I_2 \tag{12}$$

In the p^{th} antenna, the PAPR model is formulated as, in eq. (14) where $p = 1,2$ is the number of antennas

$$P_R(s_p) = \frac{\max_n \{|s_p(n)|^2\}}{E\{|s_p(n)|^2\}} \tag{14}$$

The minimum PAPR is achieved by multiplying the transmitted vectors like S_1 and S_2 with the phase sequence. Here, in SLM technique the OFDM frames of the antenna are continuously enhance with same single-phase sequence. This has reduced the number of bits to be transmitted. The different representation of the signals Z_1 and Z_2 are represented as follows.

$$S_1^d = IFFT_N\{S_1 \quad k^d\}$$
$$S_2^d = IFFT_N\{S_2 \quad k^d\} \tag{14}$$

Where $0 \le d \le D \quad 1$

The range of the phase sequence k^d is randomly selected between 0 and π which should have equal probabilities. The complexity of the phase rotation is low since the value of $k^d(k) = e^{j0} = +1$ or $k^d(k) = e^{j\pi} = -1$. So after the multiplication, the sequence k^d is moved according to the variation of sign of the symbols. The pairs $[k^d(2v), k^d(2v+1)]$, $0 \le v < N/2$, $0 \le d < D \quad 1$ takes the values [+1, -1], [-1, +1], [-1,-1] and [+1, +1] with equal probabilities.

The vectors S_1 and S_1 after the multiplication of the phase sequence have made the matrix C_{ortho} into another form as,

$$C_o = \begin{matrix} k^d(2v)S(2v) & k^d(2v+1)S(2v+1) \\ k^d(2v)S \quad (2v+`1) & k^d(2v+1)S*(2v) \end{matrix} \tag{15}$$

The determination of the index of the optimum phase sequence $\bar{d}$ is essential to identify the transmitted symbols $S(j)$, $0 \le j \le N-1$ accurately at the receiver side. Further, the cyclic prefix and FFT is applied and the received vector $G = [G(0), G(1), ...G(N \quad 1)]^T$ is represented in eq. (17) where $B_p(k): p = 1,2........M$ and $F(j)$ are the base band equivalent coefficient of the channel between the p^{th} transmit antenna and the receiver antenna and the noise component of the j^{th} subcarrier.

$$G(j) = B_1(j)S_1^d(j) + B_2(j)S_2^d(j) + F(j), \; 0 \le j \le N \quad 1 \tag{16}$$

The maximum-likelihood (ML) detection for $\bar{d}$ and S is expressed in eq. (18).

$$[d^{(ML)}, S^{\ (ML)}] = \underset{0 \le d \le D}{\arg\min} \sum_{v=0}^{v=N/2\ \ 1} \begin{matrix} \left| G(2v) \quad B_1(2v) n^{\hat{d}}(2v) \hat{S}(2v) \quad B_2(2v) n^{\hat{d}}(2v) \hat{S}^*(2v+1) \right|^2 + \\ \left| G(2v+1) \quad B_1(2v) n^{\hat{d}}(2v+1) \hat{S}(2v+1) + B_2(2v) n^{\hat{d}}(2v+1) \hat{S}^*(2v) \right|^2 \end{matrix} \tag{17}$$

Where D represents the random phase sequences and S represents the frequency domain vectors that to be transmitted. The full diversity can be achieved at the receiver side only when the space frequency code is orthogonal.

5. Proposed MCGA

The Compact Genetic Algorithm is one of the Estimation Distribution Algorithms, which was first implemented in [28] [27]. Basically, this algorithm obtains the allotment of best solutions by the utilization of the probability vector S_V to demonstrate the possible solution. The proposed MCGA enhances the exploration capability of the general CGA algorithm. From the CGA algorithm, the proposed MCGA uses more number of probability vectors and introducing a new learning scheme in the update procedure. Basically, the update procedure of MCGA is divided to two steps such as local update and global update which is taken from the PSO algorithm [29]. The MCGA algorithm update each element of each probability of the scrambling solution based on the law in the local update of the pseudo code where as the global update is performed based on the learning factor c . This algorithm has the ability to reduce the local optimum and hence the computation complexity is highly diminished. The pseudo code of the proposed MGCA algorithm is depicted below.

ALGORITHM:1 PSEUDOODE FOR MCGA

Initialize the probability vector of scrambling solution $S_V(x)$, $\forall x = 1.2....X$

Production of the two individuals as u and v

Perform the competition between the solution as $\text{winner}, \text{loser} = \text{compete}(\text{u}, \text{v})$

Update scrambling solutions

Local update: $\forall (x = 1,2......X)$, $\forall (w = 1,2......W)$

  If $winner(x,w) \neq loser(x,w)$

    If $\text{winner}(\text{x}, \text{w}) = 1$

$$S_V(x,w) = S_V(x,w) + \frac{1}{n}$$

    else

$$S_V(x,w) = S_V(x,w) \quad \frac{1}{n}$$

    end if

  end if

Global update

$S_V best = best(S_V)$

$S_V(x) = S_V(x) + c(S_V best \quad S_V(x))$

Test out convergence

In the above pseudo code, n is the size of the population, X represents the length of the chromosome, W represents the number of scrambling solutions and c is the learning factor. The flowchart of the proposed MCGA algorithm is shown in fig. 2.

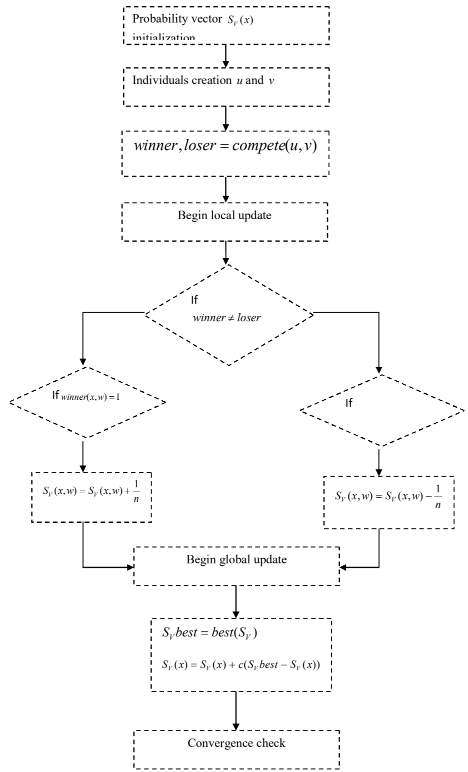

Fig. 2. *Flowchart of MCGA algorithm*

The description of the pseudo code and flowchart of MCGA algorithm is described in the following steps.

1 The probability vectors of the scrambling solution are initialized as $S_V(x)$, where $x = 1.2....X$.
2 From each element of the present probability, two individuals such as u and v are generated.
3 These two elements compete each other and select the winner. The corresponding winner is answerable for updating the probability.
4 In local update, the probability value gets increased or decreased by the factor $\frac{1}{n}$ corresponding to the value obtained by the winner.
5 In global update, the update procedure is done based on the learning factor c .
6 The convergence tested and the same procedure is repeated until the completion of the all the scrambling solutions.

6. Results and Discussions

6.1 Procedure of Experiment

The experiment of MCGA based scrambling procedure of OFDM is performed were performed in MATLAB and the performance were carried out. The corresponding performance was validated based on the analysis of APAPR and BER rate of the standard scrambling and the proposed MCGA algorithm. Here the reduced PAPR and the BER rate allow the information to be perfectly transmitted to the receiver side.

6.2 Analysis of PAPR

The value of PAPR should be less for obtaining the perfect performance of the ORPD system. Generally, the PAPR value depends on the peak power and average power of the system. Since the algorithm is performed for different iterations till the convergence, it generates different values. So the optimum value of PAPR is produced by selecting the best case and worst case scenario depending on the number of iterations performed in the experiment. Those scenarios are taken by varying the SNR value from 0dB to 10 dB which is shown in table 1 and 2.

Table 1. *Best case scenario of standard and MCGA scrambling*

SNR (dB)	0	2	4	6	8	10
Standard scrambling	9.56	9.84	9.55	9.22	9.35	9.64
MCGA	8.32	8.54	8.35	8.18	8.07	8.99

Table 2. *Worst case scenario of standard and MCGA scrambling*

SNR (dB)	0	2	4	6	8	10
Standard scrambling	9.87	9.44	9.87	9.43	9.47	9.52
MCGA	8.45	8.98	8.56	8.43	8.57	8.90

In table 1 and 2, the performance in terms of PAPR of the proposed MCGA provide high variations when compared with the standard scrambling approach. In case of the statistical report of the best case scenario, the proposed MCGA algorithm provides 14.90% better performance than the standard scrambling for SNR=0 dB. Similarly, the proposed MCGA is 15.22%, 14.37%,14.37%, 12.71%, 15.86% and 7.23% better performance than the standard scrambling for SNR=2 dB, SNR=4 dB, SNR=6 dB, SNR=8 dB, and SNR=10 dB. The statistical report in terms of the worst case scenario provides the result in such a way that the proposed MCGA algorithm provides the superior performance of 16.80%, 5.12%, 15.30%, 11.86%, 10.50% and 6.96% than the standard scrambling for SNR=2 dB, SNR=4 dB, SNR=6 dB, SNR=8 dB, and SNR=10 dB . Further, the performance of the mean, median and standard deviation of the proposed and standard scrambling is shown in table 3, 4 and 5.

Table 3. *Mean performance of standard and MCGA scrambling*

SNR (dB)	0	2	4	6	8	10
Standard scrambling	9.56	9.98	9.65	9.67	9.76	9.34
MCGA	8.23	8.56	8.65	8.91	8.43	8.23

Table 4. *Median performance of standard and MCGA scrambling*

SNR (dB)	0	2	4	6	8	10
Standard scrambling	9.64	9.23	9.53	9.46	9.56	9.35
MCGA	8.34	8.67	8.19	8.91	8.10	8.13

Table 5. *Standard deviation performance of standard and MCGA scrambling*

SNR (dB)	0	2	4	6	8	10
Standard scrambling	1.6	1.78	1.33	1.34	1.13	1.03
MCGA	0.2	0.34	0.53	0.23	0.32	0.12

The mean and median performance is obtained from the result of the best and worst case scenarios. According to the mean performance, the proposed MCGA provides improved performance of 16.16%, 16.58%, 15.30%, 11.86%, 10.50% and 6.96% when compared with the standard scrambling technique for SNR=0, SNR=2 dB, SNR=4 dB, SNR=6 dB, SNR=8 dB, and SNR=10 dB. However, the median performance make the MCGA algorithm to obtain the better performance of 15.58%, 6.45%, 16.36%, 6.15%, 18.02% and 15% than the conventional method corresponding to SNR=0, SNR=2 dB, SNR=4 dB, SNR=6 dB, SNR=8 dB, and SNR=10 dB. The standard deviation is generally calculated to verify the difference, and hence the reliability of the algorithm can be measured. From the standard scrambling method, 87%, 81%, 60%, 82%, 71% and 88% minimized deviation is obtained by the proposed MCGA algorithm.

6.3 Analysis of BER

Generally, BER is nothing but the bit errors per unit time. In all system, the best performance is provided based on the low BER rate. BER varies according to the energy level and the noise level of the system. If the nose level of the system is increased, the BER rate is also increased. So the main objective is to implement the system with less noise level. The analysis of BER rate corresponding to the best case and worst case scenario is shown in table 6 and 7. On comparing the best case scenario, the MCGA generates best performance of 17.17%, 17.25%, 8.90%, 10.75%, 4.89% and 16.46% for SNR=0, SNR=2 dB, SNR=4 dB, SNR=6 dB, SNR=8 dB, and SNR=10 Db than the standard scrambling. Consequently, the worst case scenario also make the MCGA algorithm to produce the enhanced performance of 9.37%, 9.64%, 11.46%, 21.44%, 9.36% and 10.92% than the conventional scrambling algorithm for SNR=0, dB

SNR=2 dB, SNR=4 dB, SNR=6 dB, SNR=8 dB, and SNR=10 dB.. The performance of BER in terms of mean, median and standard deviation is shown in table 8, 9 and 10.

Table 6. *Best case scenario of standard and MCGA scrambling*

SNR (dB)	0	2	4	6	8	10
Standard scrambling	9.82	9.65	9.29	9.37	9.42	9.83
MCGA	8.34	8.23	8.53	8.46	8.98	8.44

Table 7. *Worst case scenario of standard and MCGA scrambling*

SNR (dB)	0	2	4	6	8	10
Standard scrambling	9.33	9.78	9.43	9.74	9.34	9.24
MCGA	8.53	8.92	8.46	8.02	8.54	8.33

By considering the mean performance, the proposed MCGA algorithm forms the better quality performance of 15.56%, 11.82%, 12.68%, 15.45%, 19.42%, 3.35% then the standard scrambling technique for SNR=0, SNR=2 dB, SNR=4 dB, SNR=6 dB, SNR=8 dB. Similarly the mean performance of the proposed MCGA algorithm is 8.99%, 9.29%, 16.28%, 14.75%, 9.75% and 16.64% better than the conventional scrambling. Finally, the standard deviation of the proposed and conventional scrambling is analysed, and here 72%, 89%, 81%, 90%, 90% and 78% less deviation is obtained by the proposed MCGA approach when compare with the standard scrambling scheme .

Table 8. *Mean performance of standard and MCGA scrambling*

SNR (dB)	0	2	4	6	8	10
Standard scrambling	9.65	9.55	9.86	9.34	9.96	9.23
MCGA	8.35	8.54	8.75	8.09	8.34	8.93

Table 9. *Median performance of standard and MCGA scrambling*

SNR (dB)	0	2	4	6	8	10
Standard scrambling	9.45	9.76	9.71	9.16	9.56	9.53
MCGA	8.67	8.93	8.35	8.02	8.71	8.17

Table 10. *Standard deviation performance of standard and MCGA scrambling*

SNR (dB)	0	2	4	6	8	10
Standard scrambling	1.56	1.92	1.53	1.92	1.43	1.45
MCGA	0.43	0.21	0.29	0.2	0.13	0.32

7. Conclusion

In this paper, it has been shown that the previously proposed standard scrambling method is better for the ORPD operation with reduced PAPR and BER value. But still the computational complexity is considered as the challenging point. This paper has proposed the MCGA based scrambling approach for reducing the PAPR and BER with less computational complexity. The performance analysis of both the standard and the proposed MCGA base-scrambling were compared based on the PAPR and BER analysis. The comparison has stated that the proposed MCGA algorithm is better that the standard scrambling technique.

Compliance with Ethical Standards

Conflicts of interest: Authors declared that they have no conflict of interest.

Human participants: The conducted research follows the ethical standards and the authors ensured that they have not conducted any studies with human participants or animals.

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