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Hybrid approach for Power Allocation in MIMO OFDM system using PSO

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Abstract

Multiple_Input Multiple_Output (MIMO) system is a new antenna technology in wireless communications. It has several antennas in both transmitting and receiving end and it is a frequency selective for multiple path characteristics. Orthogonal Frequency Division Multiplexing (OFDM) is used to get high data rate in wireless communication systems. Combination of MIMO and OFDM system used for converting the frequency selective channels into a parallel combination of frequency flat sub channels. Due to the atmospheric conditions some noises such as AWGN are added in the channels. Due to this the system performance will be degraded.To enhancing the reliabilityfor MIMO-OFDM system uses STBC scheme. Here to minimize the BER , allocating the power at transmitting antennas using Particle Swarm Optimization (PSO) algorithm.The power allocation and pilot tones optimization is mainly depends on the diagonal matrix from the QR decomposition.The system performance of the proposed method is analyzed in terms of bit error rate.

Keywords: Multiple _ input _ multiple _ output, Orthogonal frequency division multiplexing, Space time block coding, Particle Swarm Optimization, Power allocation, Bit error rate, Signal to noise ratio.

1. Introduction

Now a days, in wireless communicationthe requirement of radio spectrum increases due to the many reasons such as online gaming, video calling and multimedia applications. Sothat theradio spectrum more and more expensive [1].Many number of techniques areutilizing for the radio spectrumsto providebetter Efficiency in MIMO communication system[2].MIMO technology is one of the best technology for 5G communications, which predominance in boosting Spectrum Efficiency and Energy Efficient with low complexity [3].In MIMO structures, though the multiplexing gain can be obtained with an equal power allocation method [4], power control among users can help to gain all the benefits brought by antenna arrays [5]-[9].

Power allocation is one ofthe major issues in a wireless communication for enhance the systemperformance. In this work, a single and multi antenna network is consideredusing amplify-and-forward relaying scheme. Considering the perfect channel stateinformation (CSI), allocating power to source and relay using Particle SwarmOptimization (PSO) with minimizing as a constraint.The PSO algorithm maintains a group of particles, where each particle in thegroup gives a possible solution. PSO gives the best optimum value for a given problemby using objective function. Hence the implemented scheme of PSO base powerallocation in cooperative network enhances the system performance.

The power allocation using beam-forming between inter-cluster and intra-cluster Networks is explained in detail in [10] and Quality of Service (QoS)expressions are derived to maximize the throughput [11]. Maximization of Power efficiency in multicellular cooperation networks also explained in [12]. In MIMO systems, power allocation done by considering the channel estimation error is also reported in [13].Co-operative relaying techniques hasbecome a major topic in the wireless research community again[14], [15].Optimization problems is the main limitation of the Co-operative relaying techniques [16]. The power allocation with imperfect CSI for interference channels has also been analyzed [17]. The issue of stability and queuing delay for burst traffic is addressed in detail for simultaneous transmission with multiple antennas [18]. While dealing the queuing and scheduling of users, the important properties of average waiting time and access time with emphasis on channel dynamics is studied [19].

To overcome the limitations, particle swarm optimization algorithmbased Power Allocation in MIMO - OFDM (PSO-MIMO-OFDM) system is introduced in this paper. This method is used for

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improving the parameters such as Signal to Noise Ratio (SNR) and Bit Error Rate (BER).

2. Literature review

Cooperative communication is a new class of transmission, the basic idea of the cooperation is that signal transmission by neighboring nodes, called relays. Wireless systems are generally suffers from fading. Diversity techniques are used to combat fading via providing spatial diversity. Cooperative diversity can also improve speed, performance and coverage. The main aim of diversity is to allow multiple antennas into wireless environment.

Jun Li *et al*. [23] has explained about the joint source and relay pre-coding design method for an AF_MIMO system. The non-convex optimization in AF MIMO relay system was used to minimize the objective function, which is Mean Square Error (MSE). It gives more feedback with the Channel State Information (CSI) but it affects the accuracy.

Jose Carlos Marinello and Taufik Abrao [24] has introduced the pilot distribution optimization in multi-cellular massive MIMO systems. It reduces the overall computational complexity in massive MIMO systems. The effective performance of this method is difficult to achieve when the pilot sequence doesn't know the long-term fading coefficients and the powers in adjacent cells.

Shuangling Wang *et al.* [25] presented the Low-Frequency Modulation (LFM) signals in the cognitive MIMO radar system. The LFM signals were transmitted based on the target and clutter-plus-noise signals and it had different bandwidths, starting frequencies. It was used to increase the signal-to-clutter-plus-noise ratio (SCNR) at the receiver. The drawback of this method is that if the clutter covariance is increased, it affects the performance of the cognitive MIMO radar system.

M.J.Rahman *et al.*[26] introduced transmit and receive beam-forming designs with an objective to minimize the transmit power of full-duplex MIMO multi-cell system while maintaining a certain QoS. In addition to the limited dynamic range at the transceivers communication system also suffers from the self-interference as well as the co-channel interference from other nodes. This method has self-interference characteristic, so the design process is convergence of the optimization algorithm and also this system operates too slow.

3. PSO-MIMO-OFDM System

The "PSO-MIMO-OFDM" system is used mainly for power allocation to the antennas present in the system. This system consists of nine major steps such as 1). Data generation, 2).QPSK Modulation, 3).Pilot insertion, 4)MIMO-OFDM transmission with OSTBC Encoding, 5).MIMO-OFDM reception with OSTBC decoding, 6).MMSE detection, 7).Pilot removal, 8).QPSK demodulation, 8).BER estimation and 9). Power and pilot tone optimization using PSO. The Block diagram of the PSO-MIMO-OFDM system is shown in the Figure 1.

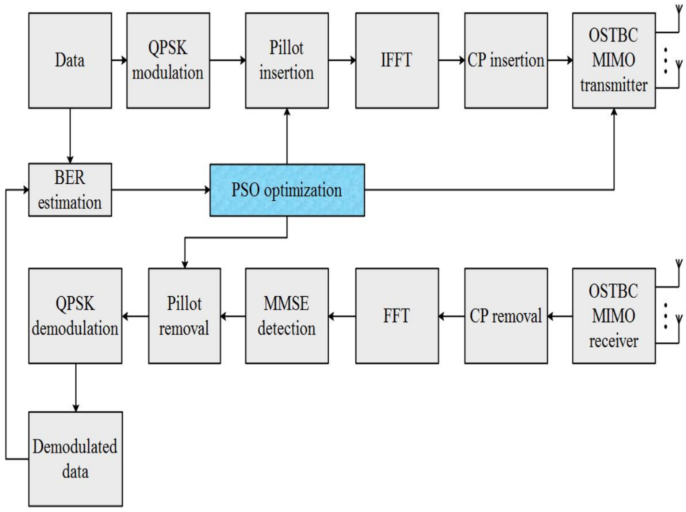

Fig1. Block diagram of PSO-MIMO-OFDM system

3.1. MIMO-OFDM system model

MIMO is an antenna technology, it is referred for making the wireless communications by placing the more number of antennas at both the transmitter and receiver. It provides the reliability in terms of diversity and spatial multiplexing. OFDM is a multicarrier modulation that produces the various sub streams by separating the transmitted bit stream. These sub streams are transmitted over a various sub channels. Generally, the sub channels which are present in this system is should be orthogonal and also the intersymbol interference (ISI) of this OFDM

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is low. For providing the very high reliability and high data rate, the combination of MIMO-OFDM is introduced. The block diagram for the MIMO-OFDM is shown in Figure 2.

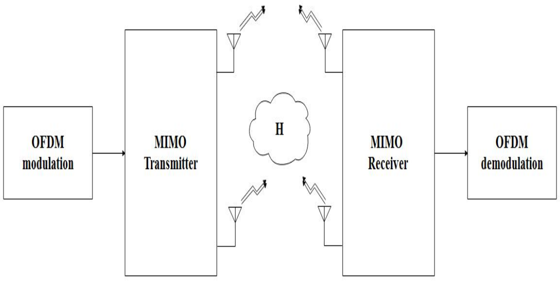

Fig 2. Block diagram of MIMO-OFDM.

Consider the MIMO-OFDM system has A_t number of transmit antennas and A_r number of receive antennas, it is represented as $A_t \times A_r$. In MIMO-OFDM-STBC system model, the ith transmit and jth receive antennas are modelled in a wide sense stationary, uncorrelated scattering as well as the M number of paths are enabled in the Rayleigh fading channel in the complex equivalent low-pass-time-variant impulse response is given in equation (2).

$$h^{(i,j)} = \sum_{m=0}^{M-1} \gamma_m^{(i,j)} \alpha(\tau - \tau_m^{(i,j)}) \quad (2)$$

Where, the mth path gain from the ith transmit antenna to the jth receive antenna, and also propagation delay for mth path from ith antenna to the jth receive antenna is denoted as $\tau_m^{(i,j)}$.

The symbol which is transmitted through the ith antenna is given as the following equation (3).

$$u_a^{(i)} = \frac{1}{\sqrt{A}} \sum_l^{A-1} U_l^{(i)} exp\left(j\frac{2\pi a l}{A}\right) \quad 0 \le a \le A-1 \quad (3)$$

Where the transmitted data sequence from the ith transmit antenna is represented as $\left\{U_l^{(i)}\right\}_{l=0}^{A-1}$, $1 \le i \le A_t$.

The MIMO-OFDM frame structure is shown in the Figure 3, the frame has one preamble. The synchronization of the MIMO-OFDM system is made by the preamble as well as it is used for the channel estimation coincidently as the orthogonal structure.

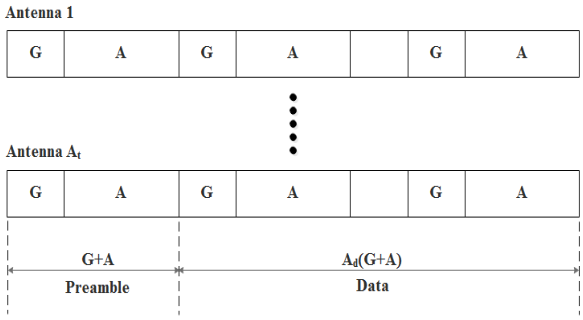

Fig 3. Frame structure for MIMO-OFDM

The following equation (4) describes the sample sequence of the receiver antenna j after neglecting the guard interval.

$$r_o^{(j)} = \sum_{i=1}^{A_t} \sum_m^{M-1} \gamma_m^{(i,j)} u^{(i)}_{(o-\tau_m^{(i,j)})O)} + w_o^{(j)} \quad (4)$$

Where, the complex Additive White Gaussian Noise (AWGN) samples with variance A_0 at the receiver antenna is denoted as $w_o^{(j)}$, the residual of integer l module A. The result is in the interval [0, A-1].

FFT is used for demodulating the received signal and it is given in the following equation (5).

$$R_l^{(j)} = FFT\{r^{(j)}\}(l) = \sum_{i=1}^{A_t} H_l^{(i,j)} U_l^{(i)} + W_l^{(j)} \quad (5)$$

3.2. OSTBC system model

The OSTBC is used for providing the maximal diversity without expansion in the MIMO-OFDM systems.

The transmitted symbols of kth block $(s(k))$ is expressed in the following equation (6).

$$s(k) = [s_1(k) s_2(k)]^T \quad (6)$$

The OSTBC encodes the transmitted data and it is mapped into a 2×2 matrix which is expressed in the following equation (7).

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$$C(k) = [c_1(k)c_2(k)]$$

$$C(k) = \sum_{n=1}^{N} A_n s_n(k) = \begin{bmatrix} s_1(k) & -s_2^*(k) \\ s_2(k) & s_1^*(k) \end{bmatrix} \quad (7)$$

Where, the encoded data of OSTBC is $C(k)$; the 2×1 coded vector in the nth time instant of the kth block is denoted as $c_n(k)$; the orthogonal coding matrix is A_n and the corresponding nth symbol of A_n is $s_n(k)$.

The channel matrix $h = [h_1 h_2]$ is constant in the successive symbol periods. Then the received signal of the OSTBC is given in the equation (8).

$$[y_1 y_2] = [h_1 h_2] \begin{bmatrix} s_1(k) & -s_2^*(k) \\ s_2(k) & s_1^*(k) \end{bmatrix} + [n_1(k) n_2(k)] \quad (8)$$

Where, the Gaussian noise with variance and zero mean is $n(k)$.

The OSTBC is typically linear STBC which has unitary property which is given in equation (9).

$$C(k)C(k)^H = \sum_{n=1}^{N} |s_n|^2 . I \quad (9)$$

The equation (8) is rewritten as follows:

$$\begin{bmatrix} y_1(k) \\ y_2^*(k) \end{bmatrix} = \begin{bmatrix} h_1 & h_2 \\ h_2^* & -h_1^* \end{bmatrix} \begin{bmatrix} s_1(k) \\ s_2(k) \end{bmatrix} + \begin{bmatrix} n_1(k) \\ n_2^*(k) \end{bmatrix} \quad (10)$$

Where, the equivalent channel coded matrix is $\begin{bmatrix} h_1 h_2 \\ h_2^* - h_1^* \end{bmatrix}$ that is denoted as H. This H is orthogonal.

3.3. Particle Swarm Optimization

In PSO, there are three different values are provided as input such as encoded data, decoded data and distance between the transmitting and receiving antennas. PSO is a computational optimization algorithm is introduced in 1950 by Kennedy and Eberhart. This algorithm revised many times due to the complexity. Search is motivated by the social behaviors of organisms. Particularly, the choreography of bird's flock led to the design of PSO.

Particle Swarm Optimization (PSO) algorithm is using for powerallocation in amplify-and-forward cooperative network using single and multi-relay isproposed. First we allocate power to system using equal power
, after that thesystem performance is compared with PSOthen differentpower is allocated to antennas at transmitting end. Particle Swarm Optimization is optimizing technique; it gives the best optimum value fora given problem by using objective function. PSO contains a swarm of particles, eachparticles in this swarm gives a possible solution. This optimizing technique is workingbased on the population search, and gives a best solution by iteration method .In PSO algorithm, all particles are move towards its optimum value. For eachiteration all the particles in this swarm are updated by its position and velocity foroptimization ability. In PSO each particle maintains its position evaluated fitness andvelocity. The velocities of the n-particles are updated by using below equation. In PSO algorithm individual fitness and it is achieved its fitness, called aspersonal best position (*pbest*). Compare each particles pbest value with the current pbestvalue. If the current value is better than pbest, update that value is current pbest value.Compare fitness evolution for overall particles with previous gbest. Ifthe current gbest isbetter than gbest, update that value is gbest. The algorithm repeated until some stoppingcondition met, usually a maximum number of iterations. PSO algorithm at lastmaintains the best value among all particles as global best value (*gbest*).

Briefly, assuming a D-dimensional search space theI^{th}particle is represented by$xi = (xi1, xi2, \dots . xiD)andvi = (vi1, vi2, \dots . viD)$ as D-dimensional arrays for the positions and velocities.$v$and$x$are updated using these two equations (11) and (12).

$$V_{id}^{k+1} = wxV_{id}^{k} + C_1 r_1 \left(pbestd - x_d^k\right) + C_2 r_2 \left(gbestd - x_d^k\right) \quad (11)$$

$$X_{id}^{k+1} = X_{id}^{k} + V_{id}^{k+1} \quad (12)$$

Where$d = 1,2, \dots \dots , D$, $i = 1,2, \dots \dots , N$,are the sizes of dimension and swarm,C_1 and C_2 are positive constants, r_1 andr_2 are random numbers, uniformly distributed in the interval$[0,1]$,$k = 1,2, \dots .$,denotes the iteration number,$pbestd$ and $gbestd$represent $pbest$ and $gbest$in the d^{th} dimension, and $w$is inertia weight which controls the influence of previous velocities on the new velocity. Larger inertia weights indicate

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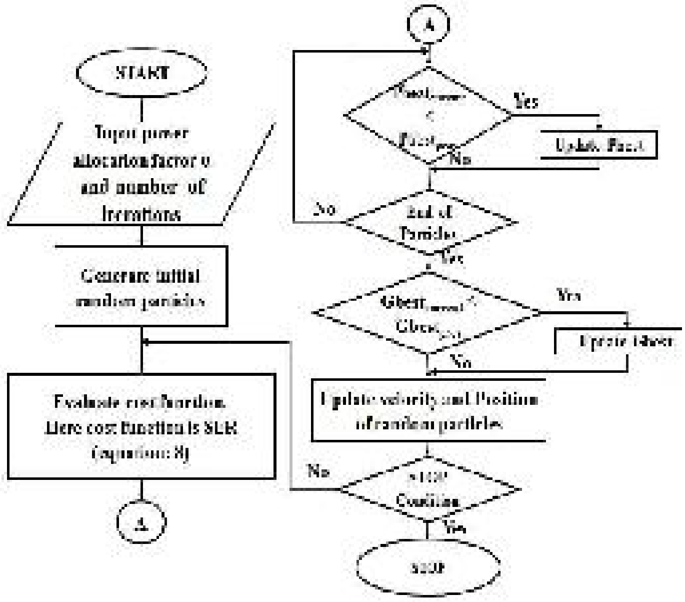
larger exploration through the search space while smaller values of the inertia weight restrict the search on a smaller space. Typically, PSO starts with a larger w, and decreases gradually over the iterations. The following equation (13) is adopted for w to simulate its descending property.

$$w = (w_{initial} - w_{final}) X \frac{(k_{max} - k)}{k_{max}} + w_{final} \quad (13)$$

Here $w_{initial}$ is the preliminary value of w, w_{final} is the final value of w, k is the iteration number, and $w = k_{max}$ is the maximum number of iterations.

Algorithm and flowchart : PSO

Define the size of the channel noise and channel distance, number of iterations iter_n
For i=1 to iter_n
    For j=1 to size of particle set (50 sets)
        For k= 1 to N
        Apply each set to the pixel
        Find the fitness value of the function
            If (current fitness <pre_fitness)
            Move for next random pixel value generation
            Else
            Go to the next particle set
            End
        End
End
Obtain the best fitness value such as optimized power by applying the corresponding channel distance, channel noise and channel matrix.
End



BER estimation

In MIMO-OFDM wireless communications, the bit errors are occurred when the received bits through the communication channel is altered by the distortion, synchronization errors, interference and noise. The BER is defined as the amount of bit errors divided by the total amount of transmitted bits and it is expressed in equation (14).

$$BER = \frac{number\ of\ errors}{total\ number\ of\ bits\ transferred} \quad (14)$$

PSO objective function for pilot tone optimization

The PSO algorithm is provides an effective location for pilot tones insertion and also it provides amount of pilot tones to be insert/eliminate in the transmitter/receiver section. Initially, the pilot tones are specified by the positions of the particle. The fitness function considered in the PSO for pilot tone optimization is BER which is given in equation (14). The $gbest$ is determined based on the positions and velocities of the particles. The velocity and positions are updated by using the equation (11) and (12) respectively. The position of the particles again updated by using the fitness function (i.e., BER). In this pilot tone optimization, if the particles position is better than the previous position, then the value of

$pbest$ is replaced by the current particle's position. Similarly, the global best ($gbest$) is identified. The

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pilot tones optimization is mainly carried out by using the BER denoted in the equation (14). The inter symbol interference is eliminated by inserting the adequate amount of pilot tones in transmitter and receiver.

4. Results and discussion

PSO-MIMO-OFDMsystem has implemented by using MATLAB 2017b software tool with communication and Neural Network tool box (for the simulation purpose) through the i5 desktop computing environment with 8 GB RAM memory capacity.The specifications of the MIMO-OFDM system is given in Table 1.

PSO-MIMO-OFDM system Testing	
Data bits	10000 bits data's
Sampling rate	1e6
Path delays	0 to 2e-6
Modulation & demodulation	QPSK
Channel enc& decoding	OSTBC
Channel type	AWGN + Rayleigh
Antenna type	2×2, 4×2, and 4×4
SNR value for analysis	-10 :3:10

Table 1. Neural network testing parameters

In PSO-MIMO-OFDM system, there are 100 random bits are produced (with the sampling rate 2e6 and block size of 64). After generating the random bits, these bits going to the modulation process under QPSK. The output of the modulator in the form of 50×1 and the cyclic prefix is added in the next step. The data's are generated for the cyclic prefix in the floor (0.5*length (modData)) and it generates the data according to the 75×1 form. Finally, IFFT and cyclic prefix is performed for protecting the OFDM signal from the Inter Symbol Interference (ISI). IFFT produces the output in the form of 75×1 complex double format. STBC encoder is used for transmitting the data and it encodes the before performing data transmission. The antenna designs which is used in the transmission such as 2×2, 4×2 and 4×4. AWGN and Rayleigh noise are added in the transmitting signal by propagating the signal through the AWGN and Rayleigh fading environment. The noise are added based on the SNR value (-10 to 10). The receiving section such as 2×2, 4×2 and 4×4 antennas receives the signal and the received signal is affected by noise and the STBC decoder decodes the received signal, after that the FFT process and cyclic prefix eliminating process and QPSK modulation is applied to the receiver signal and the output data is received. From that received signal, the amount of noise and distance between the transmitter and receiver should be estimated. These data's are used with channel matrix in PSO optimization process, it produces the optimized power and it is allocated for each transmitting antenna. Finally, the performance of PSO-MIMO-OFDM system is analyzed with the existing system [28].

Table 2. Analysis of Bit error rate for 2×2 PSO-MIMO-OFDM system

SNR	-10	-7	-4	-1	2	5	8
PSO	0.43	0.43	0.19	0.28	0.09	0.09	0.11
Existing	0.48	0.48	0.47	0.46	0.45	0.44	0.42

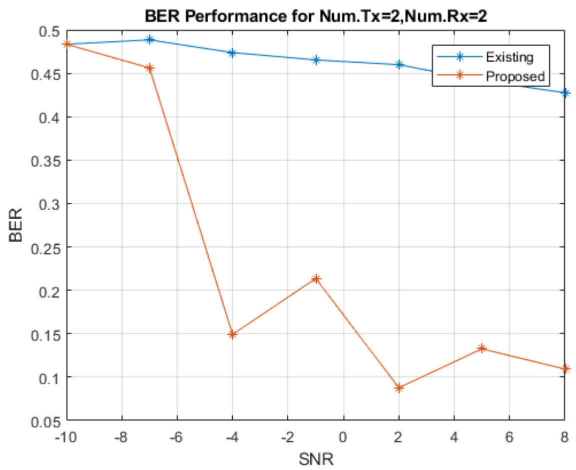

Fig 4. Bit error rate analysis for2×2 PSO-MIMO-OFDM system

Table 2 and Figure 4 Shows the comparison about the BER for 2×2 PSO-MIMO-OFDM system. From the graph, conclude that the BER is decreased by increasing the SNR as well as it has greater performance compared to the existing method [28].

Table 3. Analysis of Bit error rate for 4×2

SNR	-10	-7	-4	-1	2	5	8
PSO-	0.47	0.42	0.12	0.24	0.08	0.08	0.07
Existing	0.47	0.46	0.47	0.46	0.42	0.42	0.39

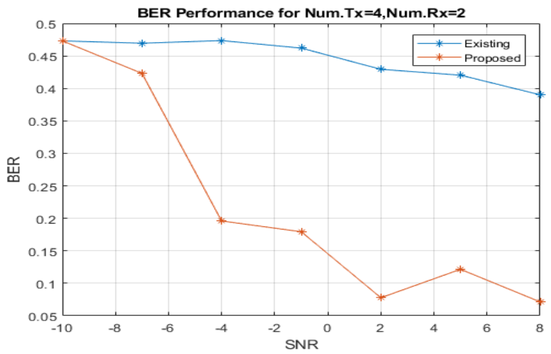

Fig 5. Bit error rate analysis for4×2 MIMO

Table 3 and Figure 5.Shows that the BER comparison for 4×2 PSO-MIMO-OFDM system.From the graph conclude that the 4×2 PSO-MIMO-OFDM system has less BER value compared to the existing [28] system

Table 4. Analysis of Bit error rate for 4×4 MIMO

SNR	-10	-7	-4	-1	2	5	8
PSO	0.48	0.43	0.13	0.21	0.03	0.02	0.03
Existing	0.48	0.47	0.45	0.45	0.43	0.42	0.37

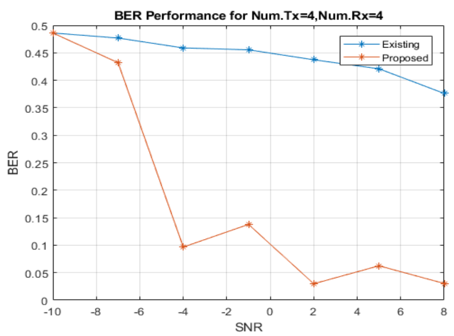

Fig 6. Bit error rate analysis for4×4MIMO

Table 4 and Figure 6.Shows the comparison for the BER in 4×4 PSO-MIMO-OFDM system. This 4×4 PSO-MIMO-OFDM system has less BER by increasing the SNR than the existing method [28].

5. Conclusion

The PSO-MIMO-OFDMsystem enables with MIMO-OFDM system with STBC along with PSO and NN used for optimizing the MIMO-OFDM system. STBC is used for enhancing the reliability by transmitting a multiple copies of an information signal across a several antennas and it combines the received signal. Distance among the transmitter and receiver and the noise is estimated, it is used for optimizing the power by PSO. The Training of NN is mainlybased on the power from the PSO and its respective channel noise.The neural network gives the exact power for each antenna and it is assigned to the respective transmitting antennas. Power allocation for each antenna makes the system with more reliability. PSO-MIMO-OFDM system improves the performance by increasing the SNR and decreasing the BER.

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