Advances and Applications in Mathematical Sciences
Volume 20, Issue 12, 2021, Pages 3319-3331

IMPROVEMENT IN ERROR PERFORMANCE THROUGH CHANNEL ESTIMATION IN MIMO-OFDM SYSTEM USING PSO

H. HARIKA, N. BALA SUBRAHMANYAM and BIRENDRA BISWAL

Department of ECE
Gayatri Vidya Parishad College
of Engineering (Autonomous)
Visakhapatnam, India
E-mail: hari.harika1996@gmail.com
drnbsubrahmanyam@gvpce.ac.in
birendrabiswal@gvpce.ac.in

Abstract

It is know that high data transmission takes place in MIMO-OFDM system, due to this, there will be an increase in error rate at the receiver. Channel estimation techniques are used to know the system performance of MIMO-OFDM. In pilot based channel estimation, it inserts pilots along with the OFDM symbol by using QAM modulation in the transmitter to recover original data at the receiver. In this paper, channel is estimated using two different algorithms, namely Least Square (LS), and Minimum Mean Square Error (MMSE). The Least square channel estimation algorithm procedure is simple to implement, but it has high mean square error. The Minimum mean square error is better than that of the LS in low signal-to-noise ratio, but it has high computational complexity. In view of this, the Particle swarm optimization algorithm (PSO) is implemented for improving the data rate and reduction in BER, MSE of MIMO-OFDM channel. The PSO provides better result compared to the LS and MMSE algorithms.

1. Introduction

The MIMO-OFDM device model provides high-speed connections, excellent service quality and minimizes the risk of error. In real-life, it optimizes the transmission power and bandwidth to reduce the complexity and cost of implementing the system. The schematic diagram of MIMO-OFDM system [1] is shown in Figure 1. The OFDM signals are generated

2010 Mathematics Subject Classification: 68.
Keywords: MIMO-OFDM, LS, MMSE, PSO, BER, MSE.
Received November 20, 2020; Accepted December 19, 2020

from the source at the transmission end and encrypted with the help of channel encoder [2]. They modulate the encoded signals using QAM and transforms the serial data into multiple parallel data streams in the serial-to-parallel converter. The Inverse Fast Fourier Transform (IFFT) [3] is applied to all symbols and to avoid interference, it uses the cyclic prefix with the symbols. The parallel data will then be translated to serial data and distributed through MIMO channels. The reverse phase takes place at the recipient. The serial data is first translated to parallel data medium, and the cyclic prefix is overlooked from symbols for the synchronization of time and frequency.

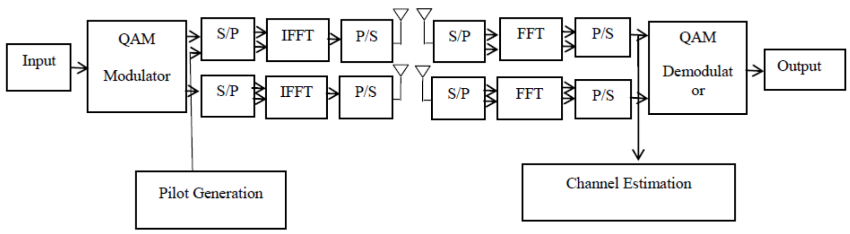

Figure 1. Schematic diagram of MIMO-OFDM system.

The Fast Fourier Transform is applied to all symbols and then it translate the parallel data stream into serial data supplied to the MIMO decoder to decode the signals. The channel is determined and decoded signals are demodulated by QAM modulation system and is decrypted by a channel decoder to retrieve the original signal from the receiver.

2. Background Works

The channel is a medium used for transmitting the data from source to destination. In terms of BER, and MSE, the channel efficiency can be calculated. To calculate the channel with minimal latency, MIMO-OFDM systems are used. Because of high data transmissions in the MIMO-OFDM system, channel H is modified. The Channel estimation algorithms are used to reduce the error rates of channel H. The Channel (H) is estimated using either LS or MMSE [4]. To improve the performance of the system and to overcome the drawbacks of LS [5] and MMSE, in this paper, the particle swarm optimization algorithm is used. In this work, channel performance is obtained with the help of BER and MSE for the corresponding value of SNR in MIMO-OFDM system. The channel state knowledge is determined in the form of training-based channel approximation for the obtained signal, which is referred as identified training OFDM symbols before data transmission [6]. The channel will be in optimal state until they broadcast the next series of the OFDM signal. To estimate, they choose correctly the channel pilot positions in all OFDM series, but not in the training sequences. The inversion of a high-dimensional matrix is part of the channel calculation algorithms in MIMO-OFDM systems owing to a larger number of transmit and receive antennas. However, transmission speed is comparably less, which is a major problem in wireless communication applications [7].

LS Algorithm: It is a standard approach to find out the approximate solution of MIMO-OFDM system and is represented as

$$\hat{H}_{LS} = X^{-1}Y. \tag{1}$$

Here $\hat{H}$ is the impulse response, which can be expressed as where X is input and Y is output of the channel.

MMSE Algorithm: It describes the approach that minimizes the MSE. The MSE is estimated using the equation (2). The error of the channel is given by

$$e = H - \hat{H}. \tag{2}$$

Here, H is the actual channel estimation and $\hat{H}$ is the estimated channel estimation, respectively. The Channel estimation of MSE is represented as

$$\begin{aligned} E\{| e |^2\} &= E\{| H - \hat{H} |^2\} \\ &= E\{(| H - \hat{H} |)(| H - \hat{H} |^H)\}. \end{aligned} \tag{3}$$

Here, $E\{\ \}$ is the expectation. The auto-covariance matrixes of H and Y is designated by S_{HH} and S_{BB} correspondingly the cross covariance matrix between H and Y is S_{HB} and noise-variance by σ_z^2. Since, the channel and AWGN is not correlated, the MMSE estimation of H is given by

$$\hat{H}_{MMSE} = S_{HB}S_{BB}^{-1}Y. \tag{4}$$

If S_{HH} and σ_z^2 are known to the receiver, the MMSE estimation of H is given by

$$\hat{H}_{MMSE} = S_{HB}S_{BB}^{-1}Y$$

$$= S_{HH}X^H(XS_{HH}X^H + \sigma_z^2 I_N)^{-1}X\hat{H}_{LS}$$

$$= S_{HH}(S_{HH} + \sigma_z^2(X^H X)^{-1})^{-1}X\hat{H}_{LS}. \quad (5)$$

3. Proposed Model

The partial swarm illustrated in Figure (2) is a computing method that optimizes the issue by attempting repeatedly to improve the solution of a candidate about a certain quality measure, and here it is used to recognize the best channel. Each and every particle is called a pilot in PSO and is positioned in the feature search space, measuring the fitness function from the current position. Each particle seeks the best location in the search region by adjusting the velocity. The initial location and speed of particles are created by random in the search room. For all the iterations of the particles i, it changes the location and speed of particles on dimension d is given by

$$x_1^d(t+1) = d_1^d(t) + v_i^d(t+1). \quad (6)$$

Here, in equation (6), d is spatial solution dimension, x_i is particles where $x_i = (x_i^1, x_i^2, \ldots, x_i^D)$ and $v_i = (v_i^1, v_i^2, \ldots, v_i^D)$ is the vector location. It randomly generates particle speed and location in search of space. The location of the particle i is modified on dimension d for each iteration and can be expressed as

$$v_i^d(t+1) = wv_i^d(t) + c1r_i^1(t)(pbest_1^d(t) - x_i^d(t)) + c2r_i^2(t)(gbest^4 - x_i^d(t)). \quad (7)$$

In equation (7), $pbest_i^d = (p_i^1, p_i^2, \ldots, p_i^D)$ are the initial best location of the particles and $gbest^d = (p^1, p^2, \ldots, p^D)$ are the global best position of all particles. The r_i^1 and r_i^2 are equally distributed quantities, which are inside the interval [1-0]. Here, c_1, c_2 are cognitive and behavioral values of PSO.

$$w = w_{\max} - \frac{w_{\max} - w_{\min}}{iteration_{\max}} \times iteration. \quad (8)$$

The equation (8) represent the inertia weight w, the high weight of inertia defines global quest, whereas a limited weight of inertia defines local search. The Acceptable inertia selection offers a balance between local and global exploratory expertise which needs less inertia on average to locate the optimal answer. In this work, the frequency of inertia w is reduced linearly from $w_{\max}$ to $w_{\min}$. The particles are initialized from MIMO-OFDM channel (H) and all the probable combinations of particles are tested using fitness function $\left(\frac{H - H_{PSO}}{H}\right)^2$ [8]. If the fitness of particle's current position is enhanced than its previous position, then the velocity and position of the particles are obtained using equation (6) and (7).

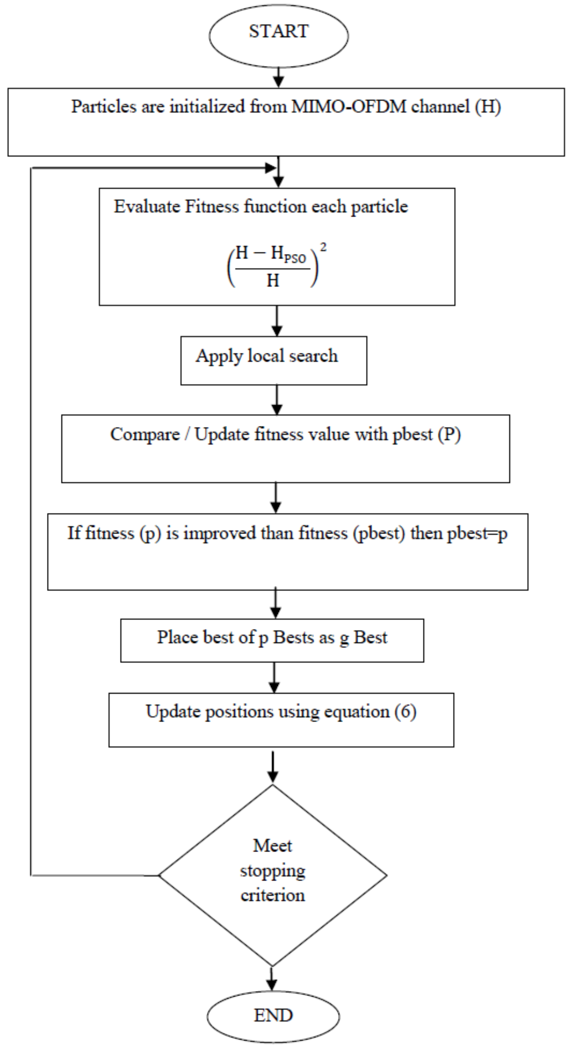

Figure 2. Flow chart of PSO.

The PSO algorithm repeats the process for fixed number of iterations or till the convergence is achieved. The BER and MSE are computed from global best particles obtained from PSO algorithm.

4. Results and Discussion

Table 1. Simulation Attributes.

Parameters	Specifications
Number of subcarriers	64,128.
FFT Size	64,128.
Pilots	No of subcarriers /2
Modulation	8-QAM, 16-QAM
MIMO channel	$2 \times 2,\ 4 \times 4$
Number of particles	100
Number of Iterations	200
Inertia weight factor	$w_{\min} = 0.4,\ w_{\max} = 0.9$
Learning factor C1, C2	1, 1.5
Channel estimation methods	LS, MMSE, PSO.

The MSE of 2x2 and 4×4 MIMO-OFDM is shown in Figure 3 to Figure 6 such as LS, MMSE, PSO using different subcarriers and Figure 7 to Figure 10 depicts the BER performance of 2×2 and 4×4 MIMO-OFDM for different Channel estimation method namely LS, MMSE, and PSO using modulation 8, 16-QAM. The channel is estimated using PSO algorithm by taking parameters with 100 particle in a search space, inertia weight factor $w_{\min} = 0.4,\ w_{\max} = 0.9,$ learning factor $C_1 = 1,\ C_2 = 1.5$ for 200 iterations is considered to reduce the error rate of channel.

The Table 2 and Table 3 show the performance of MSE and BER achieved by $2 \times 2,\ 4 \times 4$ MIMO-OFDM configurations at 5db and 10db SNR value. It is observed that increase in the SNR value will obtain decrease in error rate, that is, SNR at 10db obtained lesser error when compared to SNR at 5db. Further, it is found that, there is decrease in error using PSO algorithm considerably when compared to other configurations.

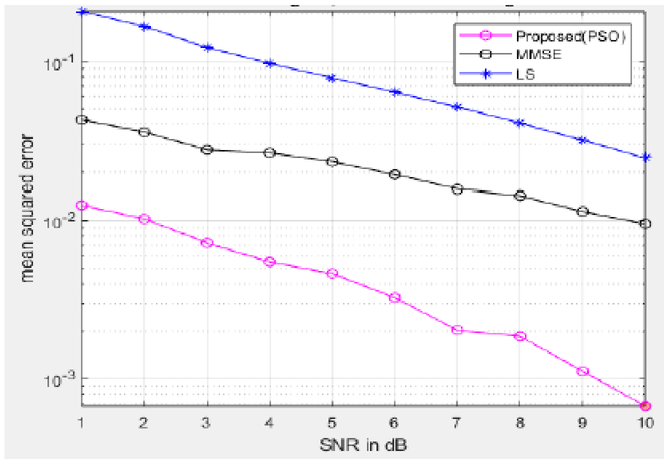

Figure 3. MSE performance of 2×2 MIMO-OFDM with 64 subcarriers using LS, MMSE, and PSO estimation.

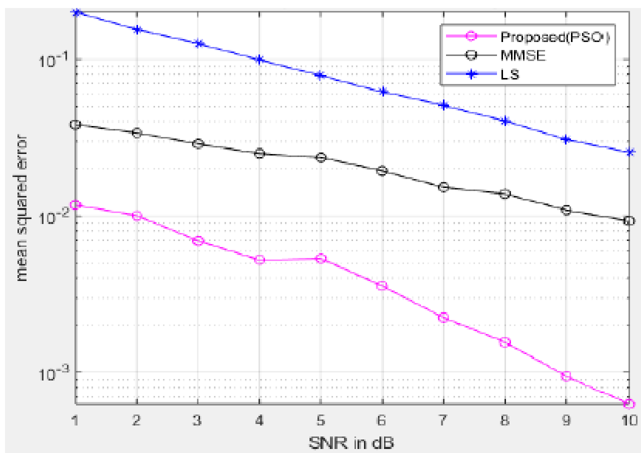

Figure 4. MSE performance of 2×2 MIMO-OFDM with 128 subcarriers using LS, MMSE, and PSO estimation.

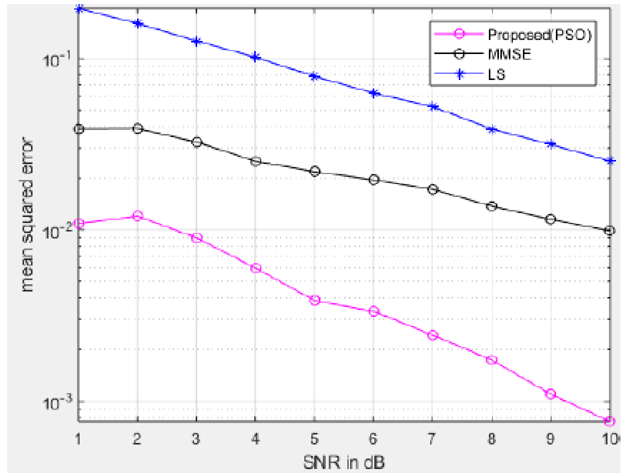

Figure 5. MSE performance of 4×4 MIMO-OFDM with 64 subcarriers using LS, MMSE, and PSO estimation.

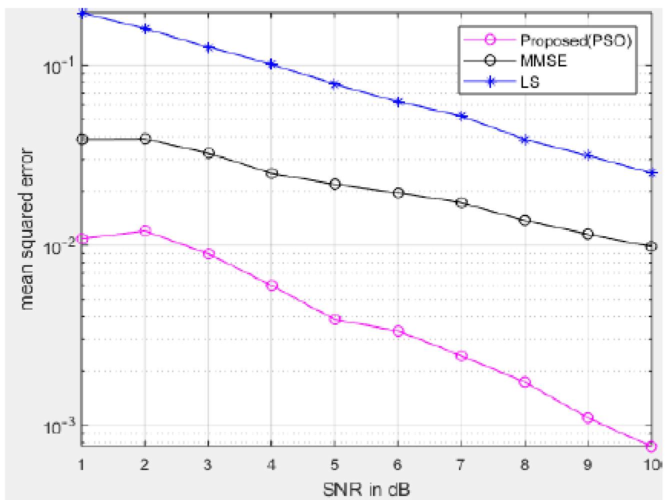

Figure 6. MSE performance of 4×4 MIMO-OFDM with 128 subcarriers using LS, MMSE, and PSO estimation.

Table 2. MSE performance of 2×2 and 4×4 MIMO-OFDM system for different channel estimation such as LS, MMSE, PSO at SNR of 5db and 10db respectively.

No of subcarriers	MIMO-OFDM order	MSE					
		LS (SNR 5db)	LS (SNR 10db)	MMSE (SNR 5db)	MMSE (SNR 10db)	PSO (SNR 10db)	PSO (SNR 5db)
64	2x2	8.72×10^{-2}	2.46×10^{-2}	6.32×10^{-2}	9.5×10^{-3}	4.47×10^{-3}	6.73×10^{-4}
128	2x2	8.45×10^{-2}	2.56×10^{-2}	5.42×10^{-2}	9.32×10^{-3}	7.21×10^{-3}	6.49×10^{-4}
64	4x4	8.52×10^{-2}	2.58×10^{-2}	3.89×10^{-2}	9.45×10^{-3}	7.48×10^{-3}	6.56×10^{-4}
128	4x4	8.69×10^{-2}	2.45×10^{-2}	3.02×10^{-2}	9.73×10^{-3}	6.57×10^{-3}	7.01×10^{-4}

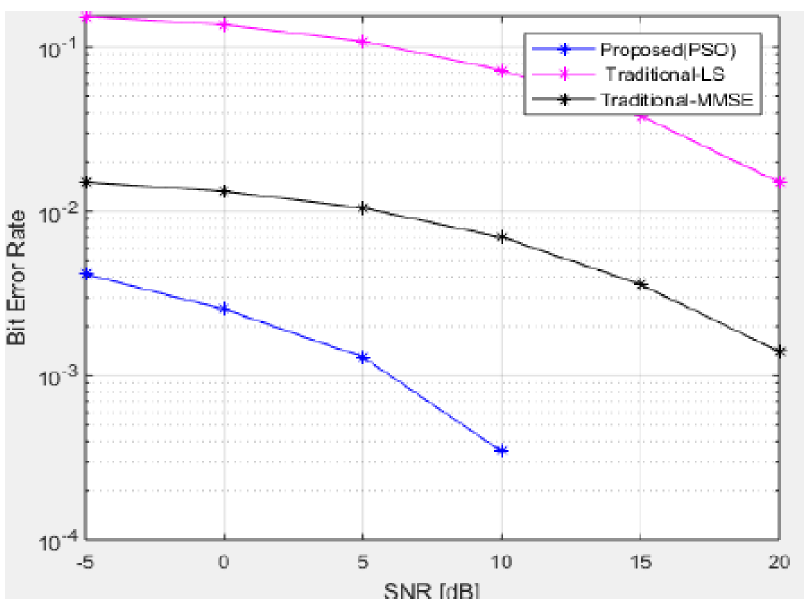

Figure 7. BER performance of 2×2 MIMO-OFDM with 128 subcarriers for LS, MMSE, PSO estimation using modulation 8-QAM.

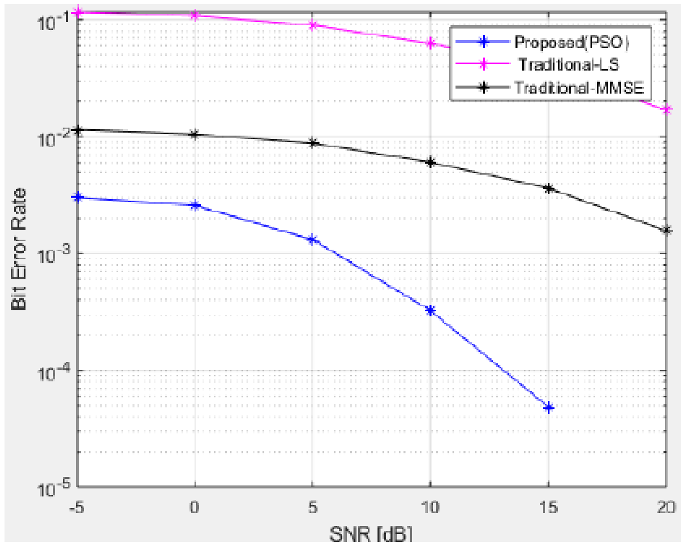

Figure 8. BER performance of 2×2 MIMO-OFDM with 128 subcarriers for LS, MMSE, PSO estimation using subcarriers for LS, MMSE, PSO 16-QAM.

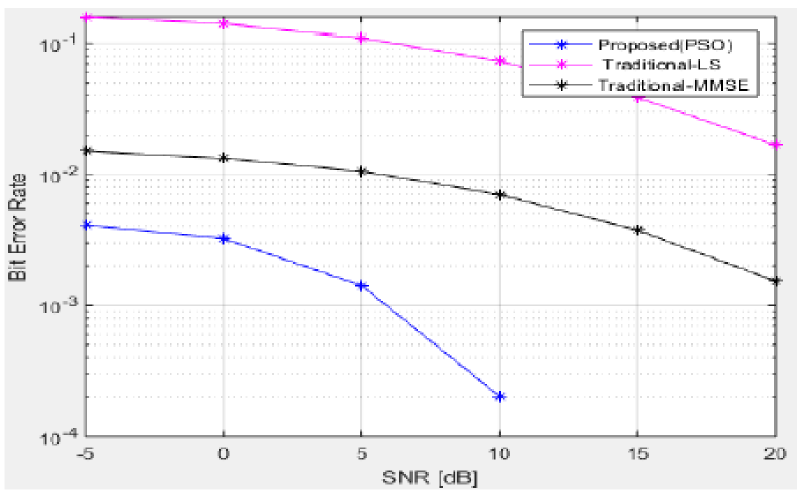

Figure 9. BER performance of 4x4 MIMO-OFDM with 128 subcarriers for LS, MMSE, PSO estimation using modulation 8-QAM.

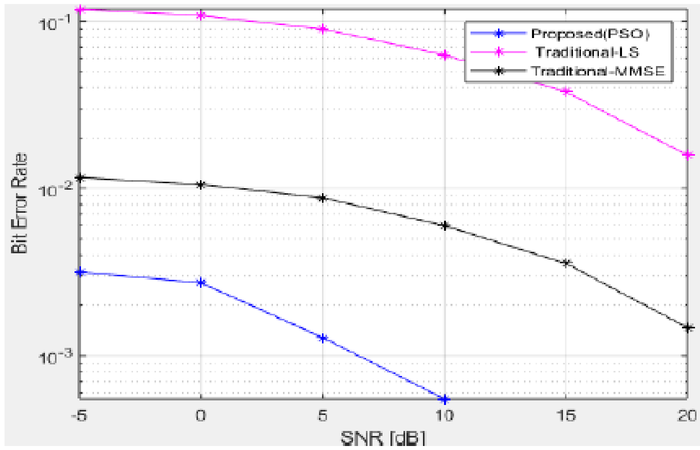

Figure 10. BER performance of 4×4 MIMO-OFDM with 128 subcarriers for LS, MMSE, PSO estimation using subcarriers for LS, MMSE, PSO estimation 16-QAM.

Table 3. BER performance of MIMO-OFDM system for different channel estimation such as LS, MMSE, PSO using 128 sub carrier with QAM data rates at SNR of 5db and 10db respectively.

Order of QAM	MIMO-OFDM order	BER					
		LS (SNR 5db)	LS (SNR 10db)	MMSE (SNR 5db)	MMSE (SNR 10db)	PSO (SNR 5db)	PSO (SNR 10db)
8	2x2	1.1×10^{-1}	7.68×10^{-2}	1.08×10^{-2}	7.68×10^{-3}	1.35×10^{-3}	5.58×10^{-4}
16	2x2	9.01×10^{-2}	3.11×10^{-2}	9.09×10^{-3}	1.26×10^{-4}	1.24×10^{-3}	1.20×10^{-4}
8	4x4	1.1×10^{-1}	8.74×10^{-2}	1.08×10^{-2}	8.49×10^{-3}	1.38×10^{-3}	4.12×10^{-4}
16	4x4	9.12×10^{-2}	7.51×10^{-2}	8.6×10^{-3}	9.74×10^{-4}	1.25×10^{-3}	5.2×10^{-4}

5. Conclusion

In this paper, various techniques are compared to optimize the MIMO-OFDM channel. To test the channel such as 2×2 and 4×4 MIMO-OFDM networks, QAM modulation is used. The channel is computed using channel estimation algorithms to know the system performance and to reduce the error rates of the system. The channel estimation techniques are implemented in MATLAB simulation software and the performance is analyzed through various metrics, namely BER and MSE. From the results, it is evident that PSO algorithm obtained less error compared to LS and MMSE.

References

[1] Seyman, Muhammet Nuri and Necmi Taşpinar, Particle swarm optimization for pilot tones design in MIMO-OFDM systems, EURASIP Journal on Advances in Signal Processing, 10.1186/1687-6180, October 2011.

[2] G. Rao, Koteswar and G. Laxminarayana, Power Allocation for Multiple Input Multiple Output system using Particle swarm optimization, International Conference on Inventive Computation Technologies (ICICT). IEEE, pp. 336-341, February 2020.

[3] M. V. Sairam, Shaik Riyaz, R. Madhu and V. Harini, Low-Complexity Selected Mapping Scheme Using a Bank of Butterfly Circuits in Orthogonal Frequency Division Multiplexing Systems, Wireless Personal Communications, vol.99, issue no. 3,pp.1315-1328, April 2018.

[4] Jian, Rongling, et al., Hybrid precoding for multiuser massive MIMO systems based on MMSE-PSO, Wireless Networks: pp.1291-1299, February 2020.

[5] Kaur, Parminder and Karamjit Kaur, Improved channel estimation in transmit diversity MIMO-OFDM using particle swarm optimization, International Journal of Research in Engineering and Technology: pp.475-479, volume: 05, June 2016.

[6] Bharadwaj, N. Nikita, Jaya Dipti Lal and S. V. Charhate, Optimal Power Allocation Using PSO in Cooperative Wireless Networks, 2018 International Conference on Inventive Research in Computing Applications (ICIRCA). July(2018), 1143-1148.

[7] Datta, Arijit, Manish Mandloi and Vimal Bhatia, Swarm Intelligent Based Detection in the Uplink of Large-Scale MIMO Wireless Communication Systems, Design Frameworks for Wireless Networks, Springer, Singapore August 2019, 303-320.

[8] K. Vidhya and K. R. Shankar Kumar, Channel estimation of MIMO-OFDM system using PSO and GA, Arabian Journal for Science and Engineering May 2014, 4047-4056.