IJCTA, 8(5), 2015, pp. 2293-2299

A Novel GA-Optimized DFT Channel Estimation in MIMO-OFDM System

R. S. Ganesh*, J. Jayakumari**

Abstract: MIMO-OFDM (multiple input multiple output-orthogonal frequency division multiplexing) is one of the preferable methodologies used in modern wireless communication. It has excellent features such as high speed transmission of voice and multimedia information with high spectral efficiency. The training-based Least Square (LS) and Minimum Mean Square Error (MMSE) channel estimation algorithms are discussed by researchers to retrieve the channel state information (CSI) at the receiver side. Both estimation techniques cannot reduce the noise levels at the receiver. Hence, Discrete Fourier Transform (DFT)-based channel estimation is introduced to minimize the receiver noise interference. Also, Genetic Algorithm-based optimized channel estimation is proposed in this paper to identify the best channel matrix from the existing LS, MMSE and DFT estimation algorithms. The simulation results prove that optimized GA-based DFT channel estimation surpasses the LS and MMSE estimation in terms of minimum MSE.

Keywords: MIMO-OFDM; genetic algorithm; DFT; LS; MMSE estimation.

1. INTRODUCTION

The high speed transmission of voice and multimedia information through wireless medium is a decisive role in this modern age. To meet this demand, Orthogonal Frequency Division Multiplexing (OFDM) technique can be utilized as an excellent multi-carrier modulation technique. The OFDM scheme carries high data rate information by multiplexing numerous parallel low rate data streams with orthogonal sub-carriers. This technique makes progress in spectral efficiency, and reduction in inter symbol interference (ISI). If this technique is united with Multi Input Multi Output (MIMO), a tremendous improvement in the channel capacity will be achieved. MIMO-OFDM system also improves the quality of service. This MIMO-OFDM technique can be incorporated in the latest wireless standards of Wi-Fi, Wi-Max, 4G LTE, etc. The detection of data and the wireless receiver becomes more complex due to the multipath fading effects and noise interference. In order to retrieve the data at receiver, the channel state information (CSI) is very much essential. This CSI may be instantaneous or statistical. The channel estimation technique is mainly employed to approximate the CSI at the receiver. This improves the accuracy and the reliability at the receiver side.

The channel estimation techniques broadly come under three categories of training-based estimation, blind estimation and semi-blind estimation. In the training-based channel estimation, block or comb-type pilots are employed as training symbols. These pilots are inserted into the precise position of each sub-carrier of OFDM symbols and transmitted through the wireless medium. This estimation provides better resistance to fast fading and time varying channels [4]. The Least Square (LS) channel estimation and Minimum Mean Square Error (MMSE) estimation are the most popular training-based techniques used widely. The LS estimation is easy and less complex. But it has higher MSE. The MMSE estimation has lesser MSE, but the complexity is higher than that of LS channel estimation. Both estimation techniques cannot minimize the noise levels at the receiver. Hence, DFT channel estimation is incorporated with LS and MMSE channel estimations to resolve the noise interference. Also, Optimized DFT channel estimation

* Associate Professor, *Email: r_s_ganesh@rediffmail.com*

** Professor & Head, Dept of ECE, Noorul Islam University, Tamil Nadu, India, *Email: hellojayakumari@rediffmail.com*

and identification of new channel by mingling LS and MMSE channels using genetic algorithm have been carried out.

This article is planned as follows: The MIMO-OFDM system model is presented in the next section followed by the study of channel estimation methodologies. The next section deals with DFT channel estimation model followed by genetic algorithm-based optimization. Simulation and results are discussed in the next section followed by the conclusion.

2. MIMO-OFDM MODEL

A simple block diagram of MIMO-OFDM system is shown in Figure 1[8]. Several pilot symbols are inserted with several data symbols and modulated by a set of OFDM modulators.

These modulator outputs are transmitted by multiple antennas at the transmitter. In the receiver side, the signals from multiple antennas are passed through a set of OFDM demodulators and the CSI can be estimated by any training based algorithms.

Pre-coding is a technique which can be applied at the MIMO transmitter with channel state information (CSI). This technique improves the quality of the received signal with less fading effect. The spatial multiplexing is recognized as another method to improve data rate and SNR. In order to get better reliability of the link, diversity coding can be utilized. The above three MIMO techniques can be either connected together or used individually depending on the need. This MIMO technique can be integrated with OFDM to get better reliability, high spectral efficiency and excellent performance. A simple diversity technique [1] was delivered with two antennas at the transmitter and one antenna at the receiver and numerous issues such as power requirements, delay effect, channel estimation errors and bit error rate performance were discussed.

2.1. Channel Estimation Methodologies

A number of channel estimation methodologies are delivered by many researchers in MIMO-OFDM wireless communication. These methodologies are broadly categorized as training-based, blind and semi-blind channel estimation techniques [5]. The LS and MMSE are the most common training-based estimation techniques [2], [3], [12] that fit into various research findings. The LS estimation has less complexity but at the same time, it has high MSE. The MMSE estimation has less MSE than LS estimation at low values of SNR with more complexity. An Evolutionary Programming-based channel estimation [12] is applied to optimize LS and MMSE estimation. This approach minimizes the MSE more than the LS and MMSE estimation. A better pilot based estimation [10], [11] is developed for fast time varying system to estimate Rayleigh channel complex amplitude (CA) and the carrier frequency offset (CFO). The performance of LS algorithm is enhanced by the optimization of pilot tones using differential evolution algorithm [9] in a new approach.

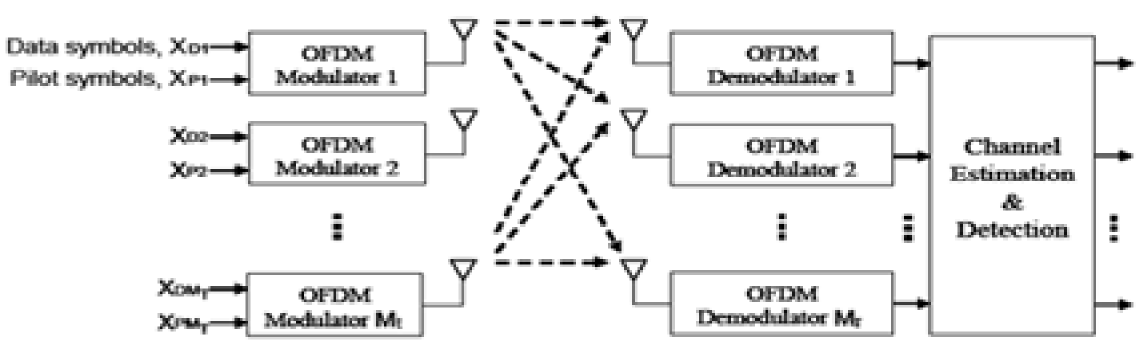

Figure1: Block diagram of MIMO-OFDM system model.

A semi-definite relaxation method is one of the blind channel estimation techniques used for slow fading channels. This estimation technique uses orthogonal space time block codes [14] to identify the finite impulse response and other channel parameters in time domain. This technique has an advantage of less complexity and better performance. A few researchers have presented various semi-blind channel estimation techniques [13] which are the hybrid combinations of blind and training-based channel estimations. Efficient joint carrier frequency offset (CFO) channel estimation [10] was presented using expectation-maximization (EM) algorithm. This algorithm estimates the channel gain and CFO. This method is more efficient than the other algorithms in the fast time varying environment. Another neural network-based channel estimator was delivered for long term evolution (LTE) uplink. The training signal with optimality condition in MIMO-OFDM system is better than non-optimal training signals [7]. In another approach, sparsity-aware channel estimation technique [6] is used to minimize narrow band interference of fast fading or frequency selective fading channels without any prior knowledge.

3. DFT CHANNEL ESTIMATION SYSTEM MODEL

Consider an MIMO-OFDM system with n transmitters and m receivers. Before the transmission of information, the serial input data is converted into parallel data stream and pilots are inserted. Then, Inverse Fast Fourier Transform (IFFT) and cyclic prefix insertion are performed. In the receiver side, cyclic prefix removal, Fast Fourier Transform (FFT) and LS and MMSE estimations are performed which are given by the following equations.

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

$$\hat{H}_{MMSE} = WR\,R^{-1}Y \tag{2}$$

where W is the weight matrix, R is autocorrelation, X is the input vector, and Y is the received vector.

The noise levels of the received signal from the existing LS and MMSE channel estimation techniques are too high and also it has more channel estimation errors. Hence DFT-based channel estimation is proposed to minimise the noise level and mean square error. The block diagram of DFT based channel estimation is shown in Figure 2.

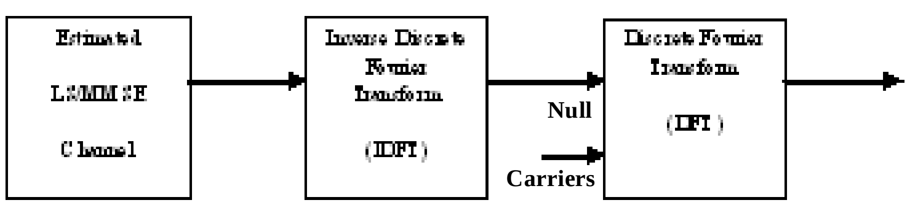

Figure2. Block diagram of DFT-based channel estimation

Let $\hat{H}[k]$ is the estimated channel gain of K' th subcarrier which is derived from LS /MMSE channel estimation. The IDFT of this channel estimate is represented as

$$\text{IDFT}\ \{\hat{H}[k]\} = h[n] + z[n], \quad n = 0, 1, 2 \ldots. N\text{-}1 \tag{3}$$

$Z[n]$ denotes the noise component in time domain. The coefficients are given as

$$\hat{H}_{DFT}[n] = \begin{cases} h[n] + z[n], & n = 0,1\ldots L-1 \\ 0, & otherwise \end{cases} \tag{4}$$

Now, DFT transform is taken for the remaining L elements in the frequency domain. It is given as

$$\hat{H}_{DFT}[k] = DFT\left\{\hat{H}_{DFT}[n]\right\} \tag{5}$$

The instantaneous Mean Square Error (MSE) is defined as the average error within an OFDM block and that can be expressed as

$$MSE = \frac{1}{N}\sum_{k=1}^{N} | H(k) - H_e(k) |^2 \tag{6}$$

The MSE is calculated for both LS and MMSE estimation and also DFT-based channel estimation.

4. GA-BASED OPTIMIZED CHANNEL ESTIMATION

The LS channel estimation algorithm has less complexity than MMSE estimation algorithm. But it has high MSE than the MMSE algorithm. The block diagram of the proposed GA-optimized channel estimation is shown in Figure3.

The main intention of the proposed GA-based optimized DFT channel estimation is to discover the best channel with less MSE than the existing LS and MMSE estimations. In the proposed method, the existing DFT-LS estimated channel is randomly mutated by GA, and the best channel matrix is identified based on the fitness function which is given as

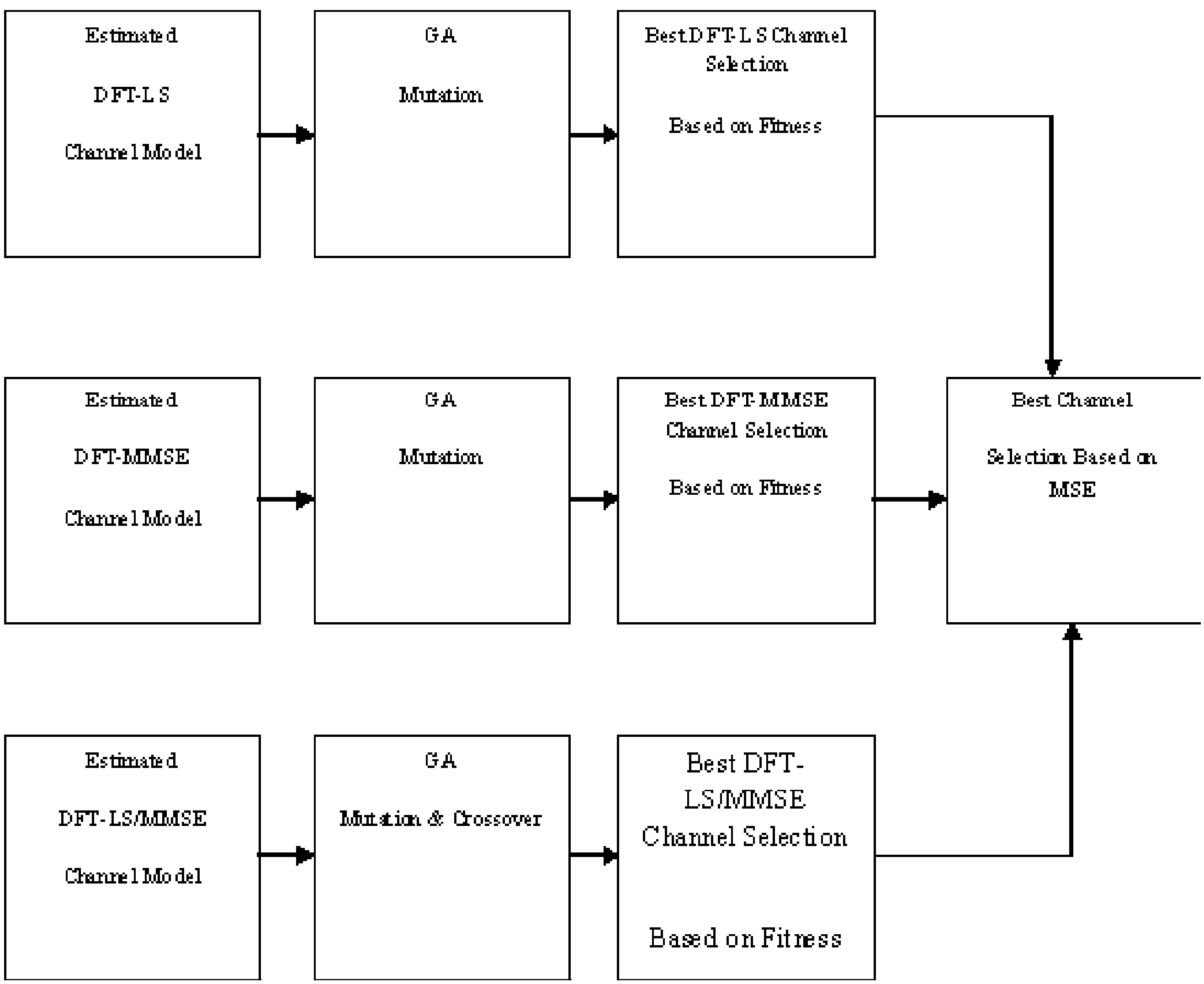

Figure3: Block diagram of GA-Optimized channel estimation

$$\text{Fitness} = [(H\text{-}H_{LS})/H]^2 \tag{7}$$

where H is the reference channel. Then, MSE is calculated for the above channel. The same steps are performed for repeated number of iterations. Similarly, DFT-MMSE estimated channel is randomly mutated by GA, and the best channel matrix is selected based on the fitness function and also MSE is calculated. The fitness function is given as

$$\text{Fitness} = [(H\text{-}H_{MMSE})/H]^2 \tag{8}$$

In the next step, a new channel is obtained by the crossover of DFT-LS and DFT-MMSE channel operation followed by mutation. Then, the best channel matrix is selected based on the fitness, and MSE is calculated as in the previous operations. Finally, the best channel with low MSE is selected from the group of DFT-LS, DFT-MMSE and DFT-LS/MMSE channels.

5. SIMULATION AND RESULTS

The performance of the proposed GA-optimized DFT-based channel estimation for 2x2 MIMO system in the presence of AWGN noise is analyzed with the system parameters shown in Table 1. The performance of DFT-LS channel estimation and GA-optimized DFT-LS channel estimation in terms of MSE is shown in Figure 4. It shows that by the introduction of GA, the best channel 1 is identified with 1.0% reduction in MSE than the existing LS estimation.

Table 1
System parameters for simulation

Parameters	*Value*
FFT Size	32
No. of Symbols	100
Modulation	QAM
No. of Pilots	8

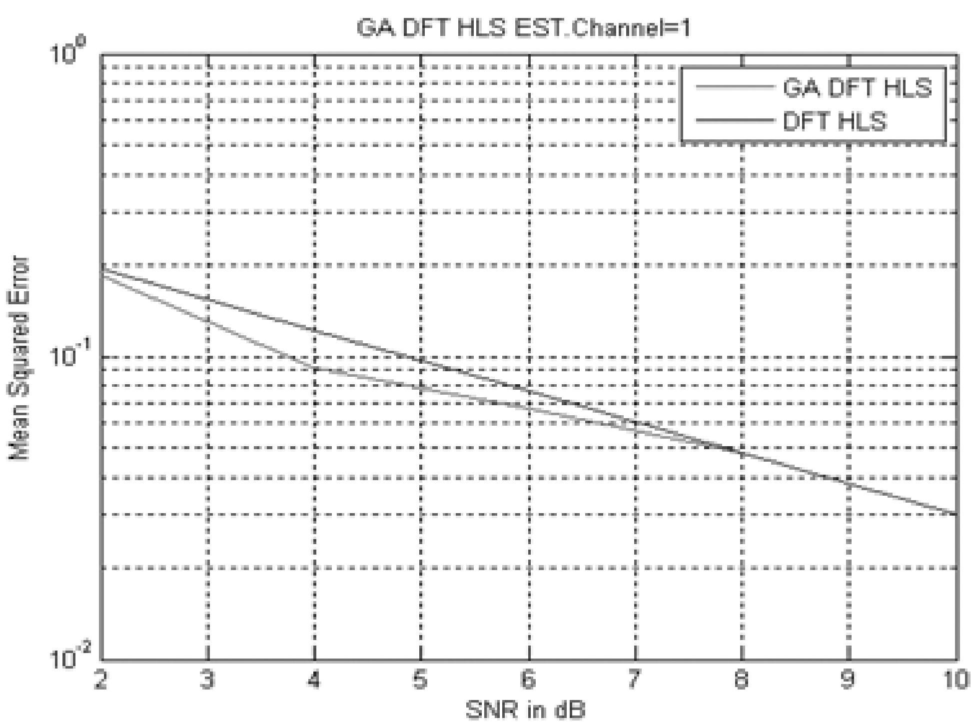

Figure4: MSE versus SNR of LS-DFT and GA-based LS-DFT Chanel Estimation

The performance of DFT-LS channel estimation and GA-optimized DFT-LS channel estimation in terms of MSE is shown in Figure 4. It shows that by the introduction of GA, the best channel 1 is identified with 1.0% reduction in MSE than the existing LS estimation.

Figure 5 clearly indicates that the GA-optimized DFT-MMSE channel estimation further reduces MSE by 0.25% than DFT-MMSE channel estimation at low SNR values.

Figure 6 shows better performance of GA-optimized combined LS/MMSE-DFT channel estimation than the combined LS/MMSE-DFT channel estimation and LS channel estimation in terms of MSE. By the introduction of GA, the best channel 1 is identified with the 1.5% reduction of MSE than the existing DFT-

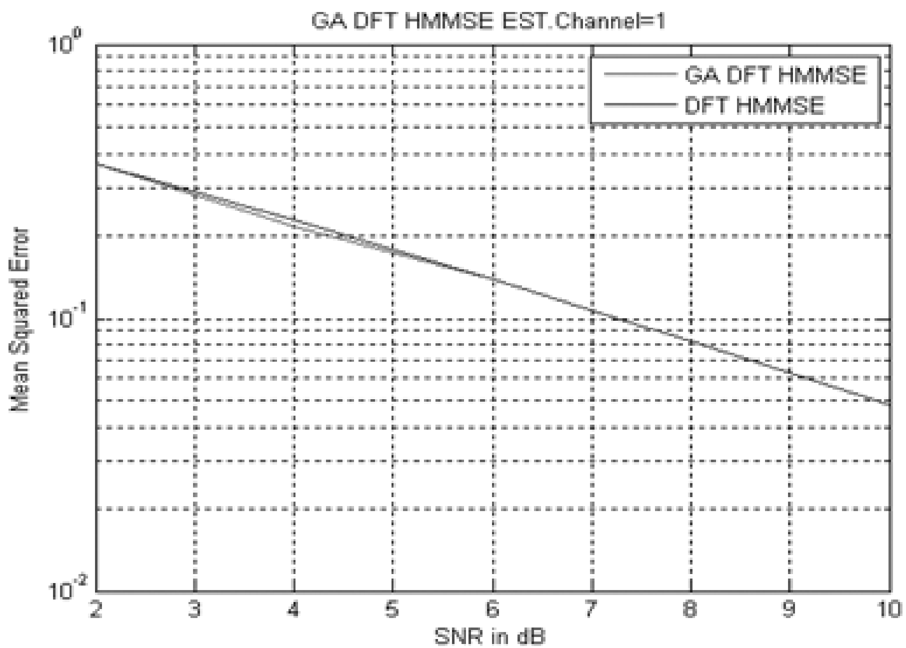

Figure 5: MSE versus SNR of MMSE-DFT and GA based MMSE-DFT channel Estimation

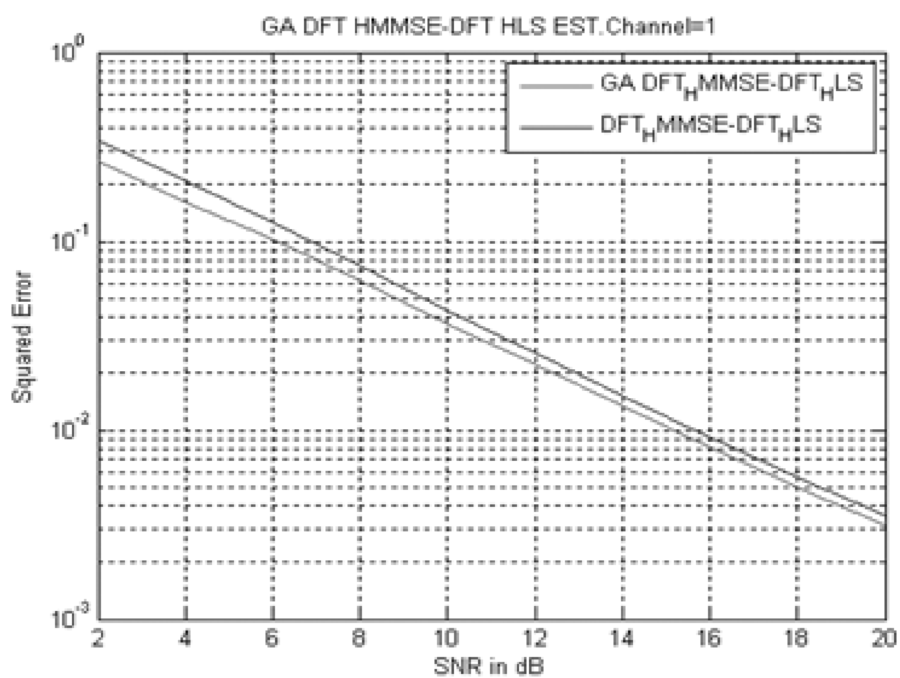

Figure 6: MSE versus SNR of DFT – LS/MMSE and GA based DFT-LS/MMSE channel Estimation

MMSE estimation and 2.63% reduction of MSE than the existing DFT-LS channel estimation. Hence GA-based combined channel estimation is identified as the best estimation.

6. CONCLUSION

A New and efficient GA-based optimized channel estimation is proposed in this paper. In this proposed scheme, implementation of LS, MMSE, DFT channel estimations and their optimization using GA has been done with the help of MATLAB. The simulation results show that MSE of GA-optimized combined channel estimation is less than 1.9% of MSE of DFT –LS/MMSE estimation and 2.63% of DFT-LS estimation. It clearly proves that the proposed GA based optimized combined channel estimation outperforms the other existing DFT-LS and DFT-MMSE algorithms in terms of MSE.

References

[1] S. Alamouti, "A simple transmit diversity technique for wireless communications," IEEE Journal of Selcted Areas in Communication. vol. 16, no. 8, pp. 1451–1458, 1998.

[2] K. P. Bagadi and S. Das, "MIMO-OFDM Channel Estimation Using Pilot Carries," International Journal of Computer Appllication. vol. 2, no. 3, pp. 81–88, 2010.

[3] R. . Ganesh and J. JayaKumari, "A Survey on Channel Estimation Techniques in MIMO-OFDM Mobile Communication Systems," International Journal of Scientific and Engineering Research. vol. 4, no. 5, pp. 1851–1855, 2013.

[4] R. Ganesh and J. Jayakumari, "Genetic Algorithm-Based Optimized Channel Estimation in MIMO-OFDM System," Middle East Journal of Scientific Research. vol. 23, no. 11, pp. 2700–2705, 2015.

[5] R. S. Ganesh, J. Jayakumari, and I. P. Akhila, "Channel Estimation Analysis in MIMO-OFDM Wireless Systems," IEEE International Conference on Signal Processing and Networking Technologies. pp. 399–403, 2011.

[6] A. Gomaa and N. Al-Dhahir, "A Sparsity-Aware Approach for NBI Estimation in MIMO-OFDM," IEEE Transcation on Wireless Communication. vol. 10, no. Xx, pp. 1854–1862, 2011.

[7] J. Jo and I. Sohn, "On the Optimality of Training Signals for MMSE Channel Estimation in MIMO-OFDM Systems," EURASIP Journal of Wireless Communication Networks, no. 105, pp. 1–9, 2015.

[8] A. Omri, R. Bouallegue, R. Hamila, and M. Hasna, "Channel Estimation for LTE Uplink System by Perceptron Neural Network," International Journal of wireless Mobile Networks,.vol. 2, no. 3, pp. 155–165, 2010.

[9] M. N. Seyman and N. Taspinar, "Optimization of Pilot Tones Using Differential Evolution Algorithm in MIMO-OFDM Systems," Turkish Journal of Electrical Engineering and Computer Science. vol. 20, no. 1, pp. 15–23, 2012.

[10] E. P. Simon, L. Ros, H. Hijazi, J. Fang, D. P. Gaillot, and M. Berbineau, "Joint Carrier Frequency Offset and Fast Time-Varying Channel Estimation for MIMO-OFDM Systems," IEEE Transcation on Vehicular Technologies. vol. 60, no. 3, pp. 955–965, 2011.

[11] E. P. Simon, L. Ros, H. Hijazi, and M. Ghogho, "Joint Carrier Frequency Offset and Channel Estimation for OFDM Systems via the EM Algorithm in the Presence of Very High Mobility," IEEE Transcation on Signal Processing. vol. 60, no. 2, pp. 754–765, 2012.

[12] K. Vidhya and K. R. S. Kumar, "Enhanced Channel Estimation Technique for MIMO-OFDM Systems with the Aid of EP Techniques," Eurasip Journal of Scientific Research. vol. 67, no. 1, pp. 140–156, 2011.

[13] F. Wan, W.-P. Zhu, and M. N. S. Swamy, "Semiblind Sparse Channel Estimation for MIMO-OFDM Systems," IEEE Transcation on Vechicular. Technologies. vol. 60, no. 6, pp. 2569–2582, 2011.

[14] N. Sarmadi, S. Shahbazpanahi, and A. B. Gershman, "Blind Channel Estimation in Orthogonally Coded MIMO-OFDM Systems: A Semidefinite Relaxation Approach," IEEE Transcation on Signal Processing. vol. 57, no. 6, pp. 2354–2364, 2009.