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AN EFFICIENT PILOT CARRIER CHANNEL ESTIMATION USING GENETIC ALGORITHM IN 4G MIMO-OFDM SYSTEM

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ABSTRACT

MIMO-OFDM (multiple input multiple output-orthogonal frequency division multiplexing) is an excellent technique used in modern wireless communication systems. It has excellent quality of high speed data/voice transmission with high spectral efficiency. The Least Square (LS) and Minimum Mean Square Error (MMSE) channel estimation are the most common methods presented by several researchers. Discrete Fourier Transform (DFT)-based channel estimation is introduced to minimize the receiver noise interference which cannot be possible in the LS and MMSE techniques. Also, Genetic Algorithm-based optimized 4G 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 clearly show that the performance of optimized GA-based DFT channel estimation is better than the LS and MMSE estimation.

Keywords: 4G, Genetic Algorithm, DFT, LS, MMSE estimation.

INTRODUCTION

Orthogonal Frequency Division Multiplexing (OFDM) technique can be used as an excellent multi-carrier modulation technique to transmit high speed multimedia information. The OFDM technique carries high data rate information by multiplexing numerous parallel low rate data streams with orthogonal sub-carriers. This technique has high spectral efficiency and also less inters symbol interference (ISI). If this technique is combined with Multi Input Multi Output (MIMO), a major improvement in the quality of service and channel capacity will be obtained. In order to retrieve the data at receiver, the channel state information (CSI) is very much essential. The channel estimation technique is mainly used to identify the CSI at the receiver. This improves the accuracy and the reliability of the wireless link. In the training-based channel estimation, pilots are inserted into the particular position of each sub-carrier of OFDM symbols and transmitted. This estimation provides better resistance to fast fading and time varying channels [5] The popular Least Square (LS) channel estimation and Minimum Mean Square Error (MMSE) estimation techniques cannot minimize the noise levels at the receiver side. Hence, DFT channel estimation is introduced with LS and MMSE channel estimations to minimise the noise. Efficient genetic algorithm based channel estimation is executed in this work by proper mutation of LS and MMSE and DFT channels.

This article is planned as follows: 4G Channel estimation in MIMO-OFDM system model is presented in the next section followed by the DFT channel estimation model. The next section deals with genetic algorithm-based optimization. Simulation and results are discussed in the next section followed by the conclusion.

CHANNEL ESTIMATION IN MIMO-OFDM

In a MIMO-OFDM system, many pilot symbols are inserted with several data symbols and modulated with a group of OFDM modulators. Multiple antennas are used to transmit the OFDM modulators output at the transmitter side. In the receiver side, the multiple signals from the transmitter are reached with a group of OFDM demodulators and the CSI can be estimated by any training based algorithms. 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. Many channel estimation techniques are described by various researchers in MIMO-OFDM system. These techniques are training-based, blind and semi-blind channel estimation techniques [6]. The LS and MMSE are the most popular estimation techniques [2, 3, 4]. 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 [14] 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 [12, 13] 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 [11] in a new approach. Also sparsity-aware approach of NBI estimation [8] is presented to improve the performance of MIMO-OFDM system.

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 [10] 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 [15] which are the hybrid combinations of blind and training-based channel estimations. Efficient joint carrier frequency offset (CFO) channel estimation [12] 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 [8].

Consider an MIMO-OFDM system with n transmitters and m receivers. In the receiver side, pilot-aided training-based channel estimation such as LS and MMSE estimation are performed which are given by the following equations.

$$\widehat{H}_{LS}^{(n,m)} = \left(X^{(n)}\right)^{-1} Y^{(m)} \tag{1}$$

$$\widehat{H}_{MMSE}^{(n,m)} = F R_{hY} R_{YY}^{-1} Y^{(m)} \tag{2}$$

where

$$X = diag\{X(0), X(1), \ldots . X(N-1)\} \tag{3}$$

$$Y = [y(0), Y(1), \ldots . y(N-1)]^T \tag{4}$$

$$R_{hY} = R_{hh}^{(m,n)} F^H (X^{(n)})^H \tag{5}$$

$$R_{YY} = X^{(n)} F R_{hh}^{(n,m)} F^H (X^{(n)})^H + \sigma^2 I_N \tag{6}$$

$$F = \begin{bmatrix} W_N^{00} & \ldots & W_N^{0(N-1)} \\ \vdots & \vdots & \vdots \\ W_N^{(N-1)0} & \ldots & W_N^{(N-1)(N-1)} \end{bmatrix} \tag{7}$$

$$H = [H(0), H(1), \ldots . . H(N-1)]^T \tag{8}$$

$$W = [W(0), W(1), \ldots . . W(N-1)]^T \tag{9}$$

The training symbols for N orthogonal subcarriers are given by the following equation.

$$X = \begin{bmatrix} X[0] & 0 & & \ldots & 0 \\ 0 & X[1] & & \ldots & 0 \\ \vdots & \vdots & \vdots & & 0 \\ 0 & 0 & \ldots & & X[N-1] \end{bmatrix} \tag{10}$$

where X[k] denotes pilot tone of K'th subcarrier. The channel gain is H, noise vector is Z and the received training signal is represented as

$$Y = XH + Z \tag{11}$$

The LS channel estimation can be represented as

$$\hat{H}_{LS} = X^{-1} Y \tag{12}$$

The MMSE channel estimation can be represented as

$$\hat{H}_{MMSE} = W R\, R^{-1} Y \tag{13}$$

where W is the weight matrix and R is autocorrelation.

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

$$MSE = \frac{1}{N} \sum_{k=1}^{N} |H(k) - H_e(k)|^2 \tag{14}$$

The MSE is calculated for both LS and MMSE estimation

DFT CHANNEL ESTIMATION SYSTEM MODEL

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 [4]. Hence DFT- based channel estimation is proposed to minimise the noise level and mean square error.

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

$$IDFT\ \{\hat{H}[k]\} = h[n] + z[n],\ n = 0,1,2 \ldots . N-1 \tag{15}$$

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

$$\hat{H}_{DFT}[n] = \begin{cases} h[n] + z[n], & n = 0,1 \ldots L-1 \\ 0, & otherwise \end{cases} \tag{16}$$

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

$$\hat{H}_{DFT}[k] = DFT\{\hat{H}_{DFT}[n]\} \tag{17}$$

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

$$MSE = \frac{1}{N} \sum_{k=1}^{N} |H(k) - H_e(k)|^2 \tag{18}$$

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

GA-BASED OPTIMIZED CHANNEL ESTIMATION

The main objective of the proposed GA-based optimized channel estimation is to identify the best channel with less MSE than the existing LS, MMSE and DFT channel estimations. The block diagram of the proposed GA-optimized channel estimation is shown in Figure-1 and Figure-2. In this proposed method, the existing LS and MMSE channels are randomly mutated by GA, and the best channel is identified based on the fitness function which is given in the equation (19) and (20). Similarly, DFT-LS and DFT-MMSE estimated channels are also randomly mutated by GA, and the best channel is identified based on the fitness function.

$$Fitness = [(H - H_{LS})/H]^2 \tag{19}$$

$$Fitness = [(H - H_{MMSE})/H]^2 \tag{20}$$

where H is the reference channel.

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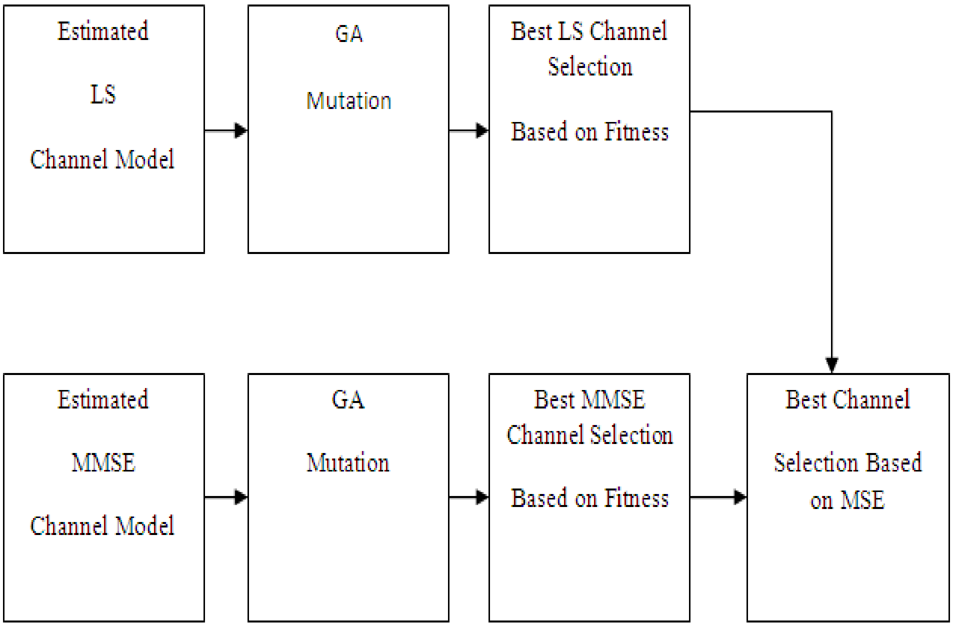

Figure-1. Block diagram of the GA-Based LS and MMSE estimation model.

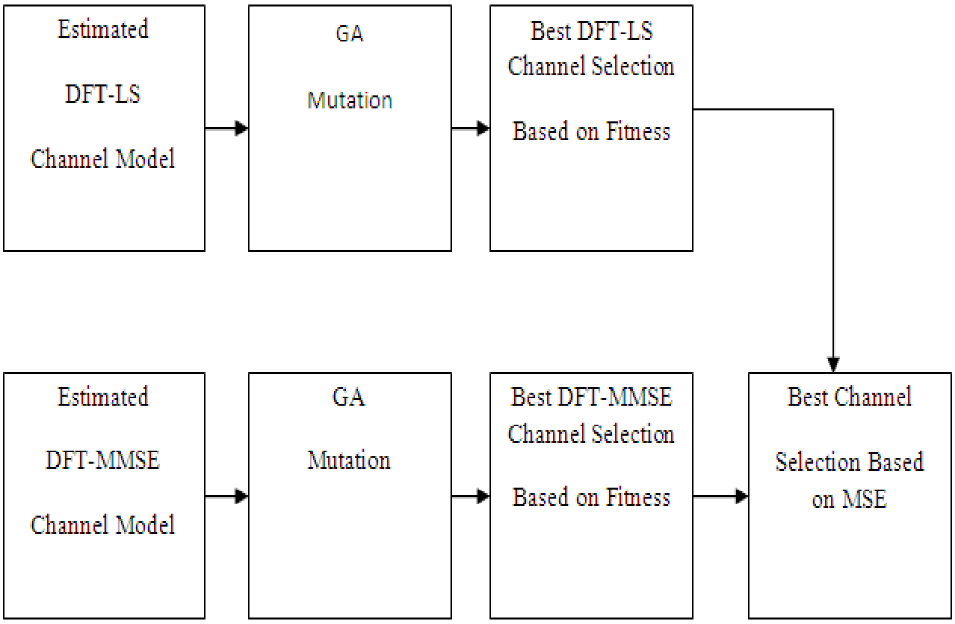

Figure-2. Block diagram of the GA-Based DFT-LS and DFT-MMSE estimation model.

Then, MSE is calculated for the GA mutated LS, MMSE, DFT-LS and DFT-MMSE channels. Finally, the best channel with low MSE is selected from the group of GA-based LS, MMSE, DFT-LS and DFT-MMSE channels.

SIMULATION AND RESULTS

The performance of the proposed GA-optimized channel estimation for 4G-based 2X2 MIMO system is analysed with the system parameters shown in Table-1.

Table-1. System Parameters for simulation

Parameters	Value
FFT Size	512
No. of Symbols	100
Modulation	QAM
No. of .Pilots	4
Channel	AWGN

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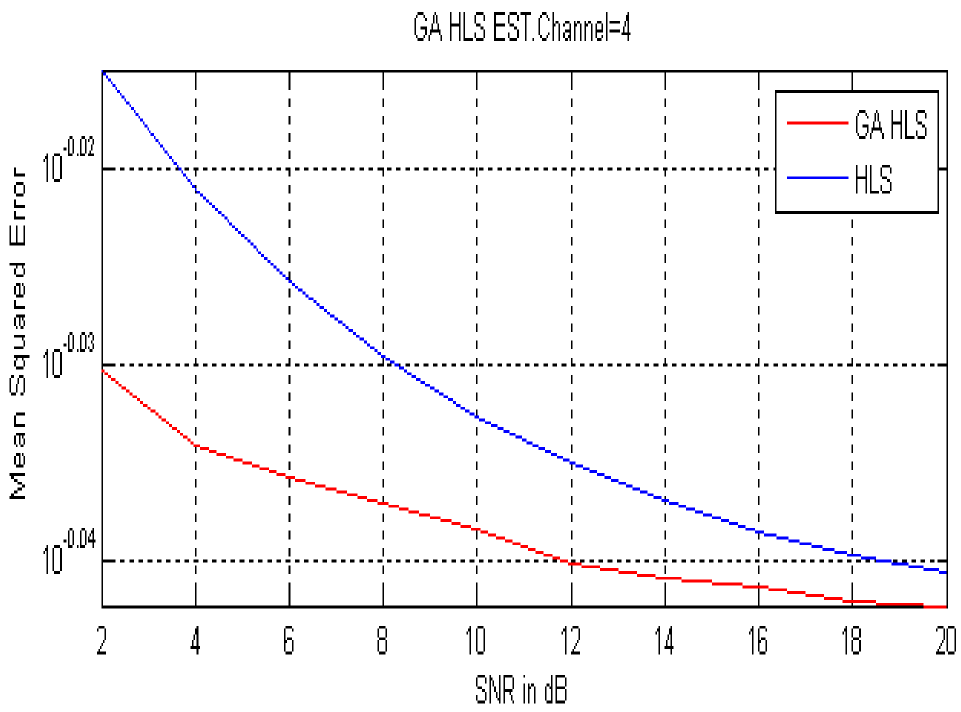

Figure-3. MSE versus SNR of LS and GA-based LS channel estimation.

Figure-3 displays the MSE versus SNR of LS channel estimation and 4G-based GA-optimized LS channel estimation. It clearly indicates that the average MSE of GA-optimized LS channel estimation is 1.5% lesser than the MSE of LS channel estimation. Figure-4 shows the MSE versus SNR of MMSE channel estimation and 4G-based GA-optimized MMSE channel estimation. By the introduction of GA based optimization, the average MSE is reduced 0.45% than the MSE of MMSE channel estimation.

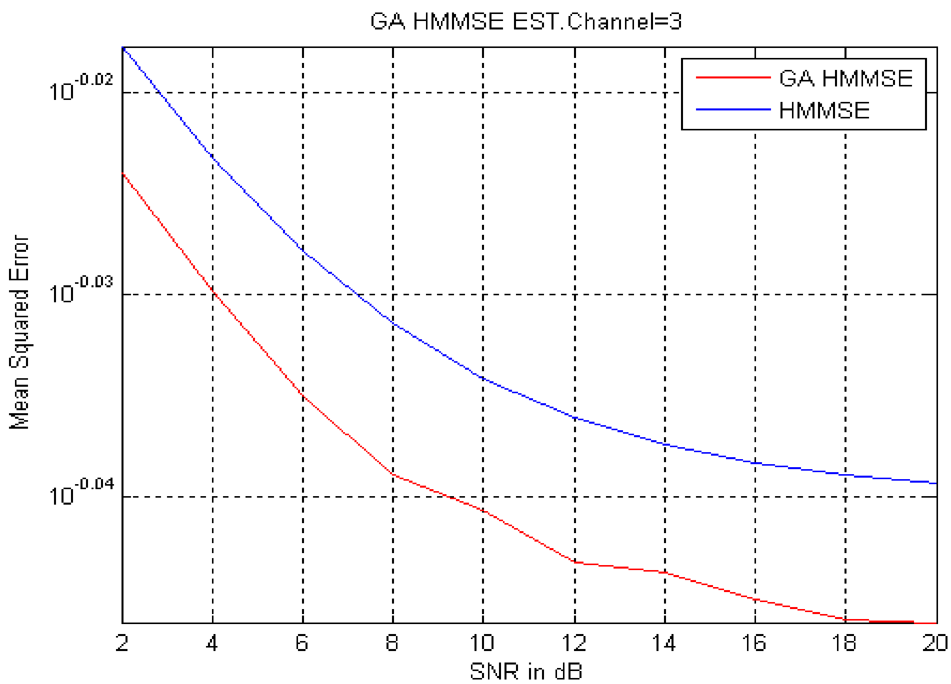

Figure-4. MSE versus SNR of MMSE and GA-based MMSE channel estimation.

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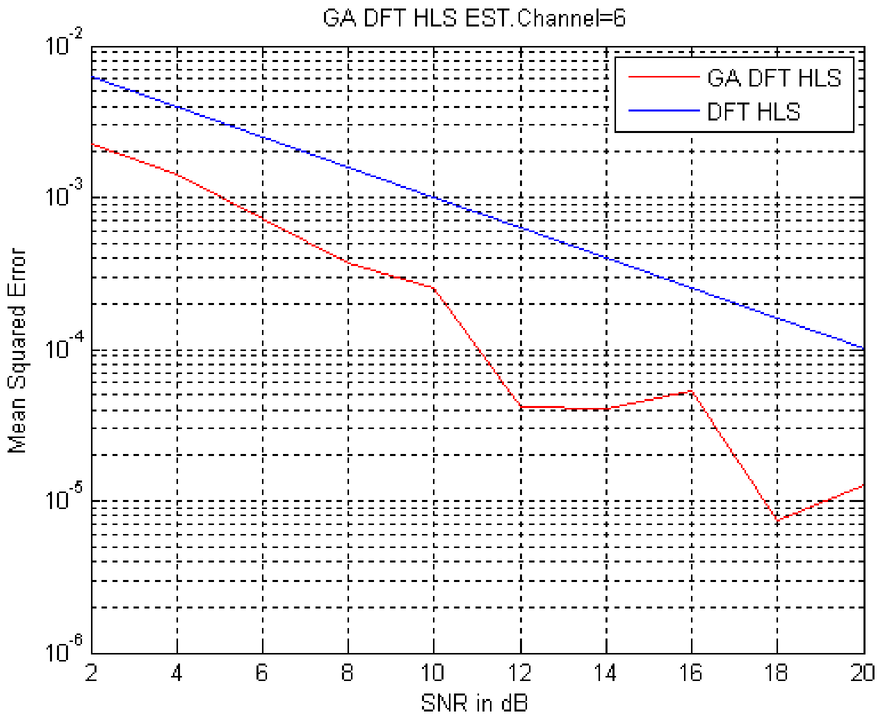

Figure-5. MSE versus SNR of LS-DFT and GA-based LS-DFT channel estimation.

Figure-5 and Figure-6 show the simulation of 4G GA-optimized DFT-LS and DFT- MMSE estimation techniques. Figure-5 clearly shows that the GA-optimized DFT-LS channel estimation further reduces the average MSE by 1.0 % than DFT-LS channel estimation at low SNR values.

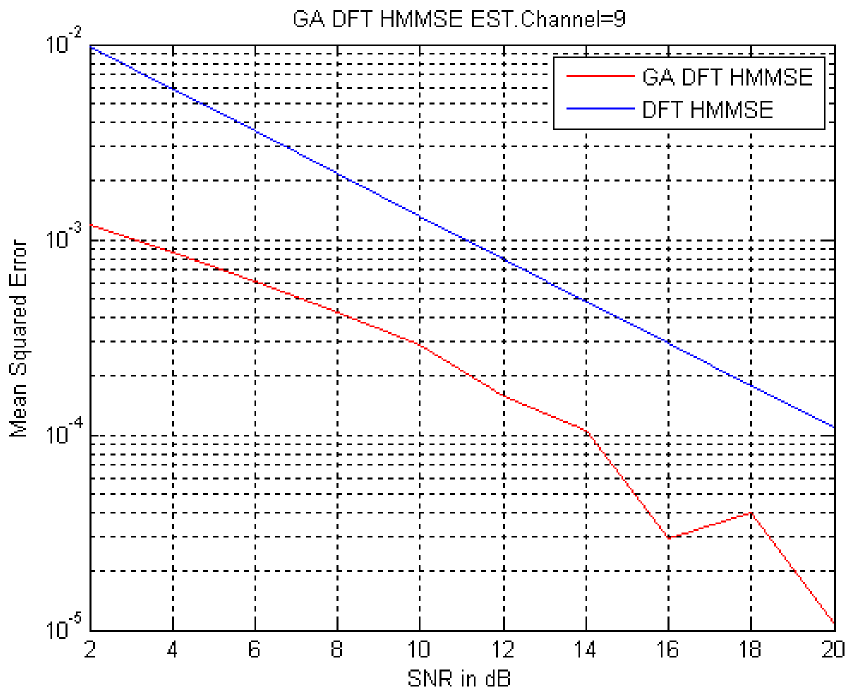

Figure-6. MSE versus SNR of MMSE-DFT and GA based MMSE-DFT channel estimation.

Figure-6 shows the better performance of GA-optimized combined DFT-MMSE channel estimation than the DFT-MMSE channel estimation and LS channel estimation in terms of MSE. By the introduction of GA, the best channel is identified with the 0.21% reduction of MSE than the existing DFT-MMSE estimation.

CONCLUSIONS

An Efficient GA-based optimized channel estimation for 4G 2X2 MIMO-OFDM system 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 DFT-LS channel estimation is 1.0% lesser than DFT-LS estimation and the GA-optimized DFT-MMSE estimation has less 0.21% MSE than DFT-MMSE estimation. It clearly proves that the proposed GA based optimized DFT-MMSE channel estimation outperforms the other existing DFT-LS and LS estimation.

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