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# Channel Estimation Analysis in MIMO-OFDM Wireless System

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**ABSTRACT**: In 4G MIMO-OFDM wireless system, a novel pilot-aided hybrid channel estimation using PSO is proposed in this paper. It focuses on the development of the new channel estimation using hybrid PSO to overcome the drawbacks of Least Square (LS), Minimum Mean Square Error (MMSE) and Discrete Fourier Transform (DFT) channel estimations. The design and development of Hybrid PSO -based crossover of LS/MMSE channel estimation has been executed using PSO for the 4G 2 X 2 MIMO-OFDM system under the Rayleigh fading channel. The Bit Error Rate (BER) and Mean Square Error (MSE) is calculated and the simulation results are compared with Hybrid-PSO, MMSE, LS channel estimations algorithms.
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**KEYWORDS**: MIMO-OFDM, Channel estimation, Hybrid-PSO, Least Square, Minimum Mean Square

## I. INTRODUCTION

In the fast growth of mobile communication techniques, high-speed wireless transmission of multimedia information is possible for the new generation wireless networks. At the same time, several issues such as efficient transmission, quality of transmission, high data rate, etc. are present till now to be solved by the researchers. Orthogonal Frequency Division Multiplexing (OFDM) has proven that this modulation technique is suitable for high data rates on time dispersive channels. It divides the high-rate data stream into parallel lower rate data streams which are transmitted simultaneously over a number of separate subcarriers. This technique is also used to eliminate Inter Symbol Interference (ISI). It also allows subcarrier bandwidth to overlap without Inter-Carrier Interference (ICI). Good spectral efficiency in OFDM can be achieved by using a special set of orthogonal carrier frequencies. MIMO-OFDM is recognized as an evolving technique in the 4G wireless communication system for this purpose. has great capability of high rate transmissionand its robustness against channel impairments such as multipath fading. In a MIMO system, multiple numbers of transmitters at one end and multiple numbers of receivers at the other end areeffectively combined in such a way to improve the channel capacity This technology can improve the spectrum efficiency, reliability& coverage. A wide variety of problems such as channel modeling, channel delays, multipath effects, channel estimation, and Peak to Average Power Ratio (PAPR) are analyzed by several researchers in the 2G, the 3G networks, and also a few in the 4G systems. Especially, Achieving frequent and accurate channel estimation has a momentous role in the MIMO-OFDM system for stable and reliable wireless communication with minimum error.

## II. RELATED WORK

There are many techniques used for better channel estimation which includes blind channel estimation, Training Based channel estimation and semi-blind channel estimation. The blind channel estimation is carried out by evaluating the information of the channel and specific properties of the transmitted signals. it is only applicable for slowly time-varying channels and it uses STBC, OSTBC algorithms for channel estimation. However, in training-based channel estimation, the receiver is aware of pilot tones or training symbols, which are multiplexed with the data stream for channel estimation. A Semi-blind channel estimation algorithm that uses the pilot carriers and other natural constraints to perform channel estimation is a combination of training-based channel estimation and blind channel estimation.. It uses linear prediction, a sparse semi-blind algorithm for better channel estimation. The training-based channel estimation can be performed by block-type pilots or comb-type pilots. In block type pilot estimation, pilot symbols are inserted into all frequency bins within the periodic intervals of MIMO-OFDM. In the pilot-based algorithm Least

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squares (LS) algorithm, Minimum Mean Square Error (MMSE) algorithm are used for channel estimation. For the actual system, due to the large calculation of matrix inversion in the MMSE algorithm, it is difficult to apply.

**LEAST SQUARE ERROR ESTIMATION**

The MIMO system is modelled as,

$$Y=H\ x+n$$

Where x and y are the transmit vector and receive vectors, **H** and **n** are the channel matrix and the noise vectors respectively.

It is assumed that the signal is transmitted over a multi path Rayleigh fading channel and is characterized by,

$$h(\tau)=\sum_{i=0}^{L-1}\alpha_i\delta(\tau-\tau_i)$$

Where $\boldsymbol{\tau_i}$the time delay of the different paths and L isthe number of multipath.

$H\hat{}_{Ls}=\arg\{\min\{Y-XH\hat{}_{Ls}\}H\{Y-XH\hat{}_{Ls}\}$

Where, $H\hat{}_{Ls}$ is the Least Squares (LS) Estimate of theChannel. Therefore it can be written as,

$H^{\wedge}_{Ls}=Y/X=H+N/X$

**MINIMUM MEAN SQUARE ERROR (MMSE) ESTIMATION**

The MMSE estimator employs the second- order statistics of the channel conditions to minimize the mean square error. The MMSE estimator yields much more performance than LS estimator, especially under the low SNR scenarios. The minimum mean square error (MMSE) estimate has better than the LS estimate for channel estimation in OFDM systems based on block type pilot arrangement.The MMSE estimate has about 0-5dB gain in SNR over LS estimate for the same MSE values .The major drawback of the MMSE estimate is its high complexity, which grows exponentially with observation samples. In a low rank approximation is applied to a minimum mean squared error estimator (MMSE estimator) that uses the frequency correlations of the channel. Using the channel second order statistics, MMSE estimators achieve the minimum mean square error. The MMSE estimator provides much better performance than the LS estimators, especially under low SNR conditions at the expense of higher computational complexity; due to matrix inversion during each execution.

The MMSE estimation can be derived by using the following equations,

$H^{\wedge}_{MMSE}=Fh^{\wedge}_{MMSE}= FR_{hy}R_{YY}^{-1}Y$
$R_{hy} = E[hY^H]= R_{hy}F^HX^H$
$R_{hy}=E[YY^H]= XFR_{hh}F^HX^H +0$

$$R_{hy}=E[YY^H]=XFR_{hh}F^HX^H+\sigma_n^2I_N$$

$$H^{\wedge}_{MMSE}=Fh^{\wedge}_{MMSE}=FR_{hh}F^HX^H(XFR_{hh}F^HX^H+\sigma_n^2I_N)^2$$

Where $R_{hh}$ is the channel auto- correlation matrix.
$\sigma_n^2$is the noise variance.
Good performance can be achieved with MMSE estimator and offers a reduced Mean Square Error value

**PARAMETER ANALYSIS**

The Channel Estimation is done in order to gain knowledge about the channel parameters. In this paper, we have considered two parameters namely,

1. Signal to Noise Ratio (SNR)
2. Bit Error Rate (BER)

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3. Mean Square Error Rate (MSE)

Signal to noise ratio is the ratio of the signal power to the noise powerIn practical SNR is important to channel parameter because it is one of the most important constraints to represent Signal value (Quality). But in theory Signal power requires predicting the errors. Thus another important constraint is Bit Error Rate (BER). BER is the ratio of the number of errors to the total number of bits sent.The average error in an OFDM block is known as Mean Square Error (MSE).

## III. PROPOSED ALGORITHM

The particle swarm optimization is a heuristic optimization technique whose mechanics are inspired by the collaborative behaviour of the biological populations such as bird flocking and fish schooling to guide particles to search for globally optimal solutions. The implementation of this algorithm is simple, having fast convergence. The PSO algorithm addresses has a problem of determining the best number of neurons in each hidden layer. Thus, the performance of ANN can be improved. In this case, we can match PSO with ANN to form the "hybrid PSO–ANN algorithm," through which the ANN can achieve a minimum distance error and bit error rate and minimum mean square error rate. While, in WSN, the ANN algorithm used to estimate the location of the mobile node or the distance between the nodes in the network. The standard PSO algorithm starts with a random swarm of M particles, each with R unknown parameters that must be optimised. To allow a global search, the initial particles are usually distributed uniformly throughout the assumed parameter space unless prior knowledge of the parameter space is available. At each iteration, the fitness of each particle is assessed using the fitness function chosen. The algorithm stores and progressively replaces the most fit parameters of each particle (pbest _i,i=1,2,…,M ) as well as a single most fit particle (gbest) as better fit parameters are encountered. The parameters of each particle (p_i ) in the swarm are updated at each iteration (n) according to the following equations:

$$
\begin{aligned}
&\overline{\mathrm{vel}_\iota}(n) = w^{*}\overline{vel_\iota}(n-1) \\
&+acc_1 * \mathrm{diag}\,[e_1, e_2, \ldots, e_R]_1 * (\text{ gbest } - p_i(n-1)) \\
&+acc_2 * \mathrm{diag}\,[e_1, e_2, \ldots, e_R]_2 * \left(\text{ pbest }_i - p_i(n-1)\right) \\
&p_i(n) = p_i(n-1) + \overline{vel_i}(n)
\end{aligned}
$$

where $\overline{vel_i}(n)$ is the velocity vector of particle I, $e_r$ is a vector of random values ∈ $(0,1)$, $acc_l, acc_2$ are the acceleration coefficients toward gbest and pbest $_i$ respectively, and $w$ is the inertia weight.
The velocity and position update equations
v[]=w∗v[]+c1∗rand()∗(pbest[]−present[])+c2∗rand()∗(gbest[]−present[])
New_present[]=present[]+v[]
where, v[]-particle velocity
present[]-current particle (solution).
New_present[]- updated particle (solution). rand()is a random number between (0, 1). c1,c2are learning factors. w–Inertia factor

The PSO optimization for BER takes on the following initial parameters
The scale of H estimate of LMMSE = 20 is equal to the number of PSO particles taken. Particles are initialized with the channel coefficients (HH)and tuned using ANN networks. Initial velocities of the particles are considered to be random complex numbers. Initial particle best values are again set to channel coefficients (HH) values of MMSE. The Initial global best value is set to the best value from channel coefficients estimate of MMSE and LS. The fitness value and best BER in PSO is estimated using parameters obtained from LS/LMMSE techniques for Rayleigh fading channel. The loop is iterated for 100 iterations to find minimum BER value and compared to the minimum BER value obtained by LS/MMSE.

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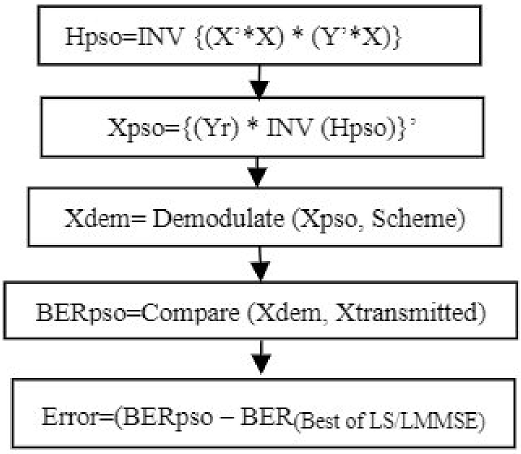


**FIGURE 1: CALCULATION OF PSO FITNESS VALUE AND BER**

## IV. SIMULATION AND RESULTS

Two transmit and receive antennas in MIMO-OFDM system are considered in this work. The three different algorithms such as hybrid-PSO channel estimation, LS channel estimation & MMSE channel estimation algorithms are applied and simulation is performed.

**Table 1:** Comparison of bit error rate of MIMO-OFDM channel using LS, MMSE and Hybrid-PSO algorithm

| SNR Value (dB) | Bit Error Rate | | |
|---|---|---|---|
| | LS | MMSE | Hybrid-PSO |
| 5 | 0.0590 | 0.0506 | 0.0120 |
| 10 | 0.0384 | 0.0329 | 0.0106 |
| 15 | 0.0246 | 0.0211 | 0.0086 |
| 20 | 0.0155 | 0.0133 | 0.0064 |

From TABLE I, it is clear that LS and MMSE channel estimation methods have higher BER than the proposed Hybrid-PSO method at various SNR's.

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**Figure 2: Bit error rate of MIMO-OFDM channel using LS, MMSE and Hybrid-PSO algorithm**

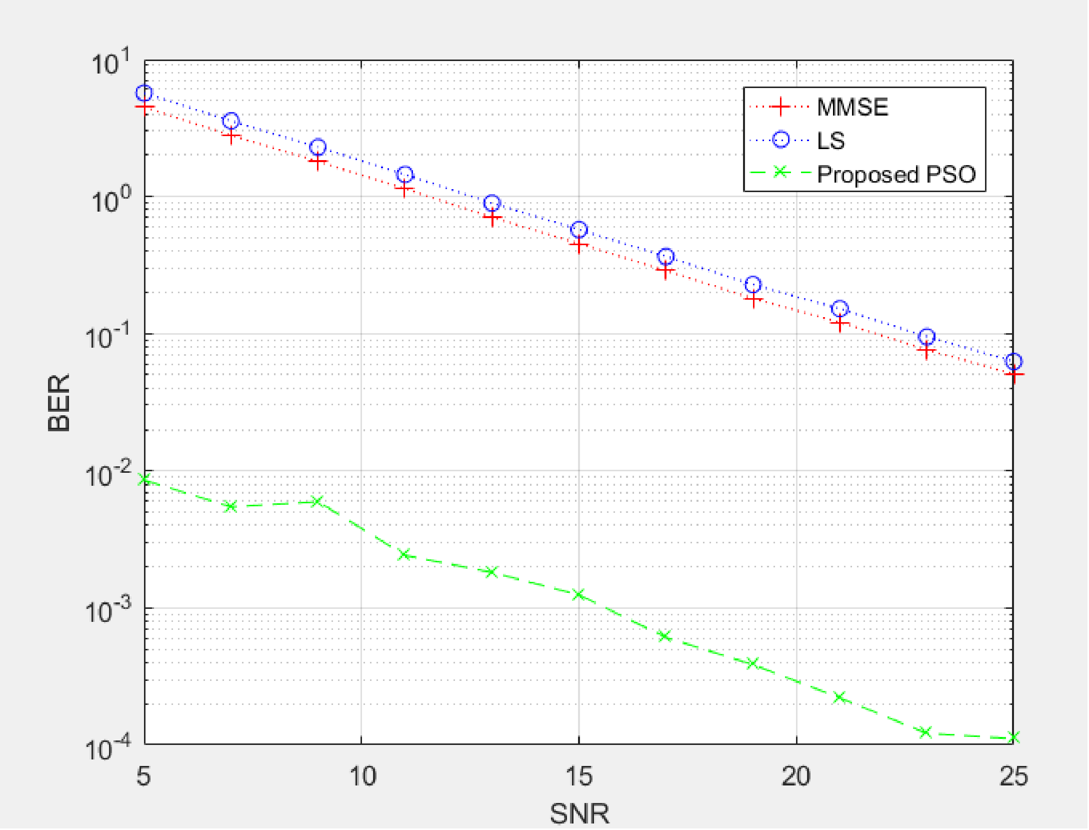


**Table 2:** Comparison of Mean square error rate of MIMO-OFDM channel using LS, MMSE and Hybrid-PSO algorithm.

| SNR Value (dB) | Mean Square Error | | |
|---|---|---|---|
| | LS | MMSE | Hybrid-PSO |
| 5 | 0.1169 | 0.0506 | 0.0017 |
| 10 | 0.0760 | 0.0329 | 0.0015 |
| 15 | 0.0486 | 0.0211 | 0.0013 |
| 20 | 0.0306 | 0.0133 | $7.94 \times 10^{-4}$ |

From TABLE 2, it is clear that LS and MMSE channel estimation methods have higher MSE than the proposed Hybrid-PSO method at various SNR's.

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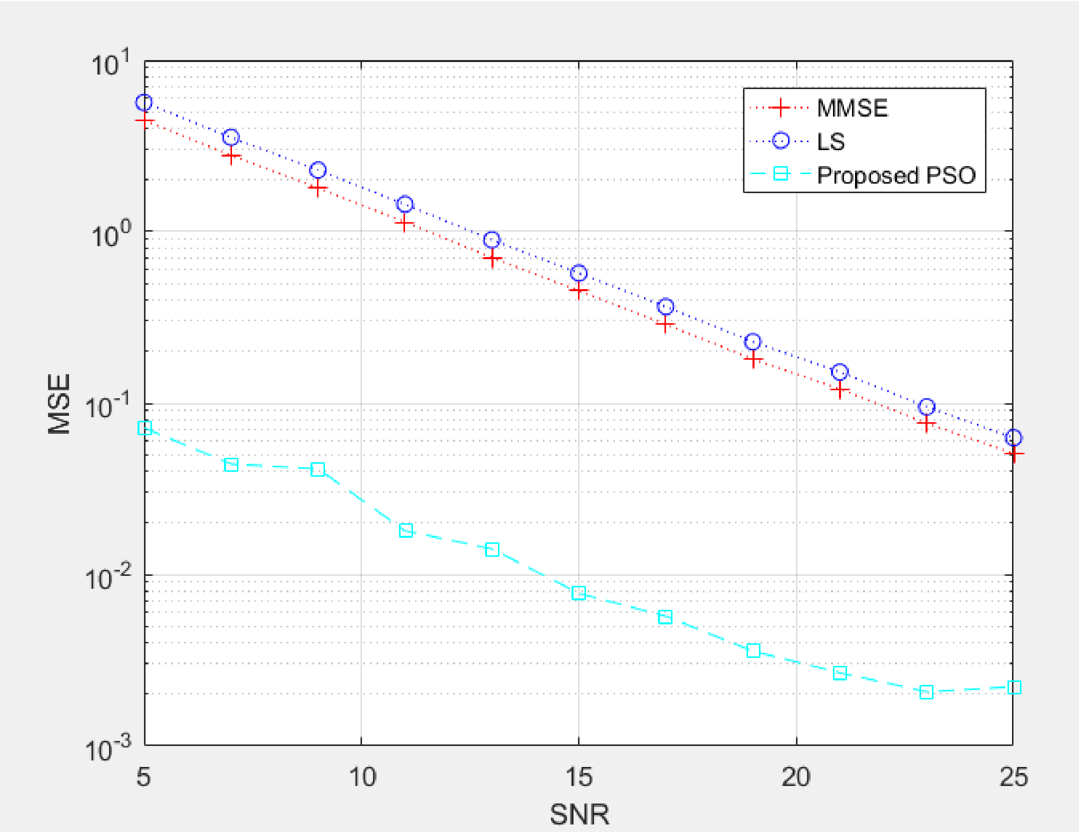
Figure 3: **Mean square error of MIMO-OFDM channel using LS, MMSE and Hybrid-PSO algorithm**




## V. CONCLUSION AND FUTURE SCOPE

In this paper channel estimation on MIMO-OFDM system for a Rayleigh fading channel is analyzed. The PSO-based hybrid channel estimation has 98.9% and 86.35% less average MSE than LS and MMSE channel estimations under Rayleigh channel. It has 72.91% and 56.5% less average BER than LS and MMSE channel estimations under Rayleigh channel. Pilot Contamination can substantially reduce the functionality of massive MIMO system and a major challenge in 5G massive MIMO networks. cannot achieve very high performance due to the complexity of large number of unknown channel coefficients. However, to alleviate the effect of pilot contamination we implemented ML Estimate to ease the pilot multiplexing and to reduce this effect of pilot contamination. Improved results by simulation work proved that ML Estimation done with hybrid PSO Simulations provides better results than conventional LS and MMSE estimation.

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