

Opposition Based Genetic Algorithm for Optimizing Pilot Pattern for MIMO-OFDM Systems

L. Swetha Rani^{1*}, Suraiya Tarannum²

¹Assistant Professor, Dept. of ECE, AMC Engineering College, Bengaluru, Karnataka, India.
Email: swethakalpak@gmail.com

²Professor, Dept. of ECE, HKBK College of Engineering, Bengaluru, Karnataka, India.
Email: ssuraiya@gmail.com

*Corresponding Author

Abstract: In this Paper, we propose an Opposition Based Learning-Cauchy Mutation (OBL-CM) Generic Algorithm (GA) for optimizing the Pilot Pattern for Sparse and Least Square Estimation (LSE) of Channel Estimation in MIMO-OFDM systems. Channel Estimation is carried out with the help of Bit Error Rate (BER) and corresponding values of Signal-to-Noise Ratio (SNR). It has been shown that substantial performance improvement can be achieved by using OBL-CM GA algorithm for Sparse Channel Estimation and also with LSE Estimation.

Keywords: Genetic Algorithm (GA), Least Square Estimation (LSE), Multi Input Multi Output-Orthogonal Frequency Division Multiplexing (MIMO-OFDM), Opposition Based Learning Cauchy Mutation (OBL-CM).

I. INTRODUCTION

Orthogonal Frequency Division Multiplexing (OFDM) has become very popular in recent years due to High Data Rate, Simple Implementation and Robustness against Frequency Selective Fading channels. Combining OFDM with MIMO provides a significant increase in Capacity through the use of transmitter and receiver Diversity techniques. MIMO-OFDM are very easily applicable to Digital Video Broadcasting (DVB), Digital Audio Broadcasting (DAB) etc., to name a few. MIMO-OFDM systems have higher and better Data Rates and Diversity reception than OFDM [1].

Equalization and Data Detection can be obtained by Channel Estimation by the use of Channel State Information (CSI), which can be obtained using different techniques, mainly Blind Channel Estimation and Pilot Aided Channel Estimation. In Blind Channel Estimation, the channel is estimated from the data itself. In Pilot Aided Channel Estimation, the estimation is performed by inserting the Pilot Tones into all of the Subcarriers of MIMO-OFDM and hence the Channel Estimation can be based on Least Square (LS) and Minimum Mean Square (MMS) Estimation.

Recently there has been an increased demand for Compressive Sensing Sparse Recovery algorithms that can be applied for

Pilot Aided Channel Estimation [2]. Sparse Channel Estimation gives better Channel Estimation as compared to the traditional LS Channel Estimation techniques.

The Optimization of Pilot Pattern in MIMO-OFDM can be evaluated using Evolutionary Algorithm Opposition based Genetic Algorithm and hence is employed in this paper for optimizing the Pilot Pattern for both Sparse and LSE Channel Estimation. Cauchy Mutation avoids the local optimal point when compared to Gaussian techniques [3].

II. SYSTEM MODEL

Consider a MIMO-OFDM system with $N_T=2$ transmit and $N_R=2$ ($\geq N_T$) receive antennas. The m^{th} OFDM symbol in i_T^{th} transmitting antenna can be written as a vector of the frequency domain signals, $[X_{i_T}(m,0), X_{i_T}(m,1), \dots, X_{i_T}(m,K-1)]^T$ where, K denotes the number of Sub-Carriers.

The Inverse Fast Fourier Transform (IFFT) processing generates a time-domain OFDM signal denoted as,

$$x_i(n) = [x_{i_T}(m,0), x_{i_T}(m,1), \dots, x_{i_T}(m,K)]$$

By omitting the time index m , we can write,

$$x(n) = [x_1(n), \dots, x_{N_T}(n)]^T \text{ and}$$

$$x_L(n) = [x^T(n) \dots x^T(n-L+1)]^T$$

$$(n = 0, 1, 2, \dots, K-1)$$

Let $H_A = [H(0)H(1) \dots H(L-1)]$

Where, $H(l)$ is l^{th} Tap of the L-tap MIMO FIR Filter.

The Channel Matrix for l^{th} tap and the output are given as,

$$H(l) = \begin{bmatrix} h_{1,1}(l) & h_{1,2}(l) & \dots & h_{1,N_T}(l) \\ \vdots & \vdots & & \vdots \\ h_{N_R,1}(l) & h_{N_R,2}(l) & \dots & h_{N_R,N_T}(l) \end{bmatrix}$$

$$y(n) = H_A x_L(n) + W(n) \tag{1}$$

where $v(n) = [v_1(n) \dots v_{N_T}(n)]^T$ is characterized by a Zero Mean and Unit Variance Gaussian Noise. This forms the System

Model considered in the present work, which is the Frequency-Selective Channel of the MIMO-OFDM system.

III. LS CHANNEL ESTIMATION

For evaluation of Channel Estimation, prior knowledge of transmitted symbols corresponding to received Pilot Symbols are used, \hat{H}_p estimated channel at Pilot Subcarrier locations kp .

$$\hat{H}_p = (X_k^H X_k)^{-1} X_k^H Y_k \quad (2)$$

$(*)^H$ is the Conjugate Transpose operation.

X_k is an $N_p \times N_p$ Diagonal Matrix whose elements are the transmitted complex-valued Pilot Sequence.

Y_k is an $N_p \times 1$ vector of the received complex-valued Pilot Sequence—after channel distortion.

\hat{H}_p is an $N_p \times 1$ vector of LS Channel Estimates at Pilot Subcarrier locations kp .

IV. SPARSE CHANNEL ESTIMATION

Nevertheless, we are more interested in the Sparse case with $N_p < L$, i.e., the number of Pilots is less than the number of channel coefficients. Considering that H has n nonzero, $n < L$ components, we can recover from (1) by solving the following *Norm Minimization Problem*.

$$\min \|h\|_0 \text{ s.t. } \|y - Xh\|_2 < W(n) \quad (3)$$

$\|h\|_0$ stands for non-zero component of h

V. OPTIMIZATION OF PILOT PATTERN

If there are NP Pilot Patterns.

1. Initialize the NP Pilot Pattern. Opposition of NP will be calculated as NP^l .
2. Fitness of NP will be calculated as $f(NP)$ and $f(NP^l)$.
3. Sort all the Pilot Patterns, $f(NP)$ and $f(NP^l)$.
4. After Sorting, only *Half of the Solution* will be considered the *Best Solution*.
5. *Cross Over Operator* will be applied.
6. *Cauchy Mutation Rate* will be calculated. Mutation is done according to the *Mutation Probability Function*.

VI. SIMULATION RESULTS

TABLE I: SIMULATION PARAMETERS

Parameters	Specifications
FFT	128
Sub-Carriers	128
Guard Interval	16
Signal Constellation	QAM

Modulation Order	4
Channel Model	Rayleigh Fading
No. of Tx/Rx	2

We consider Optimization for both Sparse and LSE Channel Estimation schemes. Fig. 1 shows that Sparse Channel Estimation with OBL-CM gives better SNR. Fig. 2 shows that LSE Estimation without Optimization is better as compared to OBL-CM Optimization.

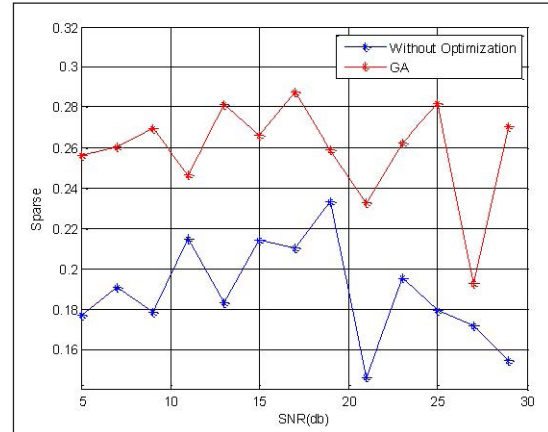


Fig. 1: Sparse Channel Estimation

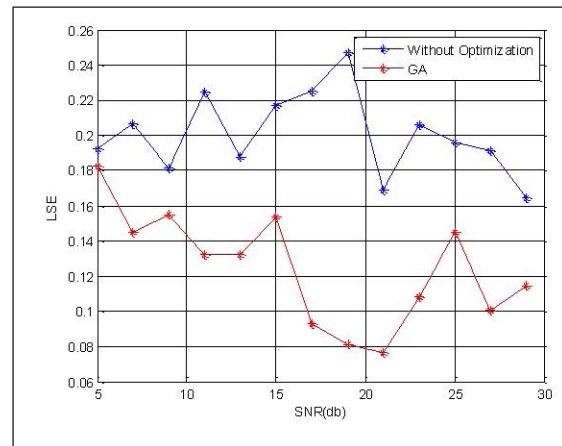


Fig. 2: LSE Channel Estimation

VII. CONCLUSION

In this paper, we have investigated the Pilot Placement for the Sparse Channel Estimation and LSE Channel Estimation in MIMO-OFDM systems. However, as seen, OGA-CM performs better for Optimization problems in terms of SNR.

REFERENCES

- [1] G. J. Foschini, and M. J. Gans, "On the limits of wireless communications in a fading environment when using multiple antennas," *Wireless Personal Commun.*, vol. 6, no. 3, pp. 311-335, Mar. 1998.

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- [2] C. Qi, and L. Wu, "Optimized pilot placement for sparse channel estimation in OFDM systems," *IEEE Signal Processing Letters*, vol. 18, no. 12, pp. 749-752, Dec. 2011.
- [3] K.-T. Lan, and C.-H. Lan, "Notes on the distinction of gaussian and cauchy mutations," *8th International Conference on Intelligent Systems, Design and Application, 2008, ISDA'08*, 26-28 Nov. 2008.
- [4] M. R. Sentinella, "Comparison and integrated use of differential evolution and generic algorithms for space trajectory optimization," *IEEE Congress on Evolutionary Computation, 2007, CEC 2007*, p. 973, 25-28 Sep. 2007.
- [5] C. R. Berger, S. Zhou, J. C. Preisig, and P. Willett, "Sparse channel estimation for multicarrier underwater acoustic communication: From subspace methods to compressed sensing," *IEEE Trans. Signal Process.*, vol. 58, no. 3, pp. 1708-1721, Mar. 2010.