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Improvement in OFDM Channel Estimation Using Hybrid Technique

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Abstract – Over the years demand for high date rate transmission is increased among the users. To enhance the data transmission rates, various efficient schemes were developed. OFDM (Orthogonal Frequency Division Multiplexing) is one of the efficient schemes widely used these days. OFDM significantly enhances the rate with which data is transmitted from source to destination. But still, some of the data bits deteriorate because of the use if less efficient channel estimation techniques. This literature contains an efficient scheme in which genetic algorithm and DFT (Discrete Fourier Transformation) based OFDM together used to minimize the mean square error values with corresponding SNR (Signal to Noise Ratio) values.

Index terms – OFDM, SNR, LS, MMSE, GA

1. INTRODUCTION

The ever increasing demand for very high rate wireless data transmission calls for technologies which make use of the available electromagnetic resource in the most intelligent way. Key objectives are spectrum efficiency (bits per second per Hertz), robustness against multipath propagation, range, power consumption, and implementation complexity. These objectives are often conflicting, so techniques and implementations are sought which offer the best possible tradeoff between them. The Internet revolution has created the need for wireless technologies that can deliver data at high speeds in a spectrally efficient manner. However, supporting such high data rates with sufficient robustness to radio channel impairments requires careful selection of modulation techniques. Currently, the most suitable choice appears to be OFDM. OFDM is becoming the chosen modulation technique for wireless communications. OFDM can provide large data rates with sufficient robustness to radio channel impairments.

1.1 OFDM

The basic idea of OFDM is to divide the available spectrum into several orthogonal sub channels so that each narrowband sub channels experiences almost flat fading. Many research centers in the world have specialized teams working in the optimization of OFDM systems. The attraction of OFDM is mainly because of its way of handling the multipath interference at the receiver. Multipath phenomenon generates two effects (a) Frequency selective fading and (b) Inter-symbol Interference (ISI). The "flatness" perceived by a narrowband channel overcomes the frequency selective fading. OFDM is simply defined as a form of multi-carrier modulation where the carrier spacing is carefully selected so that each sub carrier is orthogonal to the other sub carriers [1], [2]. Two signals are orthogonal if their dot product is zero. That is, if you take two signals multiply them together and if their integral over an interval is zero, then two signals are orthogonal in that interval. Orthogonality can be achieved by carefully selecting carrier spacing, such as letting the carrier spacing be equal to the reciprocal of the useful symbol period. As the sub carriers are orthogonal, the spectrum of each carrier has a null at the center frequency of each of the other carriers in the system. This results in no interference between the carriers, allowing them to be spaced as close as theoretically possible [3].

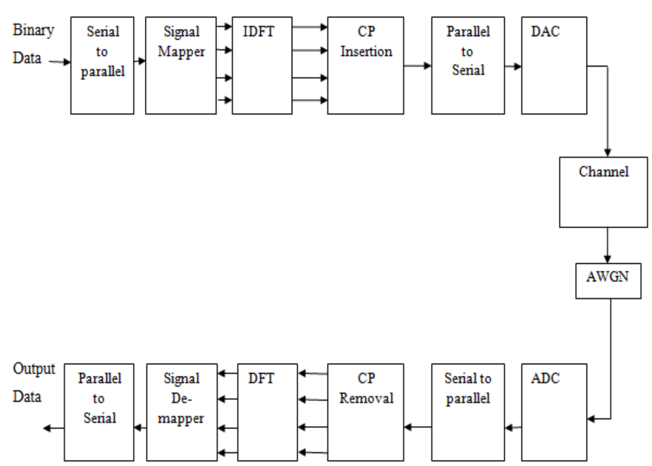

Figure 1 A typical baseband OFDM system block

2. CHANNEL ESTIMATION TECHNIQUES

The two most commonly used estimation techniques for channel estimation of OFDM system are Least Square (LS) and Minimum Mean Square Error (MMSE) which are discussed ahead:

2.1. Channel estimation based on LS criteria

It is the simplest channel estimation technique. Channel in a least square estimator is expressed as

$$Y= XH + n \tag{1}$$

Where Y is the output matrix, X is the input matrix, H is the channel matrix and n is the noise in the system. Gaussian white noise and inter channel interference have a large effect on LS algorithm because of which it does not produce very accurate results. Despite of the fact that its performance is not perfect even then it is widely used as a channel estimation algorithm because of less computational complexity associated.

LS estimator calculates the values of channel bandwidth using the following equation

$$H\hat{}_{LS}= X^{-1}Y \tag{2}$$

$$H\hat{}_{LS} = [(X_k^{-1}Y_k)]^T \quad (k=0,1.....N-1) \tag{3}$$

2.2. Channel estimation based on LS criteria

Since the accuracy of LS algorithm is not good therefore we consider an alternate algorithm MMSE (Minimum Mean Square Error) in order to improve accuracy.

The algorithm in the frequency domain is defined as:

$$h_{MMSE} = R_{HY} R_{YY}^{-1} y \tag{4}$$

$$R_{HY} = R_{HH}X^H \tag{5}$$

$$R_{YY} = XR_{HH}X^H + \sigma^2_N I_N \tag{6}$$

σ^2_N is the variance of Additive Gaussian noise.

$R_{HH} = E[HH]^H$ is the auto-correlation matrix of channel impulse response.

$$h\hat{}_{MMSE} = R_{HH} (R_{HH} + \sigma^2_N (XX^H)^{-1})^{-1} h\hat{}_{LS} \tag{7}$$

Clearly from the above expression, it's very much clear that MMSE channel estimator is quite complicated than the LS estimator because of correlation operation and matrix inversion associated. Due to complexity associated $(XX^H)^{-1}$ is replaced by $E[(XX^H)]^{-1}$ i.e. the average power is replaced by instantaneous power. When there is equal probability modulation, the term E[(XXH)]-1 can be approximated as:-

$$E[(XX^H)]^{-1} = E[|1/X_N|^2] I \tag{8}$$

where I is the identity matrix. SNR i.e. signal to noise ratio can be expressed as:-

$$SNR= E[|1/X_N|^2] / \sigma^2_N \tag{9}$$

The above written formula finally can be molded as:-

$$h\hat{}_{MMSE} = R_{HH}(R_{HH} + (\beta/SNR)\ I)^{-1} h_{LS} \tag{10}$$

Where R_{HH} is the channel autocorrelation matrix

β is the scaling factor whose value depend on the signal constellation.

Minimum Mean Square Error (MMSE) estimation includes information for the parameter to be estimated to achieve improved estimation performance. This channel estimation is given in the case of a non-invertible channel covariance matrix as a single input single output OFDM system [4], [5], [6].

3. PARAMETER EVALUATION STRATEGIES

Bit Error Rate (BER) is the number of bits received during the transmission of data through channel and that can be altered due to noise, wireless multipath fading, interference, distortion, bit synchronization etc. which causes error during transmission. The transmission BER is the number of bits that are in corrected before error correction, divided by the total number of error bits.

$$BER=number\ of\ errors/total\ number\ of\ bits\ sent \tag{11}$$

Signal to Noise Ratio (SNR) is a measure that how strong the signal is compared to the noise. If the noise is present in the signal then it will make the signal undetectable [7]. SNR is the ratio between signal powers and the noise power and it can be calculated as:

$$SNR=Psignal/Pnoise \tag{12}$$

In OFDM, a high-data-rate stream is divided up into K parallel data streams of lower data-rate sub-carriers, which are transmitted simultaneously. OFDM sub-carriers are designed such that they are orthogonal to each other. This allows them to be used in a spectrally overlapped manner, which enables the maximum use of the available bandwidth. Modulation by an orthogonal sub-carrier is easily implemented by the inverse discrete Fourier transform (IDFT) operation. By turning a high-data-rate stream into parallel lower data rate streams, the symbol period is increased and frequency-selective fading becomes flat fading. In this way, the ISI caused by a frequency-selective fading channel is mitigated by OFDM [8].

4. PROPOSED SYSTEM

The proposed computational intelligence technique is Genetic Algorithm.

4.1 Genetic Algorithm

The genetic algorithm is a search algorithm based on the mechanics of natural selection and genetics. It combines a strategy of "survival of the fittest" with a random exchange of information, but structured. The working of GA can be described by the algorithm.

Algorithm: Basic steps in the GA.

- Initialize the population of chromosomes.
- Compute the fitness level of each chromosome to rank them.
- Select the best chromosomes in terms of their fitness.
- Perform the crossover operation on selected chromosomes.
- Perform the mutation function on selected chromosomes.
- If stopping criteria is achieved terminate the GA otherwise move to step 2 of the algorithm.

The brief explanation of each step involved in the GA is as follow:

- Initialization: An initial population with i random chromosomes is generated. These chromosomes contain the available solutions to the given problem under analysis.
- Fitness Evaluation (FE) represents the evaluation of fitness of random generated chromosomes.
- Formation of New Generation.

This component performs the following steps to reproduce the chromosomes until the next generation completes.

- Selection: The chromosomes are selected in such away to have the better level of fitness in the current available population.
- Crossover: The crossover is an operator to share information between chromosomes and to create new individuals from the incoming generation.

  Mutation: The new created individual will be mutated at a definite point in the chromosome [9].

4.2 Methodology

4.2.1 Environment Generation

Length of cyclic prefix=8 bits, length of FFT=64 bits, number of multicarrier=45, Es/No = 0-25dB, SNR = 10.^(Es/No/10), Number of taps=6,8,10.

4.2.2 Transmitter Section

GENERATING MESSAGE SIGNAL - message signal is generated containing a number of random bits.

MODULATION - message signal is digitally modulated with M-QAM and M-PSK.

SIGNAL TRANSMISSION-combined signal is transmitted

4.2.3 Channel with AWGN (Additive White Gaussian Noise) For Transmitted Signal

Now the modulated message signals are transmitted through the channel. And the channel is assumed to be AWGN (Additive White Gaussian Noise) channel.

4.4.4 System Mathematical Model

Input to time domain

$$x(n) = IDFT\{X(k)\} \qquad n = 0,1,2,\ldots,N-1 \qquad (13)$$

Channel

$$y_f = x_f(n) \otimes h(n) + w(n) \qquad (14)$$

Output to frequency domain

$$Y(k) = DFT\{y(n)\} \qquad k = 0,1,2,\ldots,N-1 \qquad (15)$$

Output

$$Y(k) = X(k)\,H(k) + W(k) \qquad k = 0,1,2,\ldots,N-1 \qquad (16)$$

Channel Estimation

$$X(k) = Y(k)/H(k) \qquad k = 0,1,2,\ldots,N-1 \qquad (17)$$

4.3 Input Parameters

Table 1 Shows the different input parameters which are used for simulation of proposed algorithm.

Parameters	**Specification**
FFT Size	64
No. of Multi carriers	45
Cyclic Prefix	8
Signal Constellation	16-QAM, 16-PSK
Channel Model	AWGN
Constellation Factor	17/9
Mutation probability	0.5
Threshold	5
Number of Taps	6

Table 1 Input Parameters

4.4 Flowchart

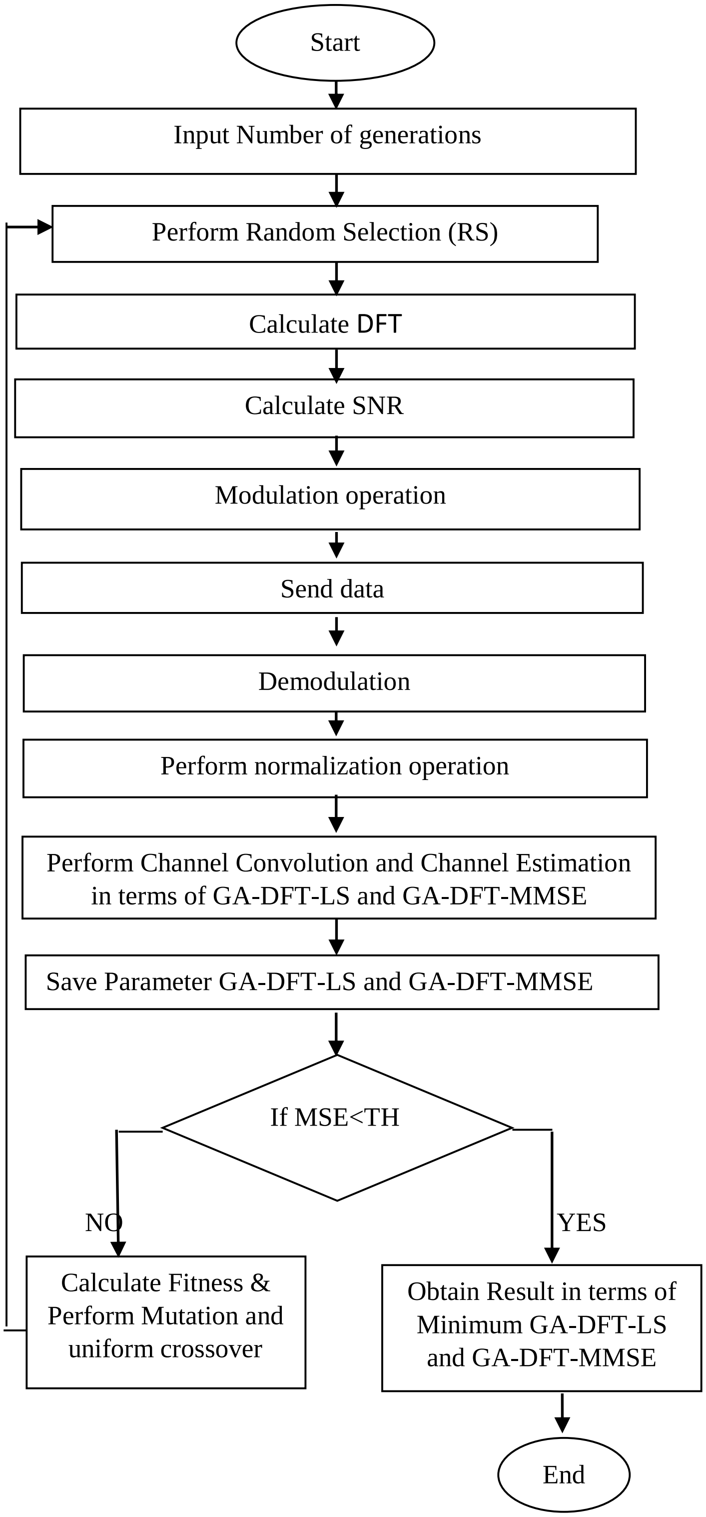

Figure 2 Flowchart of the Proposed Algorithm

5. PERFORMANCE ANALYSIS

The graph shows the comparison between DFT-LS and GA-DFT-LS and displays the performance of both of them. The graph also shows that the channel MSE of proposed LS using 16-QAM is better than traditional LS using 16-QAM and proposed LS using 16-PSK with respect to different values of SNR.

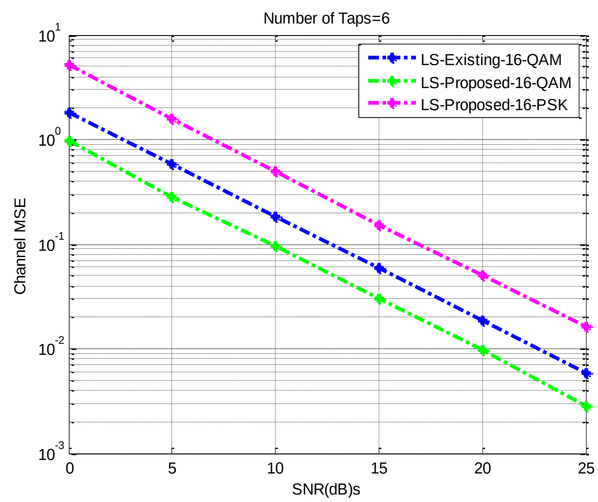

Figure 3 Comparison between DFT-LS and GA-DFT-LS

The graph shows the comparison between DFT-MMSE and GA-DFT-MMSE and shows the performance of these channel estimation techniques. The graph also shows that the channel MMSE using 16-QAM is better than traditional MMSE using 16-QAM and proposed MMSE using 16-PSK with respect to different values of SNR.

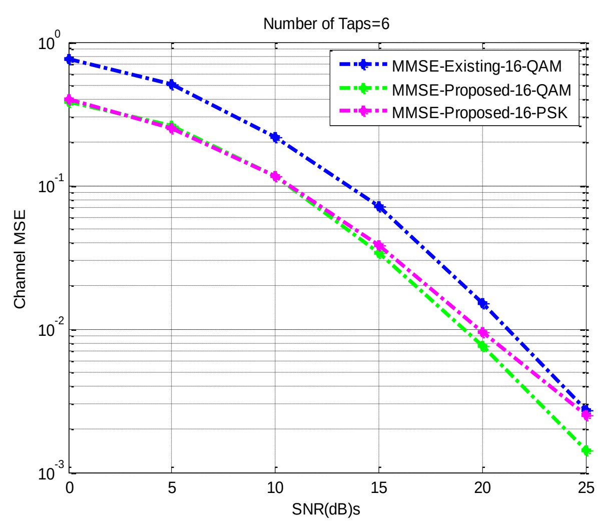

Figure 4 Comparison between DFT-MMSE and GA-DFT-MMSE

SNR(dB) / MSE	0	5	10	15	20	25
LS BASED 16-QAM	1.795	0.590	0.184	0.059	0.018	0.005
LS PROPOSED 16-QAM	0.961	0.285	0.096	0.029	0.009	0.002
LS PROPOSED 16-PSK	5.104	1.586	0.497	0.151	0.049	0.016
MMSE BASED 16-QAM	0.766	0.505	0.218	0.071	0.015	0.002
MMSE PROPOSED 16-QAM	0.380	0.263	0.115	0.033	0.007	0.001
MMSE PROPOSED 16-PSK	0.402	0.249	0.115	0.038	0.009	0.002

Table 2 Results Comparison between Existing and Proposed Technique

According to the different values of LS and MMSE in the table shows that the proposed algorithm using 16-QAM with number of taps=6 gives minimum LS-MSE and MMSE values as compared to base paper results and 16-PSK, which is shown in the above figures.

6. CONCLUSION

MMSE is an efficient mechanism for channel estimation. The result is improved by the application of genetic algorithm. The generations are evaluated and the generation giving best possible result is retained. The different values of LS and MMSE shows that the proposed algorithm using 16-QAM with number of taps=6 gives minimum LS-MSE and MMSE values as compared to base paper results and 16-PSK.

As the performance of OFDM system is improved by using genetic algorithm, in the similar way, results can be further improved by hybridization of GA with some other computational intelligence techniques like Particle Swarm Optimization (PSO), Ant Bee Colony (ABC) etc.

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