Geneti Algorithm Optimization Tool for Channel Estimation and Symbol Detection in Mimo-OFDM Systems

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Abstract

The quality of wireless media is described by three parameters. These parameters are its transmission range, transmission rate and reliability. In the conventional OFDM systems one parameter can be increased on the cost of decreasing other two parameters. However by combining MIMO with OFDM systems, all the three parameters can be improved simultaneously. Symbol detection and channel estimation are the two essential tasks of MIMO-OFDM system. These tasks can be excellently achieved by various other recently developed algorithms such as maximum likelihood (ML) detector, LMS, RLS etc. All these algorithms face a common problem of robustness. Also the complexity of these algorithms is very high in the system with large number of transmitters and receivers and having large constellation size. Therefore, we are using the NLMS estimator. But it doesn't provide the optimal solution. Genetic algorithm has the advantages of significantly less computational complexity, greater robustness and is closer to the optimal solution. Hence in this paper we are using Genetic algorithm based NLMS estimator to accomplish these tasks and to achieve results near to optimal solution. Comparisons between the results obtain from GA optimized NLMS estimator and plane NLMS estimator has been shown for better understanding.

Keywords: Genetic algorithm (GA), MIMO-OFDM systems, symbol detection, channel estimation

1. Introduction

Nowadays, wireless communication system has received a great attention because of rapidly increasing demand for high data communication. Therefore various wireless digital communication techniques have been developed to fulfill our day to day necessities. Also the services which are using wireless technology are being common. So the bandwidth of wireless link is decreasing rapidly. To fulfill these demands, high-speed wireless communication and higher network capacity are required. The MIMO-OFDM system which is a combination of Pro's of MIMO and OFDM systems is currently the best solution to meet these requirements [1]. Also, a significant capacity increase has been provided for OFDM systems by combining them with multiple-input, multiple-output (MIMO) technology in many communication systems, such as WLAN, HIPERMAN, and 4G wireless cellular systems [2].

There are various existing techniques for symbol detection and channel estimation of MIMO-OFDM systems. A detector with parallel partial candidate-search algorithm is described for estimation but it has greater computational complexity [3]. Recently, in a Turkish research Differential evolution algorithm is used for symbol detection in MIMO-OFDM system. It has less computational complexity but it lacks robustness [4]. A recently researched NLMS algorithm for channel estimation and symbol detection in MIMO-OFDM system is better than the above two algorithms as it is robust and the complexity is low. In NLMS algorithm, step size is used to repetitively update the channel. Hence it's a robust technique. But it doesn't provide the optimal solution.

Genetic algorithm has the advantages that it is closer to the optimal solution [4]. Hence a genetic algorithm based NLMS estimator is being developed as an optimization tool for channel estimation and symbol detection.

The structure of this paper is as follows: Section II describes the MIMO-OFDM system and its parameters. Section III discusses the techniques and algorithm used for symbol detection and channel estimation. Section IV consists of simulation result. Finally, conclusion in Section V.
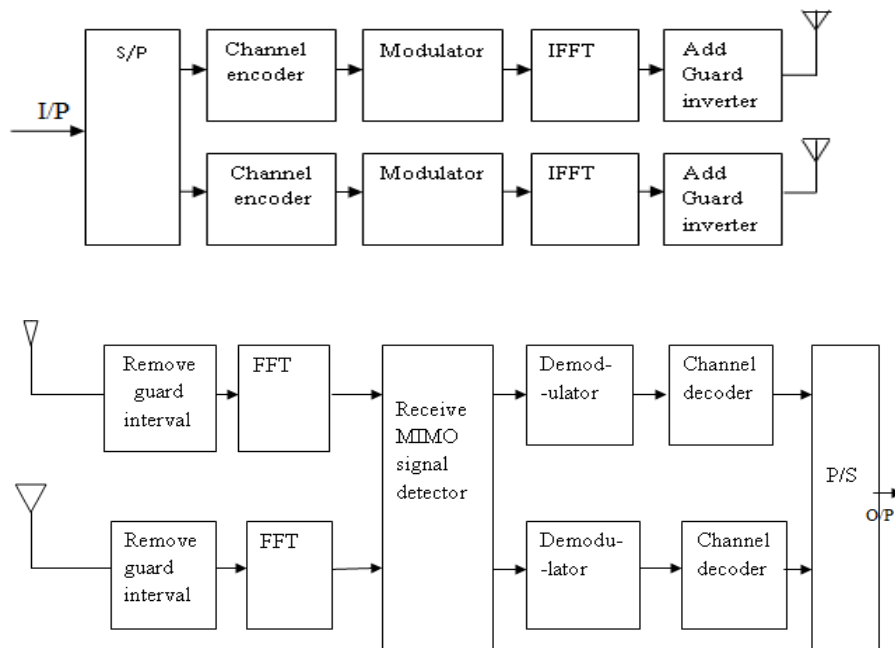
2. MIMO-OFDM System and its Parameters

MIMO-OFDM system is a system which combines the advantages of both MIMO and OFDM systems.

2.1. Motivation for MIMO-OFDM Systems

MIMO can be used with any modulation scheme or access technique. Nowadays, most digital radio systems are using Time Division Multiple Access (TDMA), Code Division Multiple Access (CDMA) and orthogonal frequency Division Multiplexing (OFDM). OFDM is a wide band system, which spreads the signal continuously over the entire channel. OFDM enroll many, discrete, lower data rate sub-channels. Implementation is much simpler- particularly at high data rates. It uses spectrum in much more efficient way by spacing the channels much more closely to each other. It makes all the carriers orthogonal to each other which prevent interference between them even when they are closely spaced. Also multi-antenna technology and OFDM modulation (MIMO-OFDM) yields a unique physical layer.

The quality of wireless link is described by transmission rate, transmission range and reliability. In conventional OFDM system, transmission rate may be increased by reducing the transmission range and reliability. By contrast, the transmission range may be extended at the cost of a lower transmission rate and reliability while the transmission reliability may be improved by reducing the transmission rate and range. However, by combining MIMO with OFDM all three parameters may be simultaneously improved.

The MIMO-OFDM system which is a combination of advantages of MIMO and OFDM is nowadays being considered as a strong candidate for the physical layer transmission scheme for next generation wireless communication system [1]. Each block of the MIMO-OFDM system has a specific importance. The input serial data stream is formatted into the word size required for transmission according to the modulation scheme used. For example 2 bits/word for QPSK, 1 bit/word for BPSK *etc* and the data is then transmitted in parallel by assigning each data word to one carrier in the transmission. The data which we want to transmit on each carrier is then differentially encoded with previous symbols, and then mapped into a PSK format. Modulation is a process of sending data signals over carrier signal to minimize noise. The use of phase shift keying produces a constant amplitude signal and was chosen for its simplicity and to reduce problems with amplitude fluctuations due to fading. Inter symbol interference is minimized using guard period. Guard period is made up of 2 sections. Half of guard period time is zero amplitude transmission. The other half of guard period is a cyclic extension of the symbol to be transmitted. IFFT transforms a spectrum into a time domain signal.

*S/P: Serial to parallel convertor *FFT: Fast Fourier transform *MIMO: Multiple input multiple output *P/S: parallel to serial convertor

Figure 1. Block Diagram of MIMO-OFDM System

2.2. Parameters of MIMO-OFDM System

Following are the techniques and parameters which can be considered for study.

Table 1. List of Blocks and their Specifications

Parameter	Specifications
Modulation Type	BPSK, QPSK, 8QAM, 16QAM
Coder	STBC
Channels	AWGN, Rayleigh, Racian
IFFT	64
Guard time	Zero level guard period

MIMO-OFDM systems can be controlled by the parameters made available by the underlying software-defined system. These control parameters are input to a fitness function. These parameters convey the information about transmission channel status, modulator and demodulator, coder and decoder, guard time *etc*; it then optimizes the objectives which are predefined, and finally outputs optimal decisions on the transmitting parameters.

Data to transmit depends on word size. Word size is the number of bits to transmit on each carrier. If word size is 2, data=0 to 3 and if word size is 8, data = 0 to 255. IFFT size is used for generating the waveform. Guard interval reduces data rate as no information is contained in guard interval. Hence in a good system design the guard interval is as short as possible. The possible modulation types include BPSK, QPSK, 8QAM and 16QAM. The objective fitness functions are BER minimization and throughput maximization. BER can be minimized by increasing S/N ratio since minimization of power consumption usually results in an increase of the BER.

3. Techniques for Channel Estimation & Symbol Detection

3.1. NLMS Estimator

Few years back, linear channel estimation methods were proposed *e.g.,* least squares (LS). These methods were based on density approach. By applying this method, the performance of linear methods depends only on the size of channel. Narrow band channel is viewed as dense channel because of its very short time delay spread. Adaptive sparse channel estimation method (ASCE) using invariable step size (ISS) least mean square algorithm was proposed (ISS-LMS). But these methods were unsuitable for low SNR ratio. To deal with the above problem a new approach was designed known as normalized least mean square (NLMS). In NLMS-based algorithms, the step size is used to iteratively update the channel. The estimation performance, convergence rate and computational cost are controlled by step size which is a very critical parameter.. In this paper we are using NLMS channel estimation method for estimating a channel for MIMO-OFDM systems. The proposed channel estimation architecture in MIMO-OFDM systems is as shown in Figure 2.
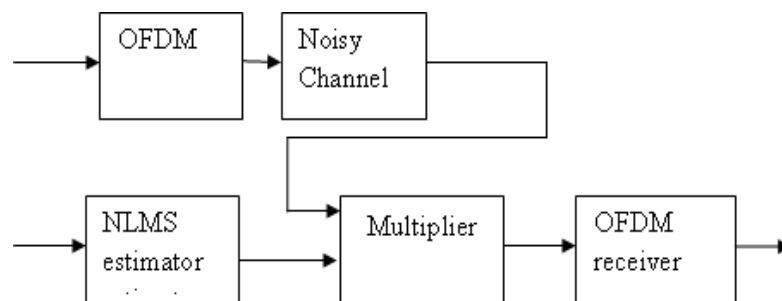

Figure 2. Block Diagram for Channel Estimation

NLMS ALGORITHM

Let,
w - weights
d - desired output (transmitted signal)
 μ = step size,
z = Received Signal;   y - weight * z

1) Initialize the weights.
2) Initialize the step size $\mu(0)$=0.95
3) Calculate error
    error(N) = Desired Signal(N) - z(N)
4) $\mu(n) = 0.95*2/(5*(0.001+var(z))) * \mu(0)$
5) New weight
    weights(N) = weights(N-1) + ($\mu(n)$*error(N)* Received Signal(N))
    i.e.,   w = w + mu/(0.001+u'*u) * u * e(n) ;

3.2. Genetic Algorithm

Genetic Algorithm is an evolutionary algorithm which utilizes the biological techniques like natural selection, crossover and mutation. Traditionally, solutions to GAs are represented in binary group of bits of 0s and 1s, but different encoding schemes are also possible.
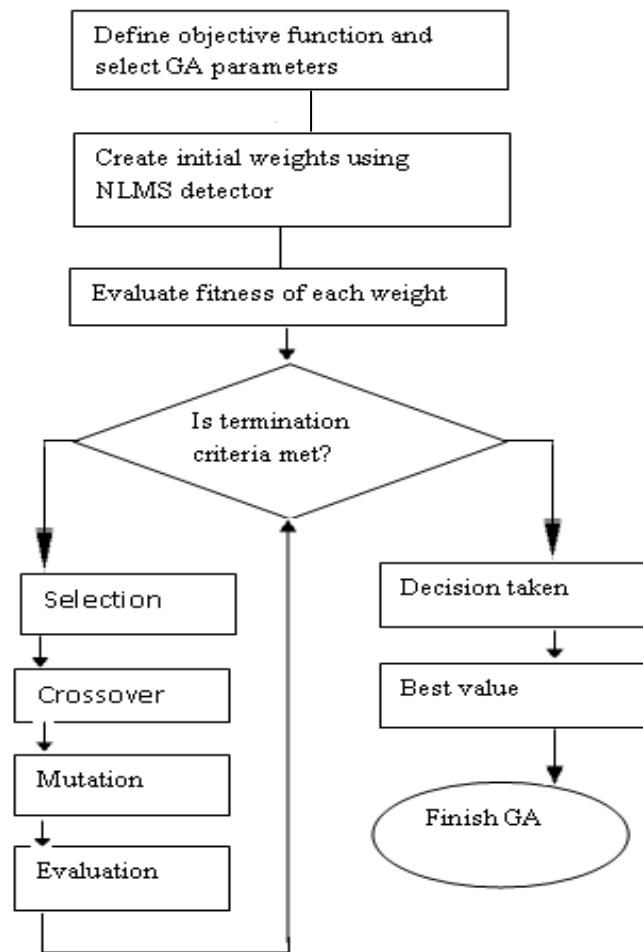
Figure 3. Flow Chart for GA

1. Overview: Nature follows a very interesting path to select an optimum solution of any problem. It chooses and keeps the best and fittest solutions and discards the others. The fittest solutions again evolve continuously. It is a continuous process to find out the most optimum result. In 1975, John Holland, first attempted to apply this natural selection technique to optimize natural selection problems [6] and he describe a new approach known as Genetic algorithm. Genetic algorithm is an intelligent search strategy inspired by biological evolution supported by biological operations. The theory of evolution was introduced by Charles Darwin to explain his observations of plants and animals in the natural ecosystem [7]. He noticed that every new generation was associated with some changes; hence the worst -fit individuals lost their survival in the competition. Thus, the basic principle survival of the fittest is adapted in all GA systems.

2. Algorithm: The terminology used in Genetic Algorithms is mix of both genetics and engineering [4]. All GA work on a population or a collection of solutions to the given transmitted wave [5]. Each individual in the population are named as a string or chromosome or weight *i.e.,* combination of frequency, modulation type, transmit power. Each individual are referred as genes coded with binary strings. For every iteration a new generation is evolved from the existing population in an attempt to produce good solutions.

The genetic algorithm begins with selecting initial weights and evolves over several generations. We are creating initial weight using NLMS detector. There are a lot of optimization techniques which works magnificently in dedicated problems but for

complex multimodal problems with a frequent change in nature the genetic algorithm is the best choice for optimization.

If the stopping criteria are not met, multiple weights are selected from current population in order to form new weights. The selection process chooses weights based upon their fitness score where higher scoring weights have a better chance to be selected. Once the selected weight have been chosen, they are modified by mutation, a random bit flip or crossover, which combines two chromosomes into one. The new weight is used in the next iteration of the algorithm.

In this paper we are developing a tool based on genetic algorithm which will provide optimal solution of the results from NLMS detector for channel estimation.

4. Simulation Results

MIMO-OFDM system is implemented under Matlab environment. Channel estimation has been done first by using plane NLMS algorithm and then by GA based NLMS estimator. The simulation parameters of MIMO-OFDM systems and channel estimation are given in Table 1 and 2 respectively. We have assumed to do perfect channel estimation. IFFT size is set to 64 in the MIMO-OFDM system with QPSK modulation. The output of NLMS method is then applied to GA optimization tool. The parameters which have been considered is shown in Table 2. Figure 4 shows the performance of NLMS estimator and Figure 5 shows the BER versus the SNR of the NLMS detector for a MIMO-OFDM system.

While, Figure 6 shows the performance of GA based NLMS estimator and Figure 7 shows the BER versus the SNR of the GA based NLMS detector for a MIMO-OFDM system.

Following are the parametric specification which has been considered during simulation:

Table 2. Basic Simulation Parameters Which Has Been Used

PARAMETER	VALUE
No. of bits transmitted	110 bpm
Frequency	8000
Amplitude	50
Channel used	AWGN
SNR	10
Modulation type	BPSK

The simulation results by apply simple NLMS estimator are as follows:
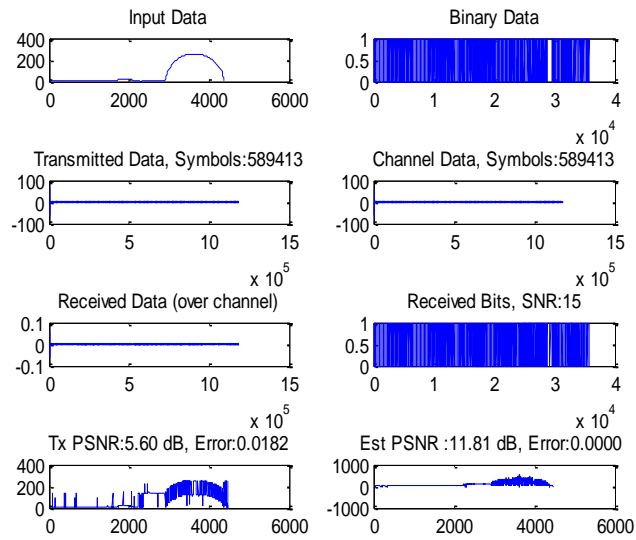

Figure 4. Performance of NLMS Channel Estimator

The performance of NLMS estimator has been seen in Figure 4. It is seen that the received signal has the PSNR=5.53 db while after applying NLMS estimator it is increased and PSNR=11.81 db. According to this performance the graph between BER and SNR has been plotted as shown in Figure 5.
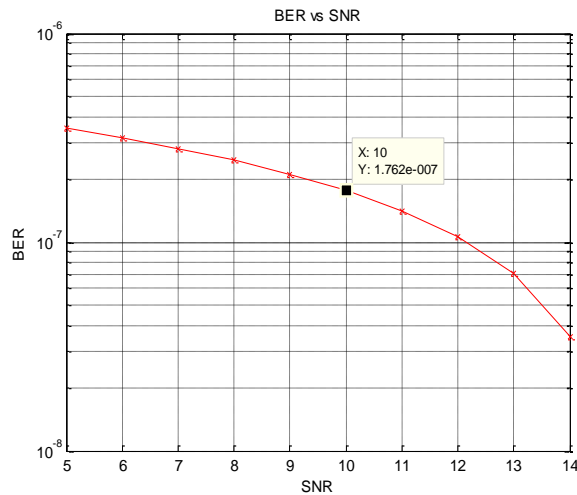

Figure 5. The BER versus the SNR of the NLMS Detector for a MIMO-OFDM System

From the above graph, the BER for SNR= 10 is near to 10^-7.

Now, the simulation results by apply GA based NLMS estimator are as follows:
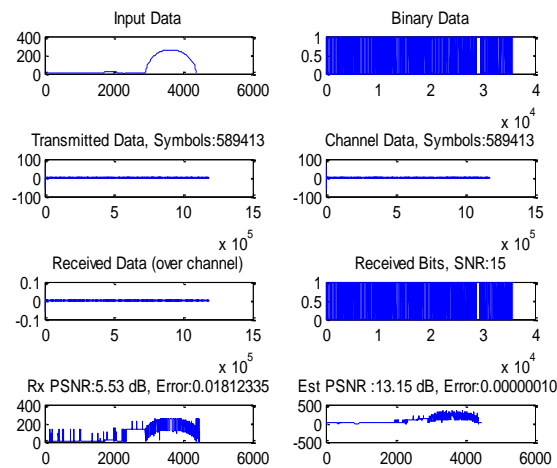

Figure 6. Performance of GA Based NLMS Channel Estimator

The performance of GA based NLMS estimator has been seen in Figure 6. It is seen that the received signal has the PSNR=5.53 db while after applying NLMS estimator it is increased and PSNR=13.15 db. According to this performance the graph between BER and SNR has been plotted as shown in Figure 7.
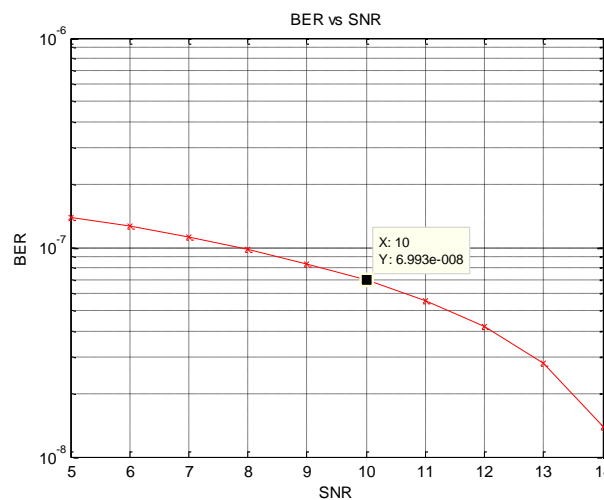

Figure 7. The BER versus the SNR of the GA based NLMS Detector for a MIMO-OFDM System

From the above graph, the BER for SNR= 10 is near to 10^-8.

From the above simulation results, it can be seen that both PSNR and BER has been comparatively improved by using GA optimized NLMS estimator.

5. Conclusion

We have presented implementation of plane NLMS estimator and GA optimized NLMS estimator on MIMO-OFDM systems. Here the comparison between both the estimator is described by PSNR improvement. The PSNR improvement of later over the previous one is shown in the Table 3. According to the table GA optimized NLMS

estimator has improved PSNR over plane NLMS as it provides the optimal solution. Also from the above simulation results we can conclude that the GA optimized estimator provides better PSNR then simple NLMS estimator also the BER is reduced by GA optimized NLMS estimator It is also simple to implement and is robust technique. Hence we can conclude that Genetic algorithm is an optimization tool for symbol detection and channel estimation in MIMO-OFDM systems.

Table 3. Comparison Table

	Value of PSNR	Value of BER
Without Estimation	$1.145 * 10^{-3}$	5.53 db
After applying NLMS estimator	$1.6067 * 10^{-3}$	9.06 db
After applying GA optimization tool	$2.3458 * 10^{-3}$	13.15 db

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