

Optimization of Beamforming using Genetic Algorithm and IPSLP Algorithm in MIMO-OFDM System

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Abstract- Beamforming is the signal processing technique used to control the directionality of transmission and reception of signals. This paper proposes beamforming design in transmitter and receiver for multiple-input and multiple-output (MIMO) with orthogonal frequency-division multiplexing (OFDM). The transmit (Tx) beam formers are set to Null Space and the receive (Rx) beam formers are calculated its signal-to-noise (SNR) while satisfying an orthogonality condition to eliminate the interferences. Joint optimization of Tx-Rx beam formers that combines SNR and signal-to-interference-plus-noise ratio (SINR) maximization. To optimize the minimum solution, Genetic algorithm and Interior Point Solver with Linear Programming Algorithm were used which will provide a better performance by reducing the bit error rate (BER). Global minima have obtained from GA and Local minima obtained from IPSLP. This system provides faster beamforming and improved error performance with comparison of both algorithms.

Keywords: Beam forming, MIMO, OFDM, Signal to Noise Ratio, Signal to Interference Plus Noise Ratio.

I. INTRODUCTION

MIMO-OFDM is the foundation for most advanced wireless local area network (Wireless LAN) and mobile broadband network standards because it achieves the greatest spectral efficiency and, therefore, delivers the highest capacity and data throughput. MIMO indicates more than just the presence of multiple transmit antennas (multiple input) and multiple receive antennas (multiple output). While multiple transmit antennas can be used for beamforming, and multiple receive antennas can be used for diversity, the word MIMO refers to the simultaneous transmission of multiple signals (spatial multiplexing) to multiply spectral efficiency (capacity). OFDM enables reliable broadband communications by distributing user data across a number of closely spaced, narrowband sub channels.^[1] This arrangement makes it possible to eliminate the biggest obstacle to reliable broadband communications, inter symbol interference (ISI). ISI occurs when the overlap between consecutive symbols is large compared to the symbols' duration. Normally, high data rates require shorter duration symbols, increasing the risk of ISI. By dividing a high-rate data stream into numerous low-rate data streams, OFDM enables longer duration symbols. A cyclic prefix (CP) may be inserted to create a (time) guard

interval that prevents ISI entirely. If the guard interval is longer than the delay spread—the difference in delays experienced by symbols transmitted over the channel—then there will be no overlap between adjacent symbols and consequently no inter symbol interference. Though the CP slightly reduces spectral capacity by consuming a small percentage of the available bandwidth, the elimination of ISI makes it an exceedingly worthwhile tradeoff. A key advantage of OFDM is that fast Fourier transforms (FFTs) may be used to simplify implementation. Fourier transforms convert signals back and forth between the time domain and frequency domain. Consequently, Fourier transforms can exploit the fact that any complex waveform may be decomposed into a series of simple sinusoids. In signal processing applications, discrete Fourier transforms (DFTs) are used to operate on real-time signal samples. DFTs may be applied to composite OFDM signals, avoiding the need for the banks of oscillators and demodulators associated with individual subcarriers. Fast Fourier transforms are numerical algorithms used by computers to perform DFT calculations.^[2] FFTs also enable OFDM to make efficient use of bandwidth. The sub channels must be spaced apart in frequency just enough to ensure that their time-domain waveforms are orthogonal to each other. In practice, this means that the sub channels are allowed to partially overlap in frequency.

MIMO-OFDM is a particularly powerful combination because MIMO does not attempt to mitigate multipath propagation and OFDM avoids the need for signal equalization. MIMO-OFDM can achieve very high spectral efficiency even when the transmitter does not possess channel state information (CSI). When the transmitter does possess CSI (which can be obtained through the use of training sequences), it is possible to approach the theoretical channel capacity. CSI may be used, for example, to allocate different size signal constellations to the individual subcarriers, making optimal use of the communications channel at any given moment of time MIMO techniques are used in OFDM (MIMO-OFDM) to enhance the system performance and it is capable of increasing the channel capacity even under severe channel condition. OFDM can also be used in multi-user cooperative communications system by assigning subcarrier to different users for overall transmit power reduction.

II. PROPOSED BEAMFORMING WITH GENETIC ALGORITHM

Beamforming is a signal processing technique used in sensor arrays for directional signal transmission or reception. Beam forming can be used at both the transmitting and receiving ends in order to achieve spatial selectivity. The improvement compared with omni directional reception/transmission is known as the directivity of the element. Beamforming is a type of RF management in which an access point uses multiple antennas to send out the same signal. By sending out multiple signals and analyzing the feedback from clients, the wireless LAN infrastructure can adjust the signals it sends out and determine the best path, the signal should take in order to reach a client device. In a sense, beamforming shapes the RF beam as it traverses the physical space. Genetic algorithm is used to generate useful solutions to optimization and search problems. Genetic algorithms belong to the larger class of evolutionary algorithms (EA), which generate solutions to optimization problems using techniques inspired by natural evolution, such as inheritance, mutation, selection and crossover. Initially the parameters are set as follows:

- i. $t = 0:0.001 : (0.001 * P * L * K)$;
for Time, sampling frequency is 1 kHz
- ii. $N = \text{length}(t)$;
- for number of samples
- iii. $s = \text{round}(\text{rand}(N, 1))$;

Assuming perfect OFDM symbol timing synchronization, then after removal of the cyclic prefix with length from round matrix and after the FFT, the received signal vector for the i^{th} user can be written:

$$y_i(p) = \sum_{k=1}^K H_{i,i}(p)v_i(p)s_i(p) + \sum_{r \neq i} H_{i,r}(p)v_r(p)s_r(p) + n_i(p) \dots \dots \dots (2.1)$$

In order to have good detection performance for all users in MIMO interference channels is the subject of widespread interest

$$SNR_i = S_i / N_i \dots \dots \dots (2.2)$$

A genetic algorithm (or GA) is a search technique used in computing to find true or approximate solutions to optimization and search problems. These are categorized as global search heuristics. Genetic algorithms are a particular class of evolutionary algorithms that use techniques inspired by evolutionary biology such as inheritance, mutation, selection, and crossover (also called recombination)

The evolution usually starts from a population of randomly generated individuals and happens in generations. In each generation, the fitness of every individual in the population is evaluated, multiple individuals are selected from the current population (based on their fitness), and modified (recombined and possibly mutated) to form a new population. The new population is then used in the next iteration of the algorithm. Commonly, the algorithm terminates when either a maximum number of generations has been produced, or a satisfactory fitness level has been reached for the population. If the algorithm has terminated due to a maximum number of generations, a satisfactory solution may or may not have been reached.

Selection: During each successive generation, a proportion of

the existing population is selected to breed a new generation. Individual solutions are selected through a *fitness-based* process, where fitter solutions are typically more likely to be selected. Certain selection methods rate the fitness of each solution and preferentially select the best solutions. Other methods rate only a random sample of the population, as this process may be very time-consuming.

1. Randomly based on these probabilities and produce offspring
2. Directly proportionate to their fitness.
- 3.

CROSSOVER: The most common type is single point crossover. In single point crossover, you choose a locus at which you swap the remaining alleles from one parent to the other. This is complex and is best understood visually. As you can see, the children take one section of the chromosome from each parent. The point at which the chromosome is broken depends on the randomly selected crossover point. This particular method is called single point crossover because only one crossover point exists. Sometimes only child 1 or child 2 is created, but oftentimes both offspring are created and put into the new population. Crossover does not always occur, however. Sometimes, based on a set probability, no crossover occurs and the parents are copied directly to the new population. The probability of crossover occurring is usually 60% to 70%.

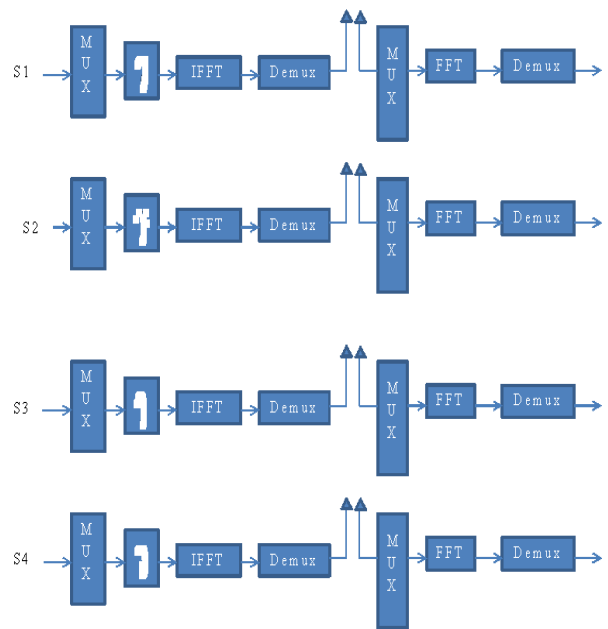


Fig: 2.1 Beamforming in OFDM using GA and IPSLP

MUTATION: New population full of individuals, Some are directly copied and others are produced by crossover. In order to ensure that the individuals are not all exactly the same, you allow for a small chance of mutation. You loop through all the alleles of all the individuals, and if that allele is selected for mutation, you can either change it by a small amount or replace it with a new value. The probability of mutation is

usually between 1 and 2 tenths of a percent. Mutation is fairly simple. You just change the selected alleles based on what you feel is necessary and move on. Mutation is, however, vital to ensuring genetic diversity within the population.

Termination: This generational process is repeated until a termination condition has been reached. Common terminating conditions are: A solution is found that satisfies minimum criteria, Fixed number of generations reached, Allocated budget (computation time/money) reached, The highest ranking solution's fitness is reaching or has reached a plateau such that successive iterations no longer produce better results, Manual inspection.

Optimization problem is denoted P for the first receiver, Multipath diversity can be also added. Following the design procedure in this section and deploying Φ , then with the subcarrier index is:

$$u^{H1}(p)y^1(p) = u^{H1}(p)H_{1,1}(p)v^1(p)s^1(p) + \dots + u^{H1}(p)n^1(p) \dots \dots \dots (2.3)$$

The $u^{H1}(p) y_1(p)$'s stacked for all P subcarriers and then this received OFDM frame is decoded by SD. Hence, instead of decoding $s_1(p)$ subcarrier-wise (if $\Phi = I_{P \times P}$), using the LCP matrix makes it possible to decode the data frame-wise while getting multipath diversity.

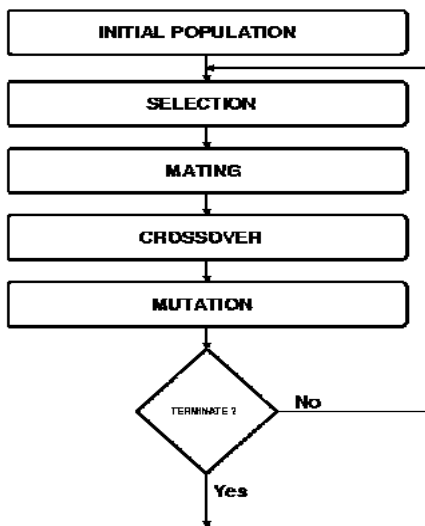


Fig: Genetic Algorithm

III. PROPOSED BEAMFORMING WITH IPSLP

Interior point methods (barrier methods) are a certain class of algorithms that solves linear and nonlinear convex optimization problems. All forms of the simplex method reach the optimum by traversing a series of basic solutions. IPSLP also has both exploration and exploitation but better exploitation when compared to exporation. Because of this we get Since each basic solution represents an extreme point of the feasible region, the track followed by the algorithm moves around the boundary of the feasible region. In the worst case, it may be necessary to examine most if not all of the extreme points.

The running time of an algorithm as a function of the problem size is known as its computational complexity. In practice, the simplex methods work surprisingly well, exhibiting linear complexity. Researchers, however, have

long tried to develop solution algorithms whose worst-case running times are polynomial functions of the problem size. The first success was attributed to the Russian mathematician who proposed the ellipsoid method which has a running time. Though theoretically efficient, code developers were never able to realize an implementation that matched the performance of concurrent simplex codes. This idea was to approach the optimal solution from the strict interior of the feasible region. This led to a series of interior point methods (IPMs) that combined the advantages of the simplex algorithm with the geometry of the ellipsoid algorithm. IPMs are of interest from a theoretical point of view because they have polynomial complexity, and from a practical point of view because they have produced solutions to many industrial problems that were hitherto intractable. There are at least three major types of IPMs:

- (1) the potential reduction algorithm which most closely embodies the construct
- (2) the affine scaling algorithm which is perhaps the simplest to implement, and
- (3) path following algorithms which arguably combine excellent behavior in theory and practice.

Highlight a category as the primal-dual path following algorithm which has become the method of choice in large scale implementations. The primal-dual path following algorithm is an example of an IPM that operates simultaneously on the primal and dual linear programming problems.

Basic Ideas:

1. The application of the Lagrange multiplier method of classical calculus to transform equality constrained optimization problem into an unconstrained one;
2. The transformation of an inequality constrained optimization problem into a sequence of unconstrained problems by incorporating the constraints in a logarithmic barrier function that imposes a growing penalty as the boundary ($x_j = 0, z_j = 0$ for all j) is approached;
3. The solution of a set of nonlinear equations using Newton's method, thereby arriving at a solution to the unconstrained optimization problem.

A linear program is a constrained optimization problem in which the objective function and each of the constraints are linear. A solution to the linear programming problem is a vector $x^* \in \mathbb{R}^n$ such that $c^T x^*$ is minimized and the constraints $Ax^* = b, x^* \geq 0$ are each satisfied.

Symbol	Name	Value
P	Number of subcarriers	16
K	Number of Users	4
N_r	Receiving antenna	4
N_t	Transmitting antenna	4
L	Channel Length	8
J	Rotation matrix	8

Table 3.1 Initial System Parameters

IV. CONCLUSION

In this Paper, faster beamforming and improved error performance has been obtained for a MIMO-OFDM interference channel. With a unit norm to transmit and receive beam formers, the algorithms comprise iterative procedures with closed-form steps allowed a faster solution. It is known that to optimize the solution using Genetic algorithm and IPSLP were used which improved the performance. The results of this project have viewed as some quantification of the trade-offs of between algorithmic simplicity for each stage in beamforming for the MIMO-OFDM interference channel.

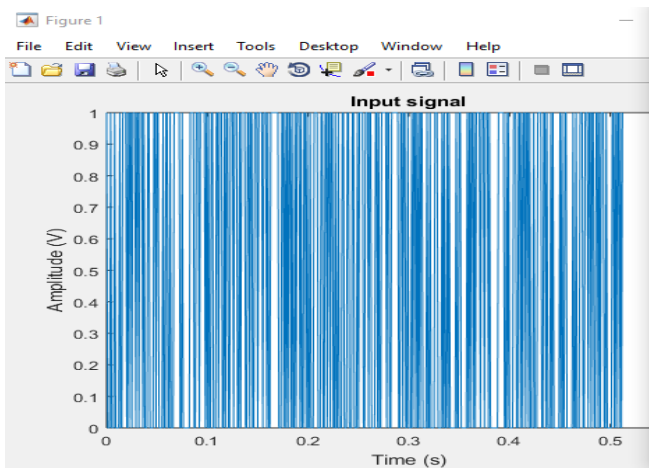


Fig. 4.1. Input signal

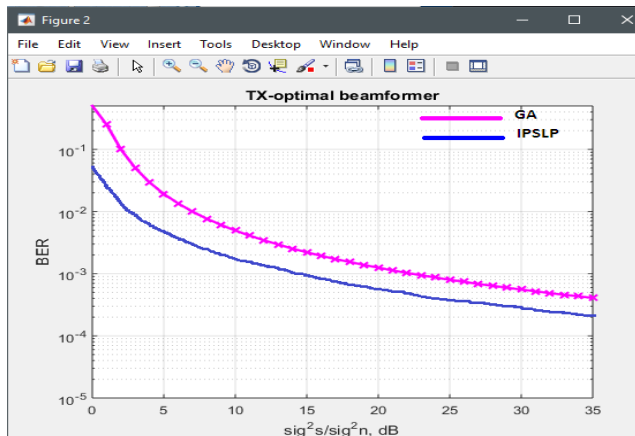


Fig. 4.2. TX-optimal beamformer

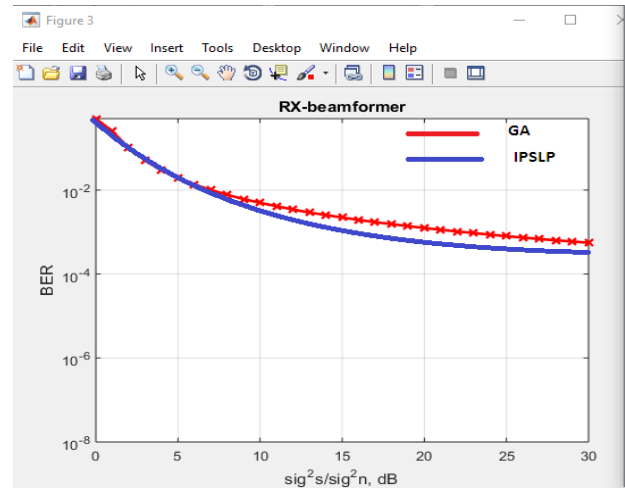


Fig. 4.2. Rx-optimal beamformer

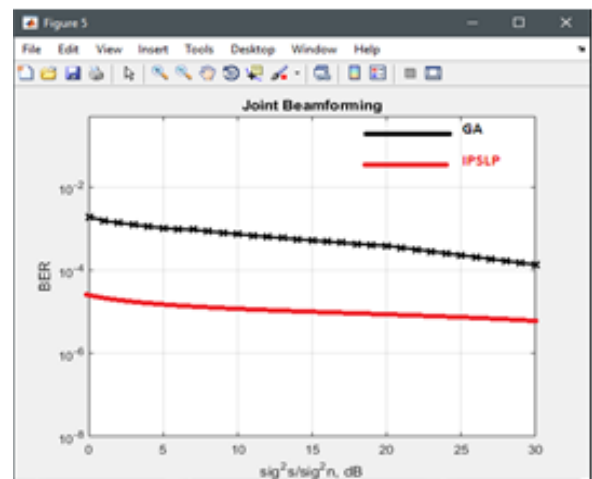


Fig. 4.2. joint-optimal beamformer

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