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GA Based Adaptive Beamforming in High-Interference Environments for XG Networks

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ABSTRACT

Beam forming is a technique used for simultaneously to direct the radiation pattern of an array antenna by adding constructively the weights of the signal in the signal of interest (SOI) path and nulling the pattern in the direction of interference. It is used in massive MIMO–OFDM systems and produces the radiation pattern (beams) from transmitting antenna to the specific receiver. Adaptive Beamforming and Beam Steering are used to achieve the task efficiently. Thus Manuscript proposes a scheme produce the good Quality of Services (QoS) such as Signal to Interference Noise Ratio (SINR), Bit Error Rate (BER), less power consumption using Genetic Algorithm (GA) in Massive MIMO-OFDM systems.GA is meta-heuristic computational method, it reflects the process of natural selection, where the fittest individuals are selected for reproduction in order to produce offspring of the next generation.

Keywords: *Beamforming, Signal of Interest (SOI), Multiple Input Multiple Output (MIMO), Orthogonal Frequency Division Multiplexing (OFDM), Genetic Algorithm.*

1. Introduction

Beamforming and Beam steering can be done in the MIMO-OFDM systems.

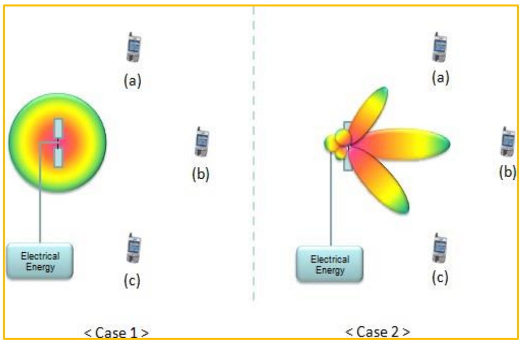

Figure 1.1: (a) Beamforming (b) Adaptive Beamforming

The antenna system is radiating the energy in almost same amount in all directions Fig 1.1 (a) shared by the three users. The radiation pattern (beam) is specially formed Fig 1.1 (b) and directed in a specific direction to the user. Beamsteering is steering the main beam in particular direction. In other words, changing the direction of main lobe of a radiation pattern as in Fig 1.2

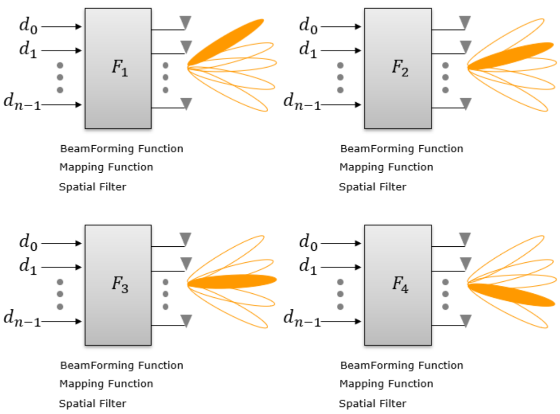

Figure 1.2: Beam steering

MIMO-OFDM is the foundation for most advanced wireless LAN and mobile broadband network standards, because it achieves the greater spectral efficiency and delivers highest capacity and data throughput.

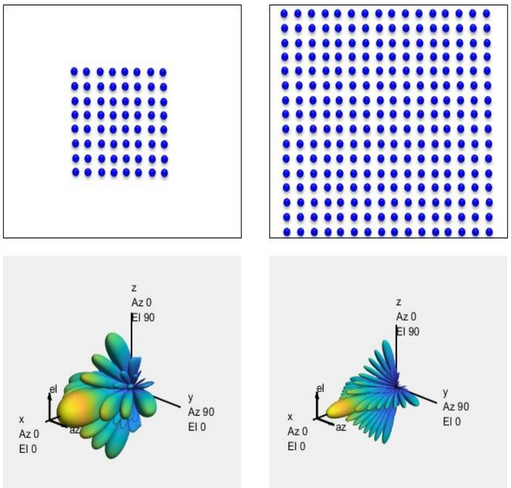

Figure 1.3: (a) Antenna Arrays (8x8, 16x16), (b) Constellation (8x8, 16x16)

MIMO indicates more than just the presence of multiple transmit antennas. OFDM enables reliable broadband communication by distributing user data across a number closely spaced narrowband sub channels. Inter Symbol Interference (ISI) occurs when the overlap between consecutive symbol is large compared to the symbol's duration.

2. Literature Survey

The process of initial Beamforming performance with finite no. of antennas/receiver and users based on Genetic Algorithm [5]. It develops a GA base beam selection and attain the throughput effectively in few iterations and it is suitable for Delay Constrained Networks. Also evaluates the end to end throughput and service outage constraint performance using different parameters. The algorithm comprises the data (bits) based on the antenna array grouping elements, polarization and encoding scheme [12]. GA processing in combination of elevation, azimuth, polarization, time domains and transmitter parameters. GA process employs unique selection mechanism, whereas calibrated systems that process receiver Beamforming information and exploits additional array calibration information and a transmitter system optimizes the worst case SINR in a group of all receivers. The static uncorrelated and correlated sources Beamforming for moving targets on CDMA systems by considering spreading code in Signal of Interest (SOI) direction based on GA [6]. At static uncorrelated sources LMS algorithm, reached zero error rate at SINR as -9dB. It shows unstable performances in Same LMS for completely correlated sources. The performance of GA-ABF technique analyzing in-terms of different interference power, direction of arrival and channel noise [14]. It performs in both stationary and dynamic interference scenarios. Also, it is observed that total time that GA user per iteration is proportional to the total generation and size of evolutions.

3. Beamforming System Model

Figure 3.1 shows that the Beamforming blocks in transmitter portion. To consider an OFDM based massive MIMO Hybrid Beamforming, the Base Station (BS) is equipped with NRF RF chains and M antennas where NRF ≤ M. For

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OFDM, K subcarriers are used for data transmission where U single-antenna users are simultaneously served on the entire band.

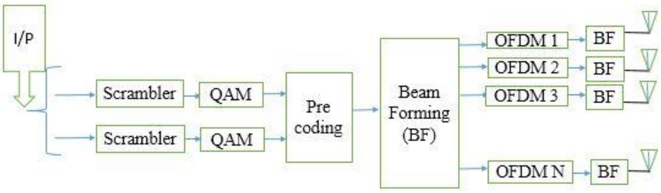

Figure 3.1: Block Diagram

At the BS, the signals at different subcarriers are first digitally precoded respectively and then transformed to the time domain by using K-point Inverse Fast Fourier transforms (IFFTs). After that, the transformed signals are finally processed by an analog precoding matrix before transmission through the antenna array. Since the analog precoder is operated on signals after IFFT, it is the same for all subcarriers, which indicates that it is flat in the frequency domain. This is the key challenge in designing the hybrid precoding over frequency selective wideband channels. Assuming a block-fading channel model, the signal received at subcarrier k can be written by,

$\mathbf{y}[k]=\mathbf{H}[k]^H\mathbf{FW}[k]\mathbf{s}[k]+\mathbf{n}[k]$ ------------(1)

Normally high data rate requires shorter duration symbols, increasing the risk of ISI by dividing the high-rate data stream into numerous low-rate data. Where $s[k] \in C^{U}\times 1$ denotes the vector of transmitted data symbols at subcarrier k with,

$E\{s[k]sH[k]\} = I$ ------------------------ (2)

$W[k] = [w1[k],w2[k],...,wu[k]] \in C^{NRF\times U}$ refers to the digital precoder at subcarrier k.

$F = [f1, f2..., fNRF] \in C^{M\times NRF}$ stands for the analog precoder.

$H[k] = [h1[k],h2[k],...,hU[k]] \in C^{M\times U}$ ——(3)

$n[k]\sim C\mathcal{N}(0,\sigma^2 I)$ refers to the additive white Gaussian noise at subcarrier k in which σ^2 is the noise power. It is notable that the analog part of the Hybrid Beamformer is typically implemented using simple analog components such as analog phase shifters which can only modify the angles of signals. Thus, every entry in F has the same constant amplitude. In this work, the fully-connected structure for Hybrid precoding is considered in which each RF chain drives all antennas. Each RF chain and each antenna is connected through only one phase shifter. Therefore, the i-th element of fn is normalized as

$|f_{ni}| = \frac{1}{\sqrt{m}}$ -------------- (4)

From (1) the received signal of the u-th user at subcarrier k is,

$\mathbf{y_u}[k]=\mathbf{h_u}[k]^H\mathbf{FW}[k]\mathbf{s}[k]+\mathbf{n_u}[k]$

$\mathbf{y_u}[k]=\mathbf{h_u}[k]^H\mathbf{F}\mathbf{w_u}[k]\mathbf{s_u}[k] + \mathbf{h_u}[k]^H\mathbf{F}\{\mathbf{w_i}[k]\mathbf{s_i}[k]\}$-------- (5)

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Where $\mathbf{y}_u[k]$, $\mathbf{s}_u[k]$ and $\mathbf{n}_u[k]$ respectively denote the u-th element of $\mathbf{y}[k]$, $\mathbf{s}[k]$ and $\mathbf{n}[k]$.

4. GA based Adaptive Beamforming

It is meta-heuristic computational method inspired by biological evaluation that aims to imitate the way of biological organisms which adopt their natural evolution in order to optimize the different aspect of Wireless Sensor Networks (WSNs).

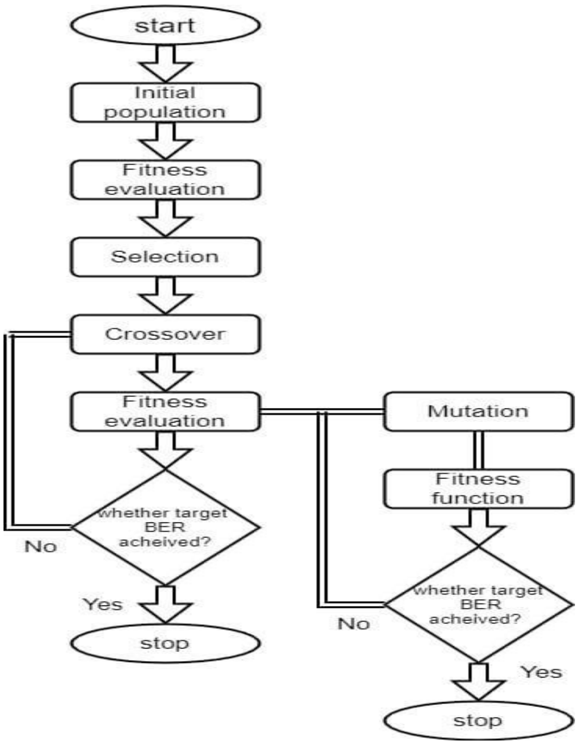

Figure 4.1: Adaptive Beamforming work flow

4.1 Population

GA operated by initially defining a population (collection of parameters) of individual parameters. These are encoded in abstract form also known as parameter combinations. The following parameters are transmitter power, transmitter gain, steering angle, No of antennas are taken as parameter combination.

Population= {Tx. power, Tx. gain, Steering angle, No. of antennas}

4.2 Fitness Function

It evaluates the individual parameters and, in a way, that the selective individual parameters as variable input parameters. Fitness score to each individual in terms of objectives. Here multi objective fitness function is used for attain low BER, less transmit power and high SINR. In fitness evaluation N worst solutions are deleted and N new solutions are followed. Also, that each solution thus needs to be awarded a figure of merit which indicates its level to reach objective by applying Fitness Function to the simulation or test results obtained from that solution.

Fitness Function denoted as,

f(tx. power, tx. gain, steering angle, no. of elements)=BER(minimum)

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4.3 Mutation

Mutation is use for randomly altering the values in the parameters and discover the new traits and horizons. Mutation helps to avoid the local optima, pave way to global optima and diversifying the population.

4.4 Crossover

The crossover process is to identify the best traits of current solution and mix them in order to improve this fitness. It randomly chooses a locus and exchanges the sub-sequences between parent parameters also creates a offspring pair. In GA crossover is referred as synthesis of best practices and mutation is referred as spontaneous inspiration and creativity.

4.5 Selection

In selection process, individual parameter values (Defining a particular feature of simulated result) are chosen from population for recombination or crossover. The filter parameter function to be passed on to the next generation. The selection procedure is repeated K iterations, where K is the generation of Fitness Function in order to find the best parameter combination as to meet the required Fitness Function. During each iteration to determine the best solution based on that objective. The optimal solution of the function is attained in the K^{th} iteration.

4.6. Pseudo code

```
t=0;
initialize (p(t=0));
evaluate (p(t=0));
while is not terminated () do
 p(t)=p(t).select parent parameter   combination();
p(t)=reproduction (P);
 mutate (p(t));
 evaluate (p(t));
 (p(t+1)) = BuildNextGenerationFrom(p(t),  p(t)) t=t+1
 end
```

5. Simulation Results

The numerical simulation results of GA based Adaptive Beamforming and performances were evaluated. Some parameters are non-tunable such as Interference Power, Interference gain, Interference angle, Receiver Power and Receiver gain whereas Transmitter power, Transmitter gain, Steering Angle are tunable (Table 5.1). These parameters are taken for fitness function by evaluating fitness combinations. Functions are simulated through MAT Lab R2018a.

5.1 Simulation Parameters

The transmitter parameters are taken for Fitness function in Genetic Algorithm.

Tunable parameters {transmitter power, transmitter gain, steering angle}

Transmitter parameters	**Values**
Transmitter power	1 to 10Watts
Transmitter gain	-10 dB to -1 dB
Steering angle	0 to 180 degrees

Table 5.1 Fitness Functions

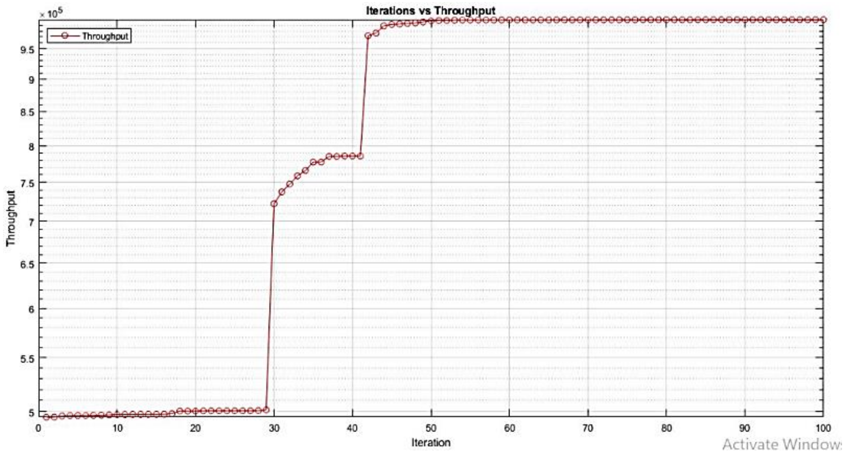

Figure 5.1 Iteration vs Throughput

Iterations (Generations) with respect to Throughput Figure 5.1 shows the better throughput performances as iterations increased as same as BER with respect to the generation in Figure 5.2 results as per the increasing iterations minimizes the Bit Error Rate.

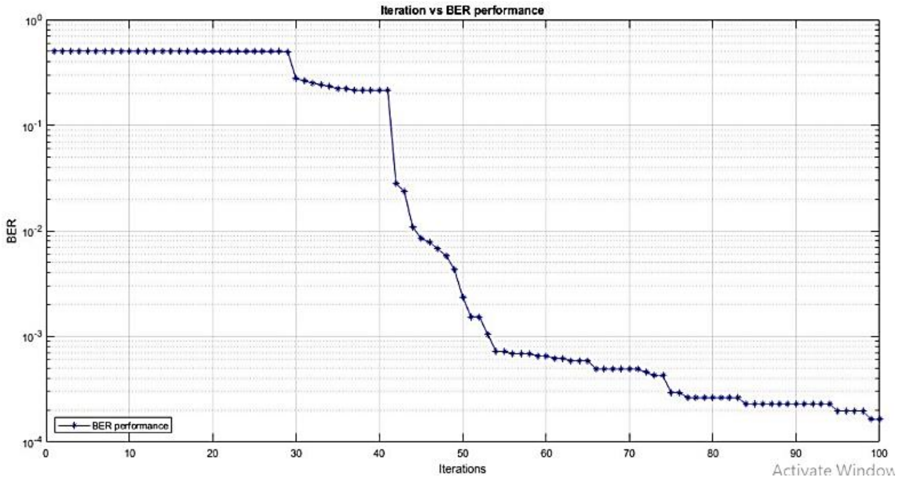

Figure 5.2 Iteration vs BER

6. Conclusion

A novel GA based Adaptive Beamformer with MIMO- OFDM systems has been developed, can be used for minimizes the BER whereas increases the throughput performances. The Genetic Algorithm is used for control the adaptive array of beams. Simulation results verified that the algorithm achieved better performances with less BER and high throughput.

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