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Enhancement in Gain and Interference of Smart Antennas Using Two Stage Genetic Algorithm by Implementing it on Beam Forming

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Abstract: In smart antenna systems, one of the most important processes is beam forming. The most important function in beam forming is changing beam pattern of antenna for a particular angle. If the antenna does not change the position for the specified angle, the signal losses will be high. For avoiding this, here we propose a new method using genetic algorithm for beam forming in smart antenna. In our method, if we give an angle as input, it will give the maximum signal gain in the beam pattern of the antenna with corresponding position and phase angle. The factors that are considered in our method are length of the beam, interference, phase angle and number of patterns. By using this method, the gain of the system gets increased and the interference will be reduced. The implementation result shows that the system achieves a good performance.

Keywords: Smart antenna, Beam forming, Genetic algorithm, Phase angle, Main beam

1. INTRODUCTION

Smart antenna system is an array of antenna elements connected to a digital signal processor where spatial filtering takes place [8]. Smart antenna technology increases the directivity of the antenna beam so as to enhance the signal at the intended receiver without causing interference to Other radio users, or using multiple receive/transmit antenna channels simultaneously in order to increase reliability and hence data capacity of the link. [2]. Smart antennas or adaptive antennas have to fulfill two additional functions in addition to their main purpose of effectively transmitting and receiving radio signals; they are direction of arrival estimation and beam steering [10].

A smart antenna is an antenna array system aided by some smart algorithm designed to adapt to different signal environments [12]. The gain of a smart antenna is typically higher than that of an Omni-directional antenna. Correspondingly smart can have higher reach ability or in other words, a larger directional range as compared to an omni-directional antenna [3]. Direction of arrival and Adaptive Beam forming are two important functions of Smart antennas [6] [7]. Adaptive beam forming system systems are those that employ adaptive array processing which is the process of creation of nulls in the direction of interference and strong beams in the direction of preferred user [13]. An adjustable weighting set is used by adaptive antennas to form the main beam towards the desired user and the null beam towards the undesired interferences [14]. Target surveillance and modern communication systems need Directional-of-arrival (DOA) estimators [15].

Beam forming is the term used to describe the application of weights to the inputs of an array of antennas to focus the reception of the antenna array in a certain direction, called the look direction or the main lobe [5]. Beam forming refers to the technique that aims at improving captured sound quality by exploiting the diversity in the received signals of the microphone array depending on the location of the source and the interference [9].

Ultrasound beam forming system has moved from the analog era to the digital era due to the progression of digital circuit design. The computational flexibility of digital system allows the dynamic receive focusing to be performed in order to achieve better image quality [11]. Beam forming presents several advantages to antenna design .Firstly, space division multiple access (SDMA) is achieved since a beam former can steer its look direction towards a certain signal. Other signals from different directions can reuse the same carrier frequency [10]. Smart antennas are used in Performance Analysis of MUSIC and LMS [1], Mobile and Base Stations in an OFDM/TDMA System [4].

In smart antenna one of the most important processes is beam forming. Beam forming is the allocation of signal in the particular position and phase angle for each antenna for the corresponding angle of the system. While reviewing the recent works, it is evident that all factors are not considered by them in beam forming. By overcoming this draw back, here we proposed a new technique using genetic algorithm that considers all essential factors while allocating signal in the particular position and angle with maximum signal gain.

2. GENETIC ALGORITHM STAGE-1

Genetic algorithm (GA) is a genetic concept based optimization method. Here we use genetic algorithm to generate set of chromosomes for different angles. The main process is to compute the phase angle and position of each antenna for getting maximum signal gain for a given angle. Maximum signal efficiency can be obtained by reducing the signal interfacing and allocating the exact phase angle to all the antennas. Figure 2 shows the flow chart which indicates the process that takes place for identifying the direction and phase angle of each array using genetic algorithm. The GA-based proposed methodology is comprised of six major stages (1) Generation of initial chromosomes, (2) Fitness evaluation, (3) Crossover, (4) Mutation, 5) Selection of best chromosomes, and (6) Termination.

2.1. Generation of Initial Chromosome

Let us consider that the length of the beam is*D*, number of beam pattern is*M*, total angle to receive & transmit the signal is θ, the position is *xp* and the phase angle is φp. A population pool of size *Np* is generated, where *Np* is the number of arbitrary chromosomes, *Xp* = {*Dp*, θp, *Mp*}, where, *Dp*, θp, *Mp* are the input genes of the chromosome and *Yp* = {*xp*,θp}, where, *xp* , φp are the output genes of the chromosome, *p* is the number of genes in the chromosome. After generating the chromosome, the fitness function is calculated.

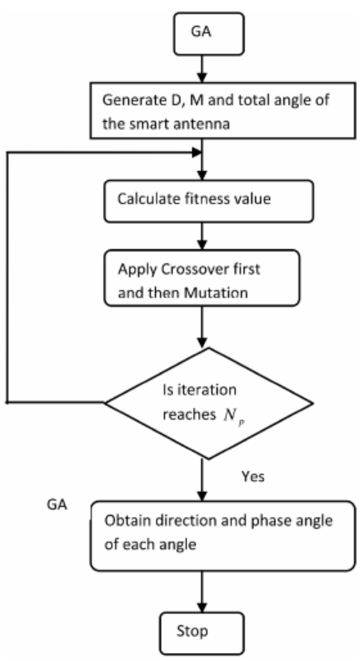

Figure 1: GA Stage 1 to Generate Set of Chromosomes for Different Angles Values

2.2. Fitness Function

The fitness of each generated chromosome is evaluated by a fitness function which is developed for that particular problem. The fitness value is calculated for each chromosome using the equation given below.

$$\text{Fitness function}, F(i) = \frac{1}{b_1.T_{tp}(i)} + \frac{1}{b_2.T_{mb}(i)} + \frac{1}{b_3.T_{sl}(i)} + \frac{1}{b_4.T_{nl}(i)} + \frac{1}{b_5.T_n(i)} \quad (1)$$

where, b_1, b_2, b_3, b_4, b_5 are the coefficients of the corresponding values, T_{tp} is the total array pattern, T_{mb} is the main beam, T_{sl} is the side lobe level, T_{nl} is the number, location and width of nulls, T_n is the number of array.

For the above fitness function,T_{tp}, T_m, T_{sl}, T_{nl}, T_n are calculated using the equations given below.

$$\text{Total array pattern, } T_{tp}(i) = \int_{r \in B} \left(\frac{S(r)}{Q} - S^{ref}(r).dr\right) \quad (2)$$

$$\text{Main beam, } T_{mb}(i) = \int_{r \in mb} \left[\frac{S(r)}{Q} - S^{ref}(r)\right].dr \quad (3)$$

$$\text{Side lobe level, } T_{sl} = \frac{Q}{\max\{S(r)\}} \quad (4)$$

Number, location and width of null,

$$T_{nl}(i) = \int_{r \in bn} \left[\frac{S(r)}{Q} - S^{ref}(r)\right].dr \quad (5)$$

$$\text{Number of array, } T_n\, M \quad (6)$$

$$\text{Beam pattern function, } S(r) = \sum_{n-0}^{1} e^{j(k.y_n.\sin\theta + \phi_n)} \quad (7)$$

Target beam,

$$S^{ref}(r) = 2.79.\cos r + 2.49.\cos 3r - 0.79.\cos 5r + 1.35.\cos 7r + \cos 9r \quad (8)$$

$$r = \sin\theta - \sin\theta_0 \quad (9)$$

$$bn_k = r_{nl_k} \pm \Delta r_{nl\,k} \quad (10)$$

Where, $S(r)$is the beam pattern function, $S^{ref}(r)$ is the target beam, θ is the incident angle and θ_0 is the steering angle of the array. By using the above equations the fitness value is calculated. After calculating the fitness $N_p/2$ best chromosome are selected based on the fitness value. After that, crossover is performed on the selected best chromosomes.

2.3. Crossover

Crossover is a genetic operator which mates two chromosomes so as to produce an offspring. In our method, crossover is done for the above selected best chromosome at a crossover C_r rate to obtain new child chromosome, N_{child} for every parent chromosome. A new set of genes are generated after applying crossover operation and after getting the set of new genes mutation operation is performed on the newly generated genes.

2.4. Mutation

The mutation operator is responsible for producing a new generation from the best initial chromosomes. The chromosomes are mutated by randomly selecting the genes at a mutation rate of M_p. A set of mutation points are generated and by using those mutation points a new set of chromosomes are generated from the above set of best chromosome. The next step after mutation is termination.

2.5. Termination

The chromosomes present in the population pool are evaluated by the fitness function as already performed and the same process is repeated iteratively. The process is repeated until it reaches a maximum number of iteration N_p. After that, a final best chromosome is obtained from the population pool based on its fitness value. The final best chromosome indicates the phase angle and position value for different angle, number of beam pattern and array length. In this stage we obtained a set of chromosomes for different angle and in the next stage using this set of chromosome as the initial chromosome corresponding position and phase angle are calculated with maximum gain and reducing interference.

3. GENETIC ALGORITHM STAGE-2

In this stage if we give the angle as an input to the genetic algorithm, it gives direction and phase angle as output. Here we didn't generate the initial chromosome. The values are taken from the best chromosome we obtained from the above stage corresponding to this array length and total angle. After taking the set of chromosomes corresponding to the given input, the fitness function is calculated. The output obtained after calculating the fitness function will be $\{x_p, \phi_p\}$, where, x_p, ϕ_p are the position and phase value of the antenna.

3.1. Fitness Function

The fitness function is calculated using the equation given below.

Fitness function,

$$F(i) = b_1.T_{tp}(i) + b_2.T_{mb}(i) + \frac{1}{b_3.T_{sl}(i)} + \frac{1}{b_4.T_{nl}(i)} + \frac{1}{b_5.T_n(i)} \qquad (11)$$

$$\text{Main beam, } T_{mb}(i) = \sum_{j=1}^{mb} \left\{ \int_{r \in mb} \left[\frac{S(r)}{Q} - S^{ref}(r) \right] .dr \right\} \qquad (12)$$

Number, location and width of null,

$$T_{nl}(i) = \sum_{j=1}^{nl} \left\{ \int_{r \in bn} \left[\frac{S(r)}{Q} - S^{ref}(r) \right] .dr \right\} \qquad (13)$$

T_{tp}, T_{sl}, T_n are calculated using the equations 2, 4 & 6 respectively.

After calculating the fitness function, the next step is crossover operation. The crossover operation applied here is explained in the section 3.1.3. After applying crossover we get a new set of child chromosome from the parent chromosome. Then next step after this is applying mutation function to the new child chromosome generated after crossover. The mutation process is done as explained in the section 3.1.4. After mutation we get a new set of chromosomes. The next step after applying mutation process is termination. In the termination process, the new set of chromosomes generated after mutation process is evaluated using fitness function. After evaluating using fitness function the chromosome that obtained the best fitness is considered as the best chromosome. The efficiency of the smart antenna can be increased if position and phase angle are set according to values obtained from the above process.

4. RESULTS AND DISCUSSIONS

The proposed technique was implemented in Mat lab 7.11. In the proposed method if we give the angle as input to the system it gives the corresponding beam as output. Here, first we give one angle as input to the system and the corresponding beam obtained is analyzed and for that beam the interference ratio and gain are calculated. The results are finally compared with that of the PSO technique. Then the number of angles is increased and again the same process is repeated. The process performed is illustrated briefly in the following sections.

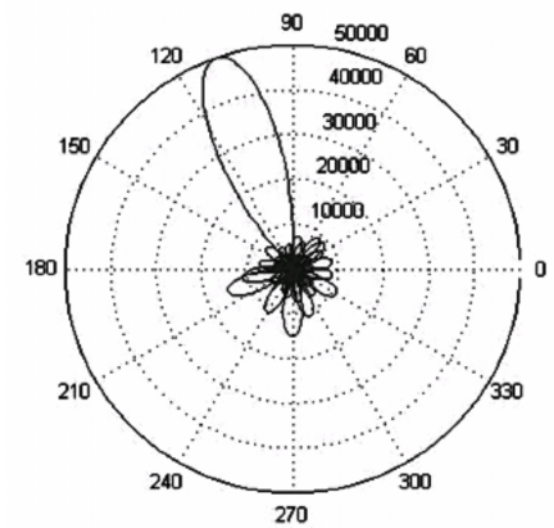

Figure 2: Beam Forming Angle at 110 Degree

Here, the input angle given is 110 degree, and from the above figure it is clear that the main beam is focused towards 110 degree, and except the main beam, all other beams existing are only side lobes. The main beam will focus towards the direction indicated by the angle that is given as input. The best chromosome obtained after applying the two stages of genetic algorithm is as follows.

Beam length (m)	9				
Number of beam patterns	5				
Phase angle (radian)	1.5843	6.7755	8.8205	0.90246	0.51998
Position (m)	1.6609	1.3756	4.1	0.10689	0.72943

Table 1
Gain, Signal to Interference Ratio and Peak Signal to Interference Ratio

Angle	*Gain db*	*Signal to Interference ratio*	*Peak Signal to interference ratio*
0	90.0028	0.89681	36.9619
110	90.0028	0.89753	37.4389
0, 90	96.0234	0.94656	36.8182
100, 200	96.0234	0.95329	36.082
0, 70, 250	99.5452	0.9876	36.002
70, 210, 300	99.5452	0.99183	36.6475

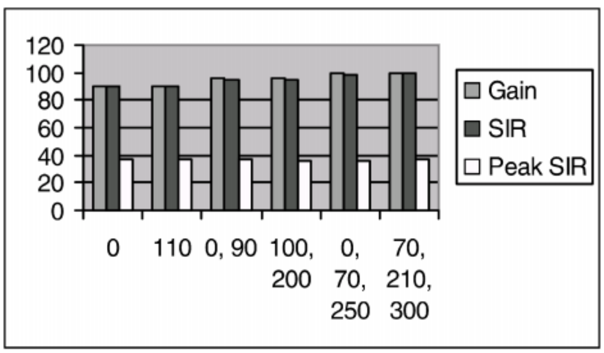

Figure 3: Gain, SIR and Peak SIR Graph

Figure 3 shows the graph for gain, signal to interference ratio and peak signal to interference ratio for the corresponding angles which are shown in the above table. In the above graph the each signal to interference ratio values shown in the Table 1 are multiplied by 100.

Our proposed method is then compared with PSO method. We compared our proposed method with PSO method [23]. In that PSO method, 110 degree angle is used. Here we compared the peak signal to noise ratio of PSO method with our proposed method.

Table 2
Comparative Analysis

	Peak Signal to interference ratio
Proposed method	37.44
PSO method	33.11

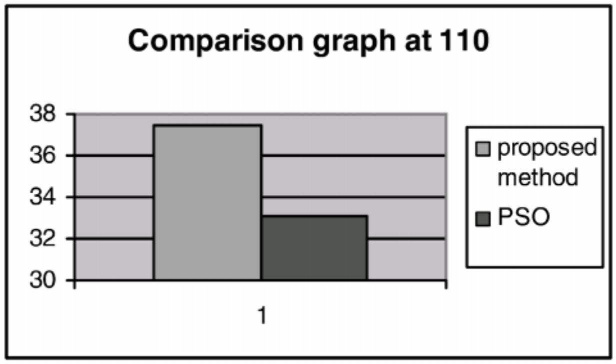

Figure 4: Comparison Graph at 110 Degree

From the above table it is clear that the peak signal to interference ratio in our proposed method is high, when compared with PSO method. From the results it is clear that, our proposed method is better than the PSO method.

5. CONCLUSION

In this paper genetic algorithm is used to locate the beam pattern with maximum signal gain for given angle in smart antennas. In the proposed technique genetic algorithm is used in two stages. In the first stage it is used to generate a set of chromosomes with angle, beam length and number of array pattern as input and phase angle and position. In the second stage, for a given angle corresponding position and phase angle is calculated by considering maximum gain and minimum interference. The proposed method is simulated in Mat lab 7.11 and tested by giving different angles as input to the system. Signal gain and interference ratio are calculated for each angles and our proposed method is compared with PSO method. From the comparison results it is clear that our proposed method gives better gain and low interference than the PSO method.

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