Optimization of linear antenna array using genetic algorithm for reduction in side lobe levels and to improve directivity

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Abstract- Radiation pattern of antenna array is most important problem in communication applications. This paper describes the synthesis method of linear antenna array radiation pattern in adaptive beam forming using genetic algorithm. Unlike Simple GA (SGA), the Genetic algorithm solver from the optimization toolbox of MATLAB is used with adaptive feasible mutation, which enables search in broader space along randomly generated directions to produce new generations. This improves the performance greatly to achieve the maximum reduction in side lobe level with minimum function calls and provide the maximum directivity towards the direction. This technique proved its effectiveness in improving the performance of the antenna array.

Keywords – Adaptive beam forming, Side lobe level, Directivity, Genetic algorithm, linear antenna array, Pattern synthesis, Array Factor.

I. INTRODUCTION

In many communication applications, it is required to design a highly directional antenna. Array antennas have high gain and directivity compared to an individual radiating element [1]. Antenna array is formed by assembling of radiating elements in an electrical or geometrical configuration. Total field of the antenna array is found by vector addition of the fields radiated by each individual element [2] Adaptive beamforming is a signal processing technique in which the electronically steerable antenna arrays are used to obtain maximum directivity towards signal of interest (SOI) and null formation towards signal of not interest (SNOI) i.e. instead of a single antenna the antenna array can provide improved performance virtually in wireless communication. Sidelobe reduction in the radiation pattern [3][4][5] should be performed to avoid degradation of total power efficiency and the interference suppression [6][7] must be done to improve the Signal to noise plus interference ratio (SINR). Sidelobe reduction and interference suppression can be obtained using the following techniques: 1) amplitude only control 2) phase only control 3) position only control and 4) complex weights (both amplitude and phase control). In this, complex weights technique is the most efficient technique because it has greater degrees of freedom for the solution space. On the other hand it is the most expensive to implement in practice.

Genetic algorithm (GA) is a powerful optimization method the synthesis of antenna array radiation pattern in adaptive beamforming. The problem is to finding the weights of the antenna array elements that are optimum to provide the radiation pattern with maximum reduction in the sidelobe level and provide the maximum directivity towards the direction. In this paper, it is assumed that the array is uniform, where all the antenna elements are identical and equally spaced. The design criterion here considered is to minimize the sidelobe level [8] at a fixed main beam width. Hence the synthesis problem is, finding the weights that are optimum to provide the radiation pattern with maximum reduction in the sidelobe level.

II. PROPOSED ALGORITHM

A. Genetic algorithm –

A genetic algorithm is a search technique used in computing to find exact or approximate solutions to optimization and search problems. This algorithm we use for finding the optimum value in our project. The genetic algorithm is a method for solving both constrained and unconstrained optimization problems that is based on natural selection, the process that drives biological evolution. The genetic algorithm repeatedly modifies a population of individual solutions. At each step, the genetic algorithm selects individuals at random from the current population to be parents and uses them produce the children for the next generation. Over successive generations, the Population "evolves" toward an optimal solution. You can apply the genetic algorithm to solve a variety of optimization problems that are not well suited for standard optimization algorithms, including problems in which the objective function is discontinuous, no differentiable, stochastic, or highly nonlinear. The genetic algorithm uses three main types of rules at each step to create the next generation from the current population.

The important steps for genetic algorithm:

1. Initial Population
2. Evolution of Fitness function
3. Selection
4. Crossover
5. Mutation.

i) Selection:

There are many different types of selection, some general methods used are Roulette Wheel Selection and Tournament Selection. The most common type - roulette wheel selection. In roulette wheel selection, individuals are given a probability of being selected that is directly proportionate to their fitness.

ii) Crossover:

This is an exchange of substrings denoting chromosomes, for an optimization problem. It may be a single point cross over, two points cross over, cut and splice, uniform crossover or half uniform crossover. The most common solution is something called crossover, and while there are many different kinds of crossover, the most common type is single point crossover.

iii) Mutation:

The modification of bit strings in a single individual. After selection and crossover, you now have a 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.

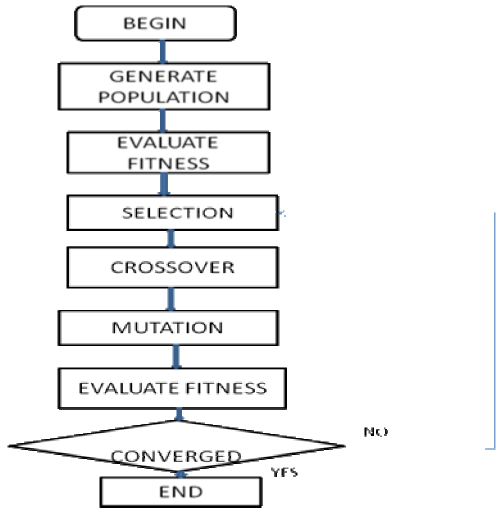

Fig 1: Flow diagram of genetic algorithm

B) *Uniform Linear Antenna Array:*

In linear antenna array, all the antenna elements a rearranged in a single line with equal spacing between them. In the antenna array synthesis and design it is often desired to achieve the minimum side lobe level (SLL) apart from the narrow beam and efficiency. In the process of formulation for the fitness function for minimizing the Side lobe level the antenna array [1][9][10], the array factor for N number of elements were considered and assumed that the elements of an array are spaced linearly and separated by λ/2 where λ is the wave length. The array factor for, N number of elements for the geometry shown in the Fig 2.

$$AF = \sum_{n=1}^{N} E_n = \sum_{n=1}^{N} e^{jk_n}$$

Where En = e^{jk_n} and K= (nkdcosθ + βn) is the phase difference. βn is the phase angle.

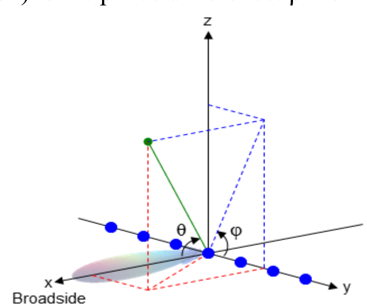

Fig 2 Linear Antenna Array

C) *Problem Formulation-*

Consider an array of antenna consisting of N number of elements. It is assumed that the antenna elements are symmetric about the center of the linear array. The far field array factor of this array with an even number of isotropic elements (2N) can be expressed as

$$AF(\theta) = 2\sum_{n=1}^{N} a_n \cos(\frac{2\pi}{\lambda d_n \sin\theta})$$

Where a_n amplitude of nth element, θ is the angle from broadside and d_n is the distance between position of nth element and array center .The main objective of this work is to find an appropriate set of required element amplitude and that achieves interference suppression with maximum sidelobe level reduction. To find a set of values which produces the array pattern, the algorithm is used to minimize the following cost function.

$$cf = \sum_{\theta=-90°}^{90°} W(\theta)\,[F_0(\theta) - F_d(\theta)]$$

Where $F_0(\theta)$ is the pattern obtained using our algorithm and $F_d(\theta)$ is the pattern desired. Here it is taken to be the Chebychev pattern with SLL -13db and $W(\theta)$is the weight vector to control the sidelobe level in the cost function.

To find a set of values which produces the array pattern, the algorithm is used to minimize the following cost function.

$$Fitness = F1 = 20 * \log 10(\frac{F}{max(F)})$$

F = abs (H)

Where H is normalized field strength.

The maximum directive gain is called as directivity of the antenna. The directivity of the antenna is defined as the ratio of maximum radiation intensity to its average radiation intensity and is denoted by D.

D= (max (F. ^2)/mean (F. ^2))*gain

III. EXPERIMENT AND RESULT

The antenna model consists of 20 elements and equally spaced with d =0.5λ along the y-axis. Only the voltage applied to the element is changed to find the optimum amplitude distribution, while the array geometry and elements remain constant. A continuous GA with a population size 20 and a adaptive feasible mutation rate is run for a total of 100 generations unlike 500 generations as in [11] using MATLAB and the best result was found for each iteration. The cost function is the minimum side lobe level for the antenna pattern and improving directivity. Fig 3 shows that the antenna array with N = 8 elements has been normalized for a gain of 2.84dB along the angle 0° and the maximum relative side lobe level of -18.19 dB and directivity 13.09.

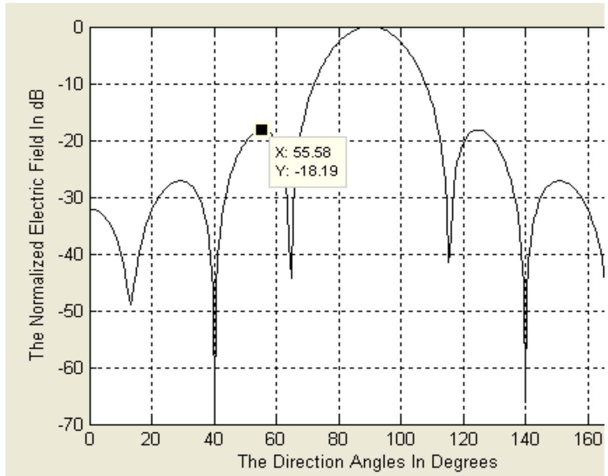

Fig. 3 Optimized radiation pattern with reduced side lobe level of -18.19 db
For N= 8 elements and directivity 13.09

Fig 4 shows that the antenna array with N = 16 elements has been normalized for a gain of 2.84dB along the angle 0° and the maximum relative side lobe level of -16.07 dB and directivity 16.26. Fig 5 shows that the antenna array with N = 20 elements has been normalized for a gain of 2.84dB along the angle 0° and the maximum relative side lobe level of -21.50 dB and directivity 16.96. Fig 6 shows that the antenna array with N = 24 elements has been normalized for a gain of 2.84dB along the angle 0° and the maximum relative side lobe level of -17.98 dB and directivity 17.98.

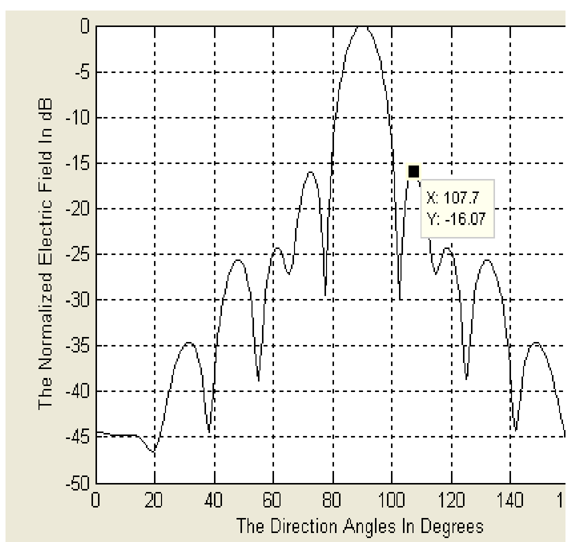

Fig. 4 Optimized radiation pattern with reduced side lobe level of -16.07 db
For N= 16 elements and directivity 16.26

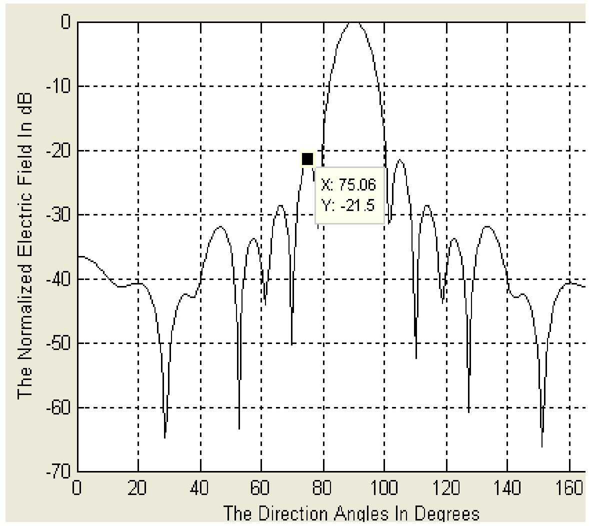

Fig. 5 Optimized radiation pattern with reduced side lobe level of -21.05 db
For N= 20 elements and directivity 16.96

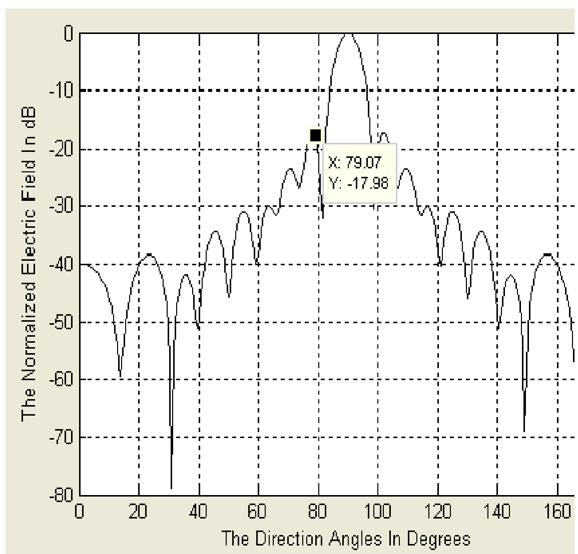

Fig. 6 Optimized radiation pattern with reduced side lobe level of -17.98 db
For N= 24 elements and directivity 17.98

Table 1- Table of obtained results

Number of elements	**Sidelobe in db**	**Directivity**
8	**-18.19**	**13.09**
16	**-16.07**	**16.26**
20	**-21.05**	**16.96**
24	**-17.98**	**17.98**

IV.CONCLUSION

In this paper Genetic algorithm Solver in Optimization toolbox of MATLAB is used to obtain maximum reduction in side lobe level relative to the main beam on both sides of 0° and improve the directivity. Genetic algorithm is an intellectual algorithm searches for the optimum element weight of the array antenna. This paper demonstrated the different ways to apply Genetic algorithm by varying values number of elements to optimize the array pattern. Adaptive feasible mutation with single point crossover showed the performance improvement by reducing the side lobe level below -10dB in most of the cases and also improves the directivity. The best result of -21.05 dB sidelobe is obtained for 20 elements in 50 generation of GA with best fitness value of 27.2451 and means fitness value of 27.3439 and improves the directivity 16.96 level. The best result of 17.98 directivity is obtained for 24 elements.

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