BROADSIDE LINEAR ANTENNA ARRAY SYNTHESIS USING GENETIC ALGORITHM

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Abstract- This paper is based on optimization of broadside linear antenna array. In this paper optimum value of weights of each antenna element is determined which produces radiation pattern with minimum side lobe level .In this work real coded Genetic algorithm is used. MATLAB is used as a platform. Adaptive feasible mutation rate is used 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.

Keywords- Side lobe level, Genetic algorithm, broadside linear antenna array, Array factor

I. INTRODUCTION

In many communication systems, point to point communication is used, for this highly directive beam of radiation is required. By arranging several dipoles in the form of an array or other antenna elements this can be achieved. Consider a linear array of n isotropic elements of equal amplitude and separated by distance d. The total field \( E \) at a far field point P in the given direction \( \phi \) is given by,

\[
E = 1 + e^{j\Psi} + e^{2j\Psi} + e^{3j\Psi} + \cdots \cdots + e^{(n-1)j\Psi} \cdots 1
\]

Where \( \Psi \) is the total phase difference of the fields from adjacent sources. It is given by;

\[
\Psi = 2\pi \left( \frac{d}{\lambda} \right) \cos \phi + \mu
\]

One method to achieve a highly directional beam is to use adaptive beamforming. Adaptive beam forming is an adaptive signal processing technique in which an array of antenna is exploited to achieve maximum reception in a look direction in which the signal of interest is present, while signal of same frequency from other directions which are not desired (signal of not interest) are rejected.

The characteristics of the antenna array can be controlled by the geometry of the element and array excitation. But side lobe reduction in the radiation pattern [28],[31] should be performed to avoid degradation of total power efficiency and the interference suppression [2],[9] must be done to improve the Signal to noise plus interference ratio (SINR). Side lobe 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).

The process of choosing the antenna parameters to obtain desired radiation characteristics, such as the specific position of the nulls, the desired sidelobe level [4] and beam width of antenna pattern is known as pattern synthesis. Analytical studies by Stone who proposed binominal distribution, Dolph the Dolph-Chebyshev amplitude distribution, Taylor, Elliot, Villeneuve Hansen and Woodyard, Bayliss laid the strong foundation on antenna array synthesis[20]-[24]. Today a lot of research on antenna array [2] – [12], is being carried out using various optimization techniques to solve electromagnetic problems due to their robustness and easy adaptivity. One among them is Genetic algorithm [13]. R.L.Haupt has done much research on electromagnetics and antenna arrays using Genetic Algorithm [13]-[22].

In this paper, it is assumed that the array is uniform, where all the antenna elements are identical and equally spaced. The design criterion considered here is to minimize the sidelobe level [7] 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. GENETIC ALGORITHM

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 to produce the children for the next generation. Over successive generations, the population "evolves" toward an optimal solution. GA’s can be used when objective function is discontinuous, non differentiable, stochastic, or highly nonlinear. The flowchart is shown in Figure 1.

In this paper, performance improvement is analyzed in order to obtain a desired pattern of linear antenna array using GA. Fixed mutation rate approach is used in classical GA. In this paper, adaptive feasible mutation rate is used, which shows improvement in performance throughout the evolution.

The genetic algorithm uses three main types of rules at each step to create the next generation from the current population:

- **Selection rules** select the individuals, called parents, that contribute to the population at the next generation.
- **Crossover rules** combine two parents to form children for the next generation.
- **Mutation rules** apply random changes to individual parents to form children.

Two more parameters are involved in GA i.e. population and number of generations.

They are defined as given below

- **Selection**
  Evaluation of the fitness criterion to choose which individuals from a population will go on to reproduce. Some general methods used are Roulette Wheel Selection and Tournament Selection

- **Crossover**
  This is an exchange of substrings denoting chromosomes, for an optimization problem. It may be a single point cross over, two point cross over.

- **Mutation**
  Mutation allows the population to change by introduction of random characteristics. Without mutation the population would quickly converge to a solution that may be or may not be correct. Mutation randomly chooses alleles to alter with a probability Pmut.

- **Population**
  The number of chromosomes considered in one generation

- **Number of generations**
  The maximum number of generations that the genetic algorithm can evolve into, before terminating.

![Fig.1 Flowchart of Genetic Algorithm](image-url)
III. UNIFORM LINEAR ANTENNA ARRAY

In linear antenna array, all the antenna elements are arranged in a single line with equal spacing between them. In Fig 2 it is shown that the antenna elements are arranged with uniformly spacing, in a straight line along the y-axis, and N is the total number of elements in the antenna array with the physical separation distance as d, and the wave number of the carrier signal is \( k = \frac{2\pi}{\lambda} \). When \( kd \) is equal to \( \pi \) (or \( d = \frac{\lambda}{2} \)) the phase shift between the elements experienced by the plane wave is \( kd \cos \theta \). Weights can be applied to the individual antenna signals before the array factor (AF) is formed to control the direction of the main beam. This correspond to a multiple-input-single-output (MISO) system. The total AF is just the sum of the individual signals, given by the

\[
AF = \sum_{n=1}^{N} E_n = \sum_{n=1}^{N} e^{jK_n} \]

Where \( E_n = e^{jK_n} \) and \( K_n = (nkd \cos \theta + \beta n) \) is the phase difference. \( \beta n \) is the phase angle. Only the magnitude of the AF in any direction is important, the absolute phase has no bearing on the transmitted or received signal. Therefore, only the relative phases of the individual antenna signals are important in calculating the AF.

IV. SIMULATION RESULTS

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 as shown in Fig 3.

The far field array factor of this array with an even number of isotropic elements \((2N)\) can be expressed as

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

Where \( a_n \) is amplitude of amplitude of \( n^{th} \) element, \( \theta \) is the angle from broadside and \( d_n \) is the distance between position of \( n^{th} \) element and array center. The main objective of this work is to find an appropriate set of required element weight that gives maximum side lobe level reduction and narrow main beam width. To find a set of values which produces the array pattern, the algorithm is used to minimize fitness function. The fitness function associated with this array is the maximum Side Lobe Level of its associated radiation field pattern to be minimized. The fitness function used for this work is given by

\[
\text{Fitness } = F1 = 20 \log_{10} \left( \frac{F}{\max (F)} \right)
\]

\[
F = \text{abs} (H)
\]

Where H is normalized field strength.

The antenna model consists of N elements and equally spaced with \( d = 0.5\lambda \) along the y-axis. The number of elements are changed while the array geometry and spacing between the elements are constant. A continuous GA with a population size 20 and an adaptive feasible mutation rate is run for a total of 100 generations using MATLAB and the best result was found for each iteration. The cost function is the minimum side lobe level for the antenna pattern. Simulation is done for \( N = 24 \) elements. Table 1 shows the amplitude excitations for \( N=24 \) elements.

Using adaptive feasible mutation rate better results are obtained as shown in table 2 as compared to results obtained by fixed mutation as in [1].
V. 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 $0^\circ$. This paper compares the results of new design used in this paper with the design of antenna array in [1], and it is found that the changes made in this design gives better values of antenna elements weights as compared to previous work. Adaptive feasible mutation with single point crossover showed the performance improvement by reducing the side lobe level below -20dB in most of the cases. The best sidelobe level obtained is -26.1 dB for $N = 24$ which is -14.97 dB in [1]. As a compromise in directivity is observed the work can be extended to improve the directivity also while reducing side lobe level, same experiment can be done for array with large number of elements as compared to this. Fig 4 shows the optimized radiation pattern and fig 5 shows the polar plot for $N = 24$ elements.

![Fig. 4 Optimized radiation pattern with reduced side lobe level of -26.1 Db for N= 24 elements](image)

![Fig. 5 Radiation pattern for N= 24 elements](image)

### Table 1: Amplitudes excitations for N=24 elements

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<th>Wn</th>
<th>Amplitude Excitation</th>
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<tr>
<td>W2</td>
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**REFERENCES**


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