Side lobe level reduction of linear array using GA

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Abstract. This paper presents a novel optimization technique using genetic algorithms for antenna array synthesis. GA is a global optimization technique which is proved very effective for optimization based on the science. It is capable of solving linear and non-linear problems. In this paper, genetic algorithm is used to determine an optimum set of amplitudes of antenna elements that provide a radiation pattern with maximum side lobe level reduction.

1. INTRODUCTION

Application of phased array antennas is increasing in radar engineering and, more recently, in satellite and cellular communications. In present time applications, smart antennas play an important role in cellular mobile communication at base stations. Although popularity of smart antenna is increasing very fast, the optimum designs and practical fabrications of planar phased array antennas with low side lobe level and narrow beam width remains a challenging task [1]. For reducing the side lobe level commonly used method is amplitude tapering, in which the excitation amplitudes of the array elements generally decrease with the distance from the center of the array. There are several techniques are available [2,3] for obtaining amplitude shading coefficients for a uniformly spaced linear array.

The uniformly spaced point sources produces the narrowest possible beam for a given degree of uniform minor lobe suppression. However, the two major problems to solve are the reduction of the side lobe levels and the broadening of the beam widths. These two phenomena are always complementary to each other. As the beam width for any antenna array widened, the directivity of the array decreases. When the side lobe level is lower, then a wider beam width must be accepted as a compromise. Many researcher has spent a significant effort to find amplitude distribution that minimize the beam width for a given side lobe level or optimize the pattern in some other ways [4]. There are several methods are available for such analysis of antenna arrays. The most popular approaches are the transmission-line method, cavity approach, and full-wave integral equation techniques including primarily the boundary element method and the method of moments (MoM) [5]. If properly apply, then full wave models produced more accurate results and more practical. For optimization of side lobe level in recent years, application of different algorithms like fuzzy logic, neural network is increasing very rapidly. In present research the application of genetic algorithms for same purpose is discussed. So in the modeling of the electrically large phased antenna array, computational limitations can be easily exceeded.

Genetic algorithms are different from more normal optimization and search procedures in the four ways [6].

1) Genetic algorithms work with a coding of parameter set, not the parameters themselves.
2) Genetic algorithm search from a population of points, not a single point.
3) Genetic algorithms use objective function information, not any derivative or auxiliary information.
4) Genetic algorithms use probabilistic transition rules, not deterministic rules.

The genetic algorithms find their application in various engineering problems like electromagnetic field theory, antenna arrays, VLSI circuit partitioning and many more.

The Genetic algorithm is implemented using computer simulation, employing a population of individuals, which is the solution space. The individuals undergo the selection process by evaluating the fitness function, using operators such as mutation and crossover.

The most commonly used method for reducing the side lobe levels of a uniform array involves amplitude tapering, in which the excitation amplitudes of the array elements generally decrease with the distance from the center of the array. Several techniques were developed [6,7] for obtaining amplitude shading coefficients for a linear array of uniformly spaced point sources, and they produce the narrowest possible beam for a given degree of uniform minor lobe suppression. However, the two major consequences are the reduction of the side lobe levels and the broadening of the beam widths.

2. COST FUNCTION

A cost function generates an output from a set of input variables (a chromosome). The cost function may be a mathematical function, an experiment, or a game. The object is to modify the output in some desirable fashion by finding the appropriate values for the input variables. We do this without thinking when filling a bathtub with water. The cost is the difference between the desired and actual temperatures of the water. The input variables are how much the hot and cold spigots are turned. In this case the cost function is the experimental result from sticking your hand in the water. So we see that determining an appropriate cost function and deciding which variables to use are intimately related. The term fitness is extensively used to designate the output of the objective function in the GA literature. Fitness implies a maximization problem. Although fitness has a closer association with biology than the term cost, we have adopted the term cost, since most of the optimization literature deals with minimization, hence cost. They are equivalent [8].

The GA begins by defining a chromosome or an array of variable values to be optimized. In the present research cost function is defined as

$$CF = \sum_{n=1}^{N} C(n) * e^{j2\pi(n-1)Kcos\theta}$$

Where

$C(n) = n\, e^{j\varphi}$ n = 1, 2… N

N = number of element

Φ = phase of current in respective element

3. PROBLEM FORMULATION

In present discussion an array of antenna is considered with N number of elements. It is assumed that the antenna elements are symmetric about the center of the linear array. The spacing between the elements should always be less than half of wavelength (λ/2).

For optimizing array pattern the antenna elements are arranged with uniformly spacing, in a straight line and N is the total number of elements in the antenna array with the ph ysical separation distance as d than

$K = d * \lambda$ …………….. (2)

$H = \sum_{n=1}^{N} C(n) * e^{j2\pi(n-1)Kcos\theta}$ ……….……
(3)

Where θ = 0 to 2π

Equation (3) is in the forms of a finite Fourier series that relates the element excitation coefficients C (n) of the array to its AF through a discrete inverse Fourier transform. AF is periodic in Kcosθ-dimension over the interval 2π. Since AF is related to the to the element excitations through a discrete inverse Fourier transform, a discrete direct Fourier transform applied on AF over the period 2π will yield the element excitations C(n). These Fourier transform relationships are used in an iterative way to synthesize low side lobe pattern for arrays with a periodic element arrangement.

The synthesis procedure starts with the calculation of AF (i.e. H) using an initial set for the N element excitation coefficients. The calculation of AF is carried out for the whole range of u = 0 to 2π. Implementation of the algorithm for the synthesis of low side lobe patterns for linear arrays using Fourier transform method proceeds as follows.

1. Compute K by multiplying distance between elements with wavelength
2. Then C is defined as the value of current on different phase values
3. H is calculated using Genetic Algorithm

4. DESIGN AND EXAMPLES

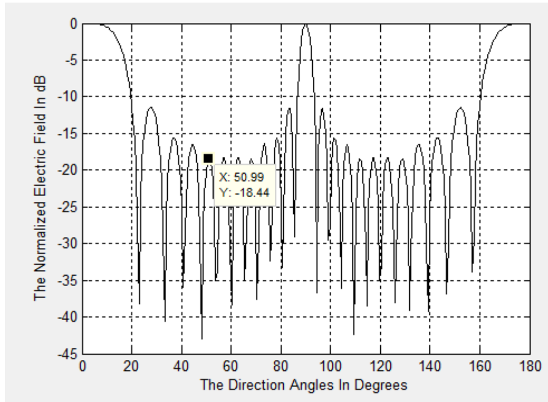
In this section, Genetic algorithm is implemented for the equally spaced symmetric linear array. The problem is to optimize the amplitudes of the elements to achieve minimum SLL. For this antenna arrays, different numbers of elements are taken. The element positions and phases are fixed as in the case of conventional array, i.e., spacing between the elements is given by $d = \lambda/2$, and phase $\varphi = 0$. For n = 1… N. When the simulation is run using genetic algorithms and implemented using MATLAB following result are achieved

5. MINIMIZATION OF THE MAXIMAL SIDE LOBE

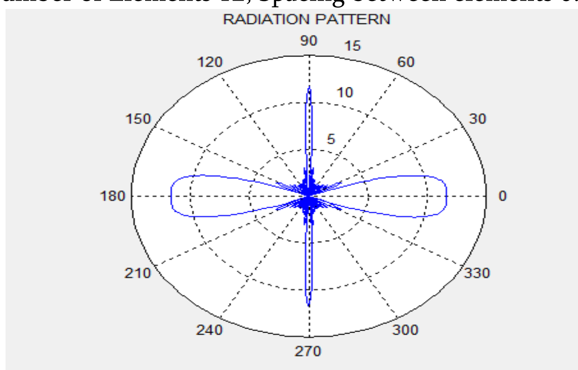
In the first example, GA is used to minimize the maximum SLL of a 12-element linear array in a specific region by varying amplitudes only. The objective function is taken as follows:

Fitness Function = min (max (20 log AF (φ))

The antenna model consists of 12 elements and equally spaced with $d = 0.5\lambda$ along the axis. With the prefix value of gain 3, the value of normalized electric field in dB is optimized till -18.8dB and directivity of 15.11 is achieved. The optimized value is achieved by 90 generation iteration of GA with best fitness value of 31.0194 and mean fitness of 31.37 as shown in fig.



Number of Elements 12, Spacing between elements 0.5λ



Number of Elements 12, Spacing between elements 0.5λ

6. CONCLUSION

This paper show how genetic algorithm can use for the linear array synthesis. Results show that the amplitudes are successfully optimized to obtain patterns with satisfactory null depth and minimum SLL. In this paper it is proved that genetic algorithms have capability to optimize the results.

7. REFERENCES

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