COMPARISON OF GENETIC ALGORITHM AND DOLPH-CHEBYSHEV METHOD IN TERMS OF REDUCING SIDE LOBES IN ARRAY ANTENNA

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ABSTRACT : *Genetic algorithm optimization for radiation pattern synthesis of linear array of antennas is used in formation of adaptive array pattern. The synthesis problem in this paper is to find stimulation amplitude and array components' phase in a way that an optimal radiation pattern is obtained with maximum reduced side lobes compared to major lobe area. In order to verify its superiority over other methods, its results have been compared with those of Newton binomial theorem and Dolph-Chebyshev method. It was shown that this method is, in particular, effective in formation of adaptive radiation for smart antenna systems.*

Keywords: Linear arrays pattern synthesis, Surface reduction in side lobes, Genetic algorithm, and Dolph-Chebyshev synthesis method.

1. INTRODUCTION

There exist a variety of problems in electrical engineering field which cannot be solved in an analysis way. In fact, electromagnetic problems are non-linear and non-differential. Numerical methods are mainly used to solve this type of problems; among which, genetic algorithm (GA) is an effective method. GA inspired by generation survival concept constitutes a population toward an optimum solution, usually a global optimum solution, by meeting all objectives faster than its conventional counterparts [1-2].

GA is based on Darwin evolutionary theorem. GA imitates evolutionary concept of generation survival. That is, population is developed by individuals and fitness of them increases. If fitness of some individuals for survival is not enough competitive, they are to be dead, clearing their genetic traits. Thus, GA is inspired by nature. GA concept and how to use it in finding optimum solutions are given in the following context.

As GA is modeled after processes of evolution and combination, building blocks of GA are defined after defining genetic components. Gens are one of these components which should be defined in the algorithm. Gens are binary coding of problem variables. In other words, each problem variable is represented by a binary number as a gene. In addition, all genes are taken as a string, called chromosome. Each chromosome from a population has a fitness determined based on objective or fitness. Fitness function or objective function is a function composing of problem objectives which should be optimized (minimized). Chromosomes are, in each population, sorted based upon their fitness function from the best to the worst. Chromosomes with higher rankings are combined (mutated) to produce a new generation, expressing their precedents' traits. This mutation should be done with a small probability, this process is iterated until a favorable solution of fitness function or a pre-defined number of generations are obtained.

2. RADIATION PATTERN

Antenna radiation pattern, or briefly antenna pattern, is defined as a mathematical function or graphical representation of antenna radiation pattern of spatial coordinates. In most cases, radiation pattern is determined in a remote field area of antenna. Radiation traits of antenna includes power flux density, radiation intensity, field intensity, ownership direction[1], phase or polarization. An illustration of received electrical or magnetic field in a constant radius is named as field amplitude pattern.

3. PATTERN RADIATION LOBES

Various parts of antenna radiation pattern are considered as lobes. These lobes are divided into major lobe(s), side or lateral lobes and back lobes. Radiation lobe is, in fact, a part of radiation pattern limited to a relatively weak area of radiation intensity. Figure (1) depicts a symmetrical three-dimension polarized pattern along with a number of lobes. Figure (2) shows lobes of the same pattern in a linear representation. Side and back lobes are seen in both figures. Major lobe is the main radiance defined as a pattern lobe at which the maximum radiation is occurred. For example, in Figures 1 and 2, main pattern radiance has the maximum radiation along $\theta=0$. In most antennas, it is possible to have more than one lobe. All radiation lobes except major lobe are names as minor lobes. Each antenna pattern radiation lobe in a direction other than proper direction is called side lobe. Side lobe is usually placed in major lobe neighborhood. Back lobe is a lobe the degree between its axis and main lobe radiance is approximately 180 degree.

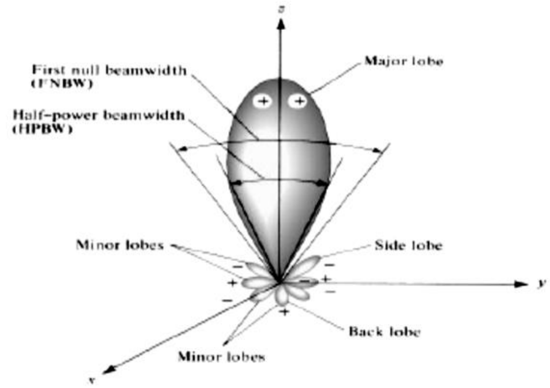

Fig.1 Polar and 3-D illustration of lobes and radiance widths of radiation pattern in an antenna.

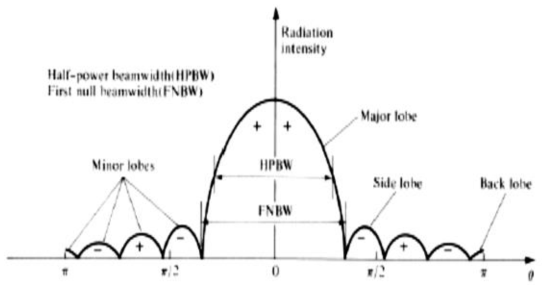

Fig.2 Linear and 2-D illustration of antenna radiation

4. A SIMPLE GA IMPLEMENTATION STEPS [1-2]:

1) A random generation of chromosomes is initialized.
2) Fitness function is estimated for each population.
3) Population individuals are ranked based on their fitness function.
4) A new generation is obtained by combination of good individuals.
5) Selected individuals are mutated.
6) If desired criterion is met, the algorithm terminates; otherwise, it goes to step 2.

5. GENS AND CHROMOSOMES DEFINITION

Each variable of optimization problem should be coded as gene and all variables connected and form a chromosome. For instance, following expression indicates a chromosome constituting of N variables. And each variable is coded as a 5-byte binary number:

$$CHromosome=\left[\underbrace{01001}_{q_1}\underbrace{01110}_{q_2}\cdots\underbrace{10110}_{q_N}\right]$$

Where, qn is a mapping from chromosomes space to variables' space. A comprehensive understanding of boundary and necessary precision is of critical importance for each variable such that all search space of the problem is explored and it is ensured that each gene, and In turn, each chromosome created by GA is a reasonable solution for the optimization problem.

6. LINEAR ARRAY YNTHESIS USING GA

Due to their straightforward way of radiance formation, linear arrays are among most common arrays. In a conventional linear array, array components are placed in a homogenous way distances equal to half of the wavelength. They are also stimulated in a uniform way. In this paper, phase of existing components in array is assumed to be zero and their stimulation amplitude is different. Main objective is, in fact, determination of array components in order to obtain minimum rate of first side lobe surface to that of main lobe in array pattern. Figure 3 shows this array with its components as point isotropic sources. Sources are positioned in a d=λ/2 intervals.

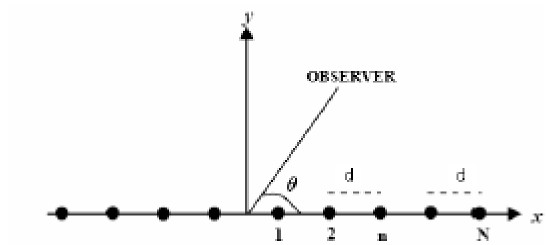

Fig.3 Linear array including 2N components.

Due to symmetrical fashion, array factor can be written mathematically as [3]:

$$E(\theta)=2\sum_{n=1}^{N} I_n\, e^{j\Phi n} \cos((n-N-.5)kdu) \qquad (1)$$

Where, $k=2\pi/\lambda$ is wave number, $d=\lambda/2$, and $u=\sin\theta$. I_m is nth component stimulation amplitude and Φ_n is its phase.

For this array, fitness function optimize (minimized) by GA should be defined as:

$$\text{Fitness}=\max(20\log(|E(\theta)|/\max|E(\theta)|)) \qquad (2)$$

These coefficients are improved using GA in a way that minor lobes' surface to the major lobe is less than a desired value.

In this paper, radiation pattern is considered against interference to major lobe as well as homogenous synthesis of linear arrays' radiation pattern with various number of components, i.e. 20 and 40. For all arrays, phase of all components was considered as 0*0. Figures 4 and 5 show the results of this synthesis obtained by GA compared to Dolph-Chebysheve.

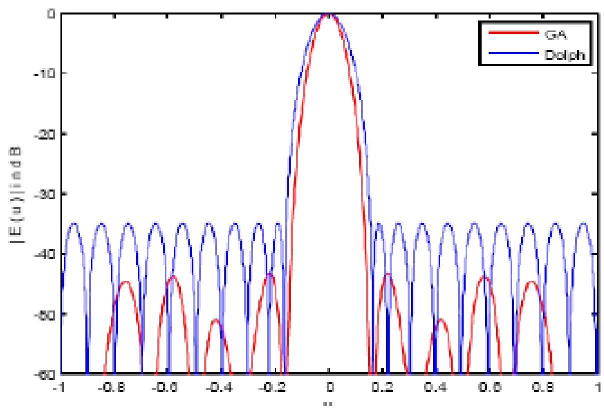

Fig.4 Array radiation pattern with 20 isotropic components obtained by Dolph-Chebysheve method and GA.

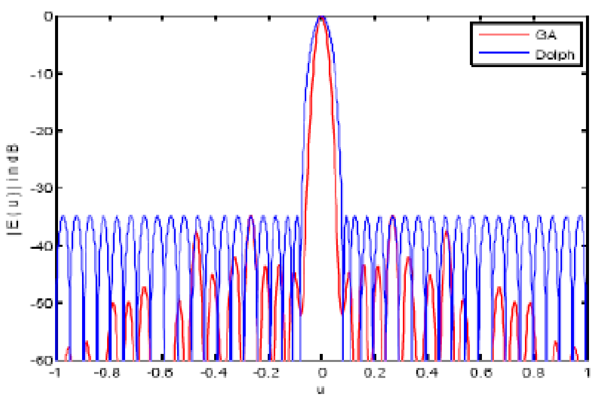

Fig.5 Array radiation pattern with 40 isotropic components obtained by Dolph-Chebysheve method and GA.

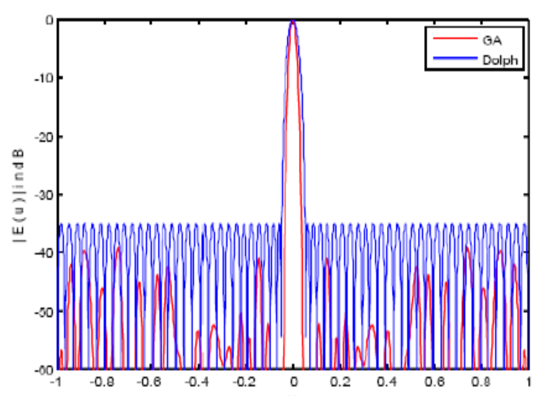

Fig.6 Array radiation pattern with 60 isotropic components obtained by Dolph-Chebysheve method and GA.

The first side lobe in synthesis by GA is less than that of Dolph-Chebysheve. Moreover, the distance between first two-zeros in synthesis by GA is less than Dolph-Chebysheve, indicating that radiance owing direction In GA is better than Dolph-Chebysheve. Although the array components were of isotropic type in this paper, one can use real-world components in GA. However, only isotropic components, as an ideal case, can be utilized in Dolph-Chebysheve. Thus, GA not only is capable for real-world synthesis, but it can be implemented easily.

Table 1. A 20-array components' amplitude coefficients for Dolph-Chebysheve and GA.

Array component no.	Amplitude coefficients in Dolph-Chebysheve	Amplitude coefficients in GA
1	0,1935	0,8175
2	0,2180	0,4538
3	0,3215	0,8034
4	0,4389	0,4317
5	0,5636	0,3395
6	0,6874	0,9427
7	0,8012	0,6665
8	0,8961	0,6692
9	0,9643	0,3763
10	1,0000	0,5830
11	1,0000	0,5830
12	0,9643	0,3763
13	0,8961	0,6692
14	0,8012	0,6665
15	0,6874	0,9427
16	0,5636	0,3395
17	0,4389	0,4317
18	0,3215	0,8034
19	0,2180	0,4538
20	0,1935	0,8175

7. CONCLUSION

Contrary to Dolph-Chebysheve, side lobes' surface is not homogenous in array synthesis using GA. Since GA is a randomized searching algorithm with solutions that, contrary to analysis methods, are not unique. That is, each time it runs, different results are obtained. In addition, with GA, one can obtain half-power radiance width. In other words, with Dolph-Chebysheve, by selecting the number of components, the surface of side lobes as well as half-power radiance width are constant with no control. Furthermore, synthesizing arrays with homogenous amplitude using Dolph-Chebysheve is not viable something that is possible when GA is used.

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