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Research Article

Antenna Linear Arrays Synthesis Using the Genetic Algorithm

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***Abstract*— This work introduces an effective technique for the linear antenna array pattern synthesis using the genetic algorithm (GA) based on optimization approach. Numerical designs are discussed to explain the diverse abilities of this technique for varying numbers of antennas with uniform inter-element spacing between elements (d=λ/2). Thereby preventing the occurrence of grating lobes. The key design of this work is to generate the excitation amplitudes only of the linear antenna array to place the nulls toward unwanted signals, while the main lobe pattern is steered toward the intended signal by altering the phase excitation currents. An objective function based on minimizing the error between the desired and synthesized radiation patterns is employed to guide the optimization process and maximize the fitness of the candidate solutions. Finally, this technique proved its effectiveness in improving the performance of the antenna array.**

***Index Terms*—Antenna linear arrays, Optimization, Genetic algorithm.**

I. INTRODUCTION

WIRELESS communication systems extensive use of antenna arrays particularly in civil and military purposes. These antennas have high directivity, low side-lobes and narrow beamwidth. These arrays can be taken several configurations such as a linear, planar (circular or rectangular) and conformal arrays [1,2,3,4].

In order to reduction of signal interference in undesired direction and to minimize degradation of the signal to noise ratio in communication systems. Adaptive nulling capability for antenna array is the process of choosing the antenna parameters to obtain main lobe pattern in the desired direction and the specific position of the nulls in the undesired direction [5]. Phased array antennas having adaptive nulling capability can provide improved performance virtually in radar or wireless communications applications [2].
In order to receive the interested signal through the main beam and positioning nulls in the undesired directions through the sidelobes, an adaptive array modifies the antenna pattern utilizing complex excitation current of the element signals.

The field of antenna array synthesis has received a lot of interest in recent decades. It has a wide range of study such as numerical method such as iterative and empirical and optimization methods, analytical method and optimization methods. Over the past ten years, synthesis of antenna has relied on optimization methods like artificial neural network (ANN)[6], genetic algorithm (GA)[7], deep and machine learning [8], ant colony optimization algorithm [9], Particle Swarm Optimization (PSO)[10] and bee algorithms are utilized in synthesis of antenna array[11].

Various design methodologies for interference suppression have been explored in the literature. One prominent category of null controlling by altering the complex weights (both amplitude and phases of currents). It often suffers from inherent challenges such as ineffective and slow for large arrays. Karaboga [5] used the complex weights method and ant colony optimization algorithm to synthesis of linear antenna array. Hans[12] achieved nulls at the desired directions by using full amplitude and phase control.

A second methodology involves the phase-only weight control. Chao [13] used both phase-only controlling and memetic algorithm to achieve pattern synthesis for interference cancellation. Mahanti [14] establishes a real programmed evolutionary method for the construction of reconfigurable dual-main pattern of linear antenna arrays. Digital phase shifters only employ their phases as control parameters.

The third method only makes use of the current's amplitude. Tapaswi [15] used a circular array with a genetic algorithm (GA). By using GA to optimize each element's current amplitude excitations, single and multiple nulls are imposed. In the fourth method, nulls the linear antenna array design by using unequal spacing. Kurup [16] used the differential evolution approach for uniform amplitude arrays with equal phases and unequal spacing.

In this work, genetic algorithms are utilized in the synthesis of linear antenna array. It is considered all elements are identical and equally distance. The key design is of this paper is to create the excitation amplitudes only of the linear antenna array to place the nulls toward unwanted signals and then avoiding interference or undesired signals, while the main lobe pattern is steered toward the intended signal by altering the phase excitation currents.

Genetic algorithm is implemented using MATLAB program. The rest of the paper is structured as follows: The optimization problem's mathematical model is examined in Section II. The actual GA method with the objective function is suggested in part III. Section IV achieves the simulation of GA with several examples. The paper is finally concluded in Section V.

II. Problem Formulation

The configuration employed in this design, depicted in Fig. 1, it is considered linear antenna array of N elements that are equally spaced along the x-axis. The linear array elements are symmetric excited and the enter-element spacing is half-wavelength. so that the desired pattern $F_{des}(\theta)$ and the output pattern ($F_{out}(\theta)$) are identical. The array factor (AF) is calculated by:

$$AF(\theta) = \sum_{n=0}^{N-1} I_n e^{jn\psi} \quad (1)$$

Where:

$\psi = \beta d \cos\theta + \alpha$

$\beta = 2\pi/\lambda$ = phase constant.

λ is the wavelength.

d is the enter-elements space.

α Phase excitation current.

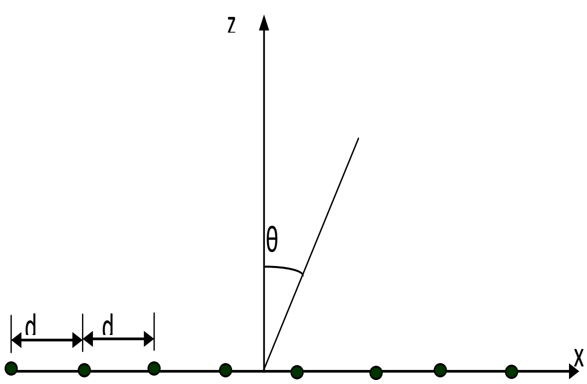

Fig. 1. This is a sample of a figure caption.

III. Propososed Technique

The GA iteration has a four essential steps[3]. The genetic algorithm begins by creating an initial population of this design. A chromosome is consists of genes which represent current weights. Chromosomes is generated randomly in this issue. The first step is to generate random matrix vectors (M_{nm}), n =1,2,3,…,N, m =1,2,3,…,C. where N is the number of genes which represent number of elements, and C is the number of chromosomes[17] Individual chromosomes are represented in this work using real number encoding.

$$C=[d1\ d2\ d3\ \ d4\ \ d5 \ldots d_N] \quad (2)$$

Where d_n which represents the current distributions of linear array elements. The selection operator is the second step which recognizes the better chromosomes from the worse chromosomes utilizing their objective function. The fitness scores are then used to select parents and create offspring. Roulette Wheel selection is applied in this work in which the better individuals are the more chances to be selected and parents are selected according to their fitness [18].

A crossover is substitute of genetic materials between two parent chromosomes to create a child chromosome which occur in the third step. The simplest method is to select a crossover point randomly, copy everything from the first parent before it, and then copy everything from the second parent after it. Crossover comes in a variety of forms, including arithmetic, uniform, two-point, and single-point. This paper uses a single point crossover with an 85% crossover probability. A single crossover point is chosen at random, and two offspring are created by exchanging the parts of two parents after the crossover point. The fourth Step is mutation which change the genes in the chromosome with 15% mutation probability [19,20].

Lastly, evaluation the fitness of each chromosome. A fitness value is determined for each chromosome. Examine the fitness value of each chromosome individually. If one chromosome can provide superior fitness than the current best fitness value, it will renew the values of the defined vector and variable with this chromosome and its fitness value. If not, maintain their current settings. The objective function or cost function is the difference between the desired pattern and array outputs.

$$error = (F_{out} - F_{des})^2 \quad (3)$$

And then the objective function is

$$\max = \frac{1}{error} \quad (4)$$

The genetic algorithm selects parents with the highest fitness values. The iterative process continues until the maximum number of generations is reached or the improvement in the objective function becomes negligible. A flowchart of the GA for synthesis the pattern of linear antenna array utilized in this design is illustrated in algorithm 1.

Algorithm 1 Genetic Algorithms for nulling the pattern of linear antenna array
Initialize the population randomly by generating (P) chromosomes representing the excitation current weights of the linear antenna array. Generate pattern **E=F$_{des}$** Objective Function **error= F$_{out}$-F$_{des}$**

Evaluate fitness function **max=1/error**
Selection
Crossover
Mutation
Create new population
Is max number of generations is achieved
Obtain best chromosome

IV. Simulation Results

In this section, five examples are considered to demonstrate proposed pattern synthesis technique and the various capabilities of this approach.

Example 1:

In this design, a Genetic Algorithm GA is utilized for linear antenna array pattern synthysis. In this case, it is used eight istropic elements with an inter-element spacing of d=0.5λ. It is notcied that the normalized pattern has 3 nulls at (20°, 40°, and 60°) and the main lobe at angle 80° as dipected in figure(2). Furthermore, Figure(3) illustrates the excitation coefficients for half elements of linear antenna array.

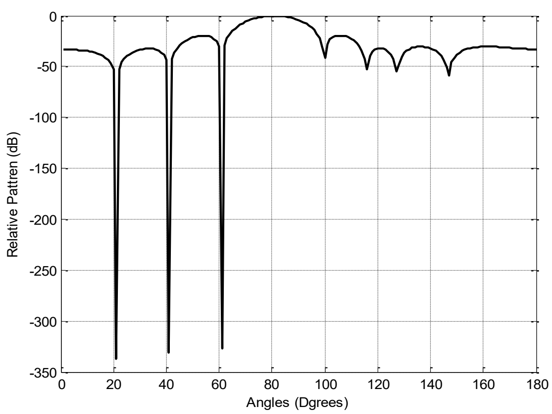

Fig. 2. Linear array pattern with 3 nulls, SLL=-20 dB.

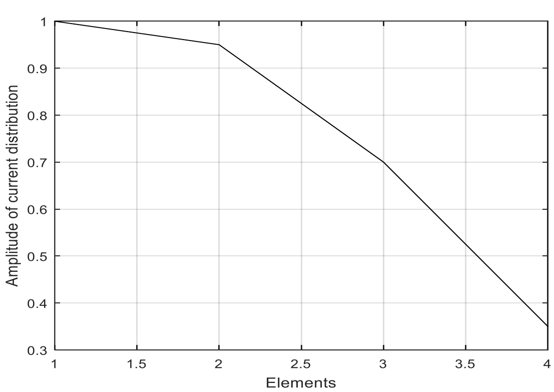

Fig. 3. Antenna array current distribution.

Example 2:

In this design, linear antenna array pattern synthesis utilized GA, In this case the number of elements is equal to 8 and distance between elemnts d=0.5λ. It is notcied that the relative pattern has 4 nulls at angles (40°, 88°,104° and 120°) and the main pattern at angle 60° as shown in figure(4). Figure(5) illustrates the excitation coefficients for half elements that produce four nulls at directions (40°, 88°, 104°, and 120°) and the main pattern direction at 60°.

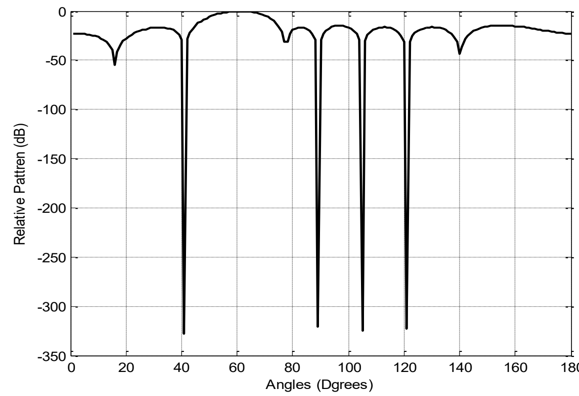

Fig. 4. Linear array pattern with fourth nulls and SLL=-20 dB.

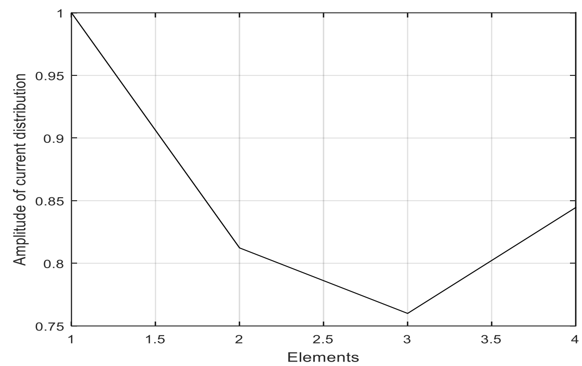

Fig. 5. Antenna array current distribution.

Example 3:

design of a linear antenna array with eight elements using GA. The normalized pattern with three zeros at directions of 20°, 80°, and 110° degrees and the main beam at an angle of 50° degrees is depicted in Figure (6). The excitation distribution for half elements is displayed in figure (7).

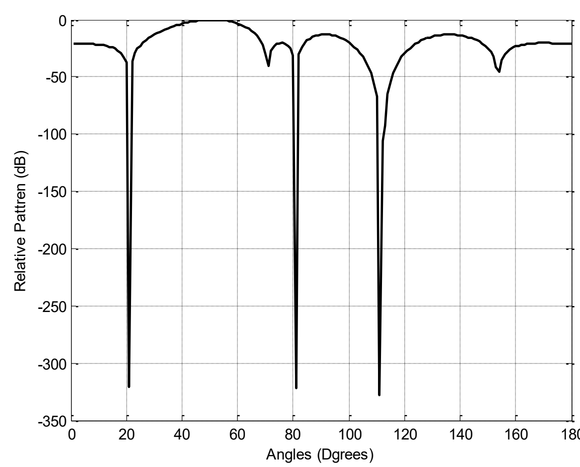

Fig. 6. Linear array pattern with 3 nulls and SLL=-21 dB.

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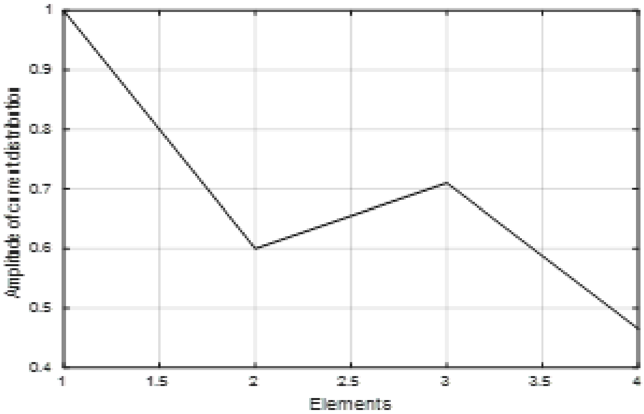

Fig. 7. Antenna array current distribution.

Example 4:

GA is used for synthesis the pattern of a linear antenna array with eight elements. The normalized pattern of a linear antenna array with six zeros at directions (25°, 49°, 60°, 120°, 130°, and 156°) and the main beam at angle 90 degrees is depicted in Figure 8. The excitation distribution for half elements of a linear antenna array with six zeros at directions ((25°, 49°, 60°, 120°, 130°, and 156°) and the main beam at angle 90° is displayed in figure (9).

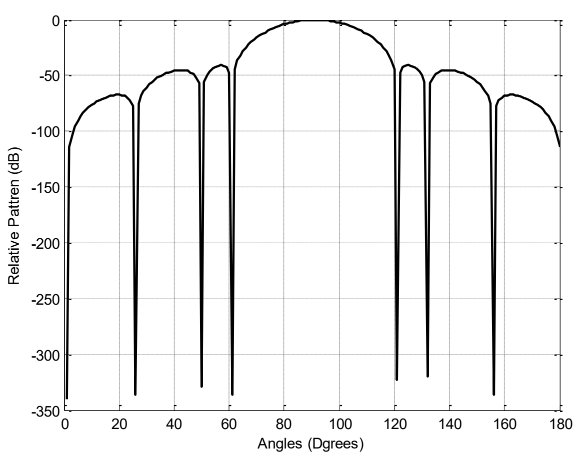

Fig. 8. Linear array pattern with 6 nulls and SLL=-40 dB

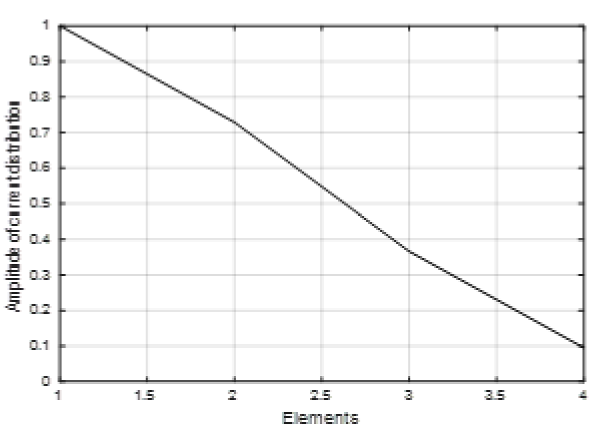

Fig. 9. Antenna array current distribution.

Example 5:

GA is used for synthesis the pattern of a linear antenna array with ten elements. The normalized pattern of a linear antenna array with the main beam at direction 0° and one null at angle 30° is depicted in Figure 10. The excitation distribution for half elements of a linear antenna array with one zero at angle (30°) and the main pattern at normal direction is displayed in figure (11).

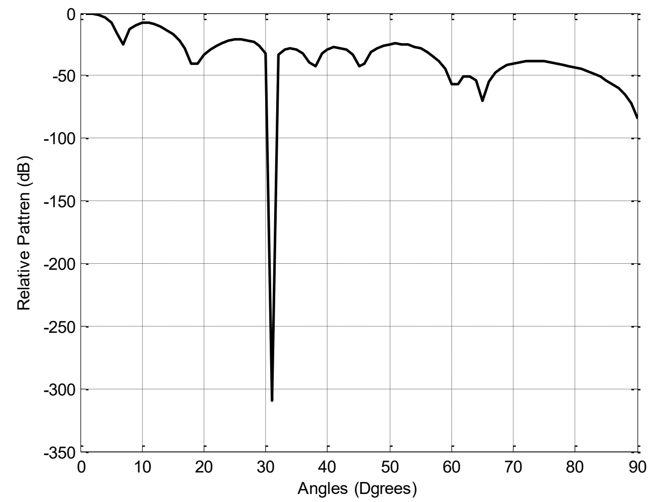

Fig. 10. Linear array pattern with one null and SLL=-18 dB.

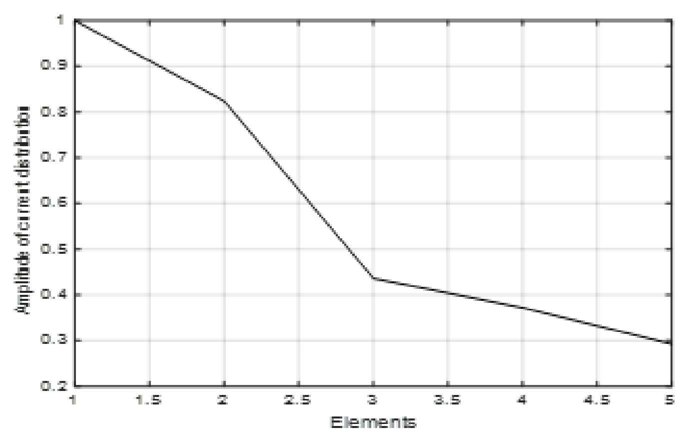

Fig. 11. Antenna array current distribution.

Example 6:

GA is used to design of a linear antenna array with 20 elements

The normi;ized pattern of antenna array with two zeros at directions of 15° and 27° degrees and the main pattern at brodside is depicted in Figure 12. The excitation distribution for half elements of a linear antenna is displayed in figure 13.

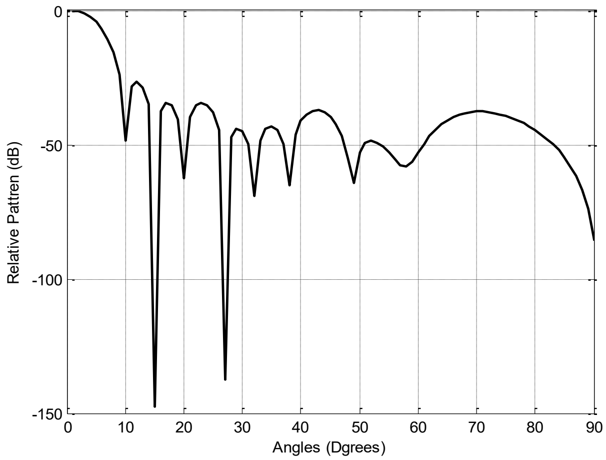

Fig. 12. Linear array pattern with 2 nulls and SLL=-30 dB.

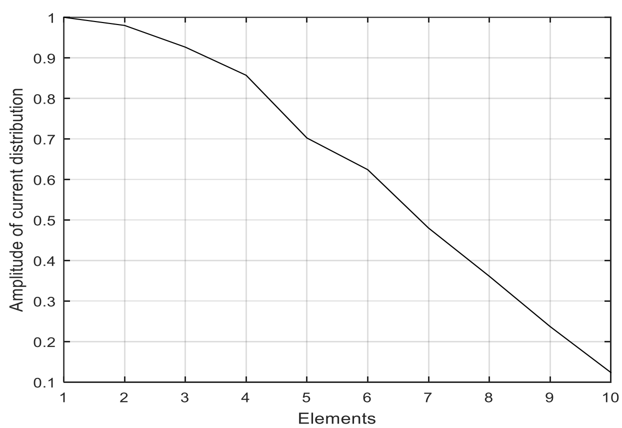

Fig. 13. Antenna array current distribution.

To illustrate the different capabilities of this method, Table (1) compares the aforementioned cases in terms of the number of elements, number of nulls, side lobe level, direction of main beam , direcion of nulls and depth of the nulls.

TABLE I

COMPARISONS BETWEEN SIX EXAMPLES

Example	No. of Elem ents	SLL (dB)	No. nulls	Main beam angle	Null Angle	The depth of the nulls(dB)
1	**8**	**-20**	**3**	**80**	**20,40, and 60**	**-330**
2	**8**	**-20**	**4**	**60**	**40,88, 104, and 120**	**-326**
3	**8**	**-20**	**3**	**50**	**20,80, and 110**	**-325**
4	**8**	**-40**	**6**	**90**	**25,49, 60,12 0,130 and 156**	**-335**
5	**10**	**-18**	**1**	**0**	**30**	**-310**
6	**20**	**-28**	**2**	**0**	**15, and 27**	**-150**

Comparison with Previously Publishing Work

The results from this technigues and two additional technigues (Memetic method [6], Taguchi's algorthim [10] Particle Swarm Optimization (PSO)[14] and Machine Learning[22]) are compared in Table (2) in terms of the zeros number, side lobe level, and nulls depth. It is found that there are more than two ways with nulls, and that the nulls depth is -320 dB, but in other methods it is -180 dB.

TABLE II

COMPARISON THE PROPOSED METHOD WITH OTHER METHODS WITH RESPECT TO NUMBER OF ELEMENTS, SLL AND DEPTH OF NULL

Method type	nulls No	SLL (dB)	Nulls depth (dB)	Remarks
Memetic method**[13]**	**2**	**-5**	**-180**	Combines local and global search but requires higher computational effort.
Taguchi's Method **[10]**	**2**	**-10 to -15**	**-50**	Good global optimization ability and stable convergence for continuous variables.
Particle Swarm Optimization (PSO)[14]	**4**	**−15 to −35**	**-200**	Simple implementation and fast convergence but may suffer from premature convergence.
Machine Learning[22]	**4**	**−20 to −40**	**-150**	Provides real-time beamforming capability but requires large training datasets
The proposed method	**6**	**-15 to -40**	**-320**	Produces multiple deep nulls with robust global search capability.

V. CONCLUSION

This paper presented a genetic algorithm (GA)-based optimization technique for linear antenna array synthesis. In order to generate a set of current weights for the linear antenna array synthesis, the proposed study indicates the utilize of the genetic algorithms (GA). The design optimization involves steering the nulls in undesirable directions, their weights were optimized.

The numerical results demonstrate that the genetic algorithm can suppress multiple interfering signals instead of just one (the nulls numbers achieved in this work are 1, 2, 3, 4, and 6), and that amplitudes alone are successfully optimized to obtain patterns with satisfactory null depth (less than -320 dB) and acceptable side lobe level SLL which is less than -18 db. In addition, SLL is smaller than uniform linear antenna arrays.

Furthermore, the optimization process displys fast convergence and high accuracy in determining the desired null locations without compromising the overall radiation pattern. These results confirm that the proposed method is an efficient and robust solution for adaptive linear antenna array synthesis, offering excellent interference suppression and improved radiation performance suitable for modern wireless and radar communication applications.

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The preferred spelling of the word “acknowledgment” in American English is without an “e” after the “g.” Use the singular heading even if you have many acknowledgments. Avoid expressions such as “One of us (S.B.A.) would like to thank ... .” Instead, write “F. A. Author thanks ... .” In most cases, sponsor and financial support acknowledgments are placed in the unnumbered footnote on the first page, not here.

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