DESIGN OF PLANAR ARRAY ANTENNA WITH CHEBYTSHEV METHOD AND GENETIC ALGORITHM

Amor Hammami*, Ridha Ghayoula & Ali Gharsallah
[1]Unité de recherche : Circuits et systèmes électroniques HF
Faculté des Sciences de Tunis, Campus Universitaire
Tunis EL-Manar, 2092, Tunisie
*Email:hammami.a.fst@gmail.com

ABSTRACT

In this paper, a method of a Multiobjective Optimisation based on Chebytshev's method and Genetic Algorithm for the synthesis of planar array antenna was investigated. This method for antenna pattern synthesis could suppress multiple interferences by placing nulls at the directions of the interfering sources and placing the main beam in the direction of the desired signal by controlling the phase and the amplitude. To verify the performance of the proposed method, several examples of planar array patterns with 10×10 one-half wavelength spaced isotropic elements to set the main beam in the direction of the useful signal while suppress the interfering narrow or wide band signals were performed.

Keywords: *Chebyshev , Genetic-algorithm, synthesis method, antenna array*.

1. INTRODUCTION

Planar arrays antennas are several antennas connected and arranged in a matrix array to reduce the electromagnetic environment pollution by minimizing the side lobe level and steering nulls to the direction of interference and placing the main beam directed to the desired signal. Instead linear array which makes beam steering only in single plane possible, planar arrays has two dimensions of control, permitting a narrow pencil beam to be produced and the control of the beam steering in two planes [11].

In last decade, several antenna pattern synthesis methods have been developed for planar antenna arrays [10]-[20]. Genetic algorithm has proved to be appropriate for pattern synthesis of planar array[5]-[21] which is able to generate several patterns with different shapes and side lobe levels by changing the amplitude and/or phases excitation of the array elements.

In this paper, we have developed a method based on a combination of Chebyshev method and genetic algorithm to synthesis steered beams with nulls in desired direction by controlling both the amplitude and phase.

The paper is organized as follows; the radiation pattern formulation is presented in section 2. The genetic algorithm method is presented in section 3. Section 4 shows numerical results, and finally, section 5 makes conclusions.

2. PROBLEM FORMULATION

An antenna array is a multiple radiating elements arranged in space and interconnected to produce a directional radiation pattern. The radiation pattern of an antenna array is determined by the number of antenna elements, the type of single elements used, their positions in space, and the amplitude and phase of the currents feed them [1].

We consider a planar array of N×M equispaced isotropic antenna elements with inter-element spacing $\frac{\lambda}{2}$, (where λ is the signal wavelength).

These elements are excited with current I_{ij} and with a gradient of phase α_{ij} $(i = 1, 2, \dots, N, j = 1, 2, \dots, M)$.

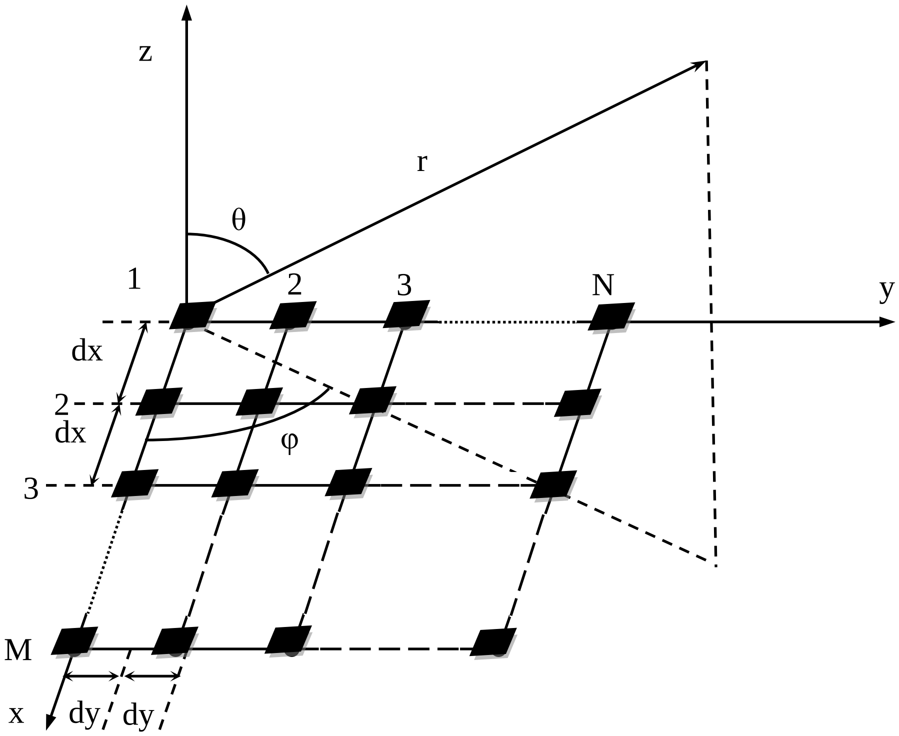

Figure1. The structure of an M×N element radiation antenna array.

The array factor can be written as

$$AF(\varphi,\theta)=\sum_{i=1}^{i=N}\sum_{j=1}^{M} I_{ij}\, e^{j(kx_i sin\varphi sin\theta\ + ky_j cos\varphi sin\theta\ + \alpha_{ij})} \qquad (1)$$

Where $\alpha_{ij} \in \begin{bmatrix} \alpha_{11} & \alpha_{12} & \dots & \alpha_{1M} \\ \vdots & & \ddots & \vdots \\ \alpha_{N1} & \alpha_{N2} & \dots & \alpha_{NM} \end{bmatrix}$ represents the phase excitation of the element *(ij)* (the antenna in the beginning is taken as reference of phase: $\alpha_{11}=0$), x_i and y_i represent positions of the element *(ij)*, $k=\frac{2\pi}{\lambda}$ is the wave number, θ is the angle of incidence of desired signal, and λ is the signal wavelength.

The problem of interference suppression in antenna array is to find the amplitude and the phase for excitations in order to obtain a radiation pattern with the desired set of characteristics

(minimum of radiation in direction of the interfering signals and the maximum of radiation indirection of the useful signal).

The mathematical model of multi-objective problem is formulated to minimize an objective function subject to set of constraints.

This problem can be written as

$$\begin{gathered} \text{minimise} - f\ \ (\alpha) \\ \text{subject to } f_{\varphi_i\theta_j}(\alpha)\ \le \delta_{ij} \quad \text{with } \begin{cases} i=1,\dots,m_e \\ j=1,\dots,n_e \end{cases} \\ -2\pi \le \alpha_{mn}\ \le 2\pi \quad \text{with} \quad m=1,\dots,M, n=1,\dots,N \\ -2 \le I_{mn}\ \le 2 \quad \text{with} \quad m=1,\dots,M, n=1,\dots,N \end{gathered} \qquad (2)$$

Where

$$f\ \ (\varphi)=\left|\sum_{m=1}^{N}\sum_{n=1}^{M} I_{ij}\, e^{j(kx_n sin\varphi sin\theta\ + ky_n cos\varphi sin\theta\ + \alpha_{nm})}\right|^2$$

$f_{\theta_i} = \begin{bmatrix} f_{\varphi_1\theta_1} & f_{\varphi_1\theta_{12}} & \cdots & f_{\varphi_1\theta_M} \\ \vdots & & \ddots & \vdots \\ f_{\varphi_N\theta_1} & f_{\varphi_2\theta_M} & \cdots & f_{\varphi_N\theta_M} \end{bmatrix}^T$ is the matrix of objective functions, m_e is the numbers of the desired signal, (φ_i, θ_j) is the directions of interfering signals, δ_{ij} is the levels in the regions of the suppressed sectors respectively, and m_e and n_e are the number of the sampled angular direction along the x-axis and y-axis, respectively.
I_{nm} , with $m = 1, 2, \ldots, M, n = 1, 2, \ldots, N$ is amplitudes of each array element which is defined by -40 dB Chebyshev algorithm.

3. GENETIC ALGORITHM

The genetic algorithm is one of the most powerful optimization algorithms. It is based on principle of the evolution of the natural species introduced by Charles Darwin. The principle is to randomly create a “population” of solutions.

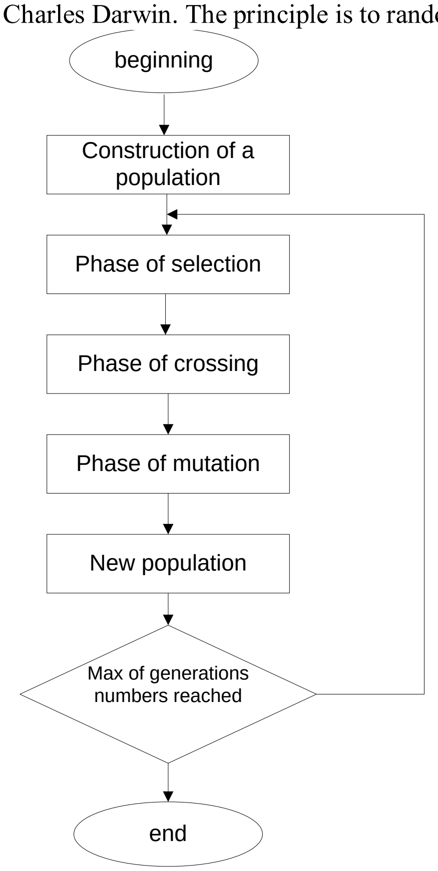

Figure 2. Flow chart of Genetic algorithm.

The implementation of the genetic algorithm is described as follows [1][2]:

Step1. Initialization: in the first step, a set of chromosomes (solutions) is randomly generated from the first population. The problem is to minimize a function of φ_{nm}. So a population φ_{nm}, made up of P chromosomes, was created. Where $n = 1,2,3, \ldots, N$ and $m = 1,2,3, \ldots, M$.

Step2. Evaluation: In this step, the fitness value of each chromosome is calculated and compared with the current best fitness value. If one chromosome can offer better fitness, the best set of weights and this best fitness value must be replaced by this chromosome and its fitness value.

Step3. Selection: the selection of the current population to survive is done based on their fitness values.

Step4. Crossover: it consists to producing the children from the survivors by combining the vector entries of pair of parents. Single point crossover is chosen. The new chromosome is carried out by two parts: the first part is copied from one parent from the beginning of chromosome to the crossover point and the rest is copied from the other parent from the crossover point to the end of the chromosome.

Step5. Mutation: this operator is introduced to mitigate the disappearance of information (bits) of the population. Its role consists in modifying by chance, with a certain probability, the value of a bit.

Step6. Stopping criteria: if the number of the current generation is equal to the predefined number of generations, end the algorithm. Otherwise, steps 2-5 are repeated. The best set of phase shift weights can be generated after termination.

4. NUMERICAL RESULTS

To demonstrate the validity of the proposed method for steering single, multiple and broad nulls with the imposed directions by controlling the element excitations, several computer simulation examples using a planar array with one half wave inter-element spaced 10×10 isotropic elements were presented.

The shape of the amplitude distribution shown in figure 3, determined by Chebyshev method, was used to reduce the side lobes level of the radiation pattern. For a focused beam, the amplitude distribution is always quadrant symmetric about the center of the array.

Our proposed method based on genetic algorithm using binary coding and binary genetic operations. The phase of each element is represented by string of 8 bits which form “gene”. The set of genes of all elements array called the chromosome shown is in figure 3. Hence, the length of a chromosome was: 10 ×10× 8 bits =800 bits.

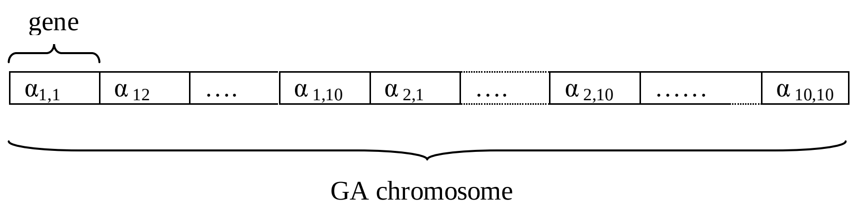

Figure 3. Chromosome construction.

The genetic algorithm parameters which are used to determine these results are: population size 100, maximum number of generations 500, crossover probability 0.8.

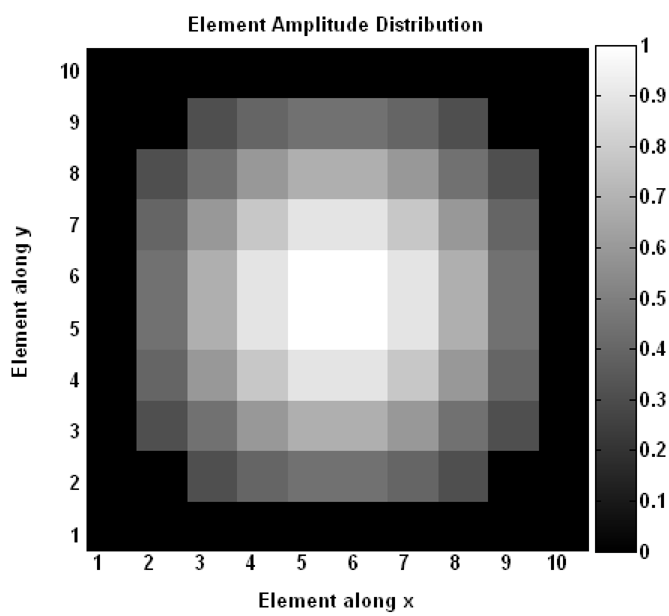

Fig. 4. The element excitation required to achieve the desired pattern (10×10 equispaced isotropic elements) given with the Chebyshev method.

The radiation pattern plot in figure 5-8 obtained by using genetic algorithm method demonstrates the aptitude of this technique to form nulls for any prescribed direction.

Figure 5 shows a 3-D surface plot of the radiation pattern of the uniform planar antenna pattern obtained by controlling both the amplitude and phase with a main beam imposed at (φ=5°,θ=20) with maximum side levels is 27*dB*.

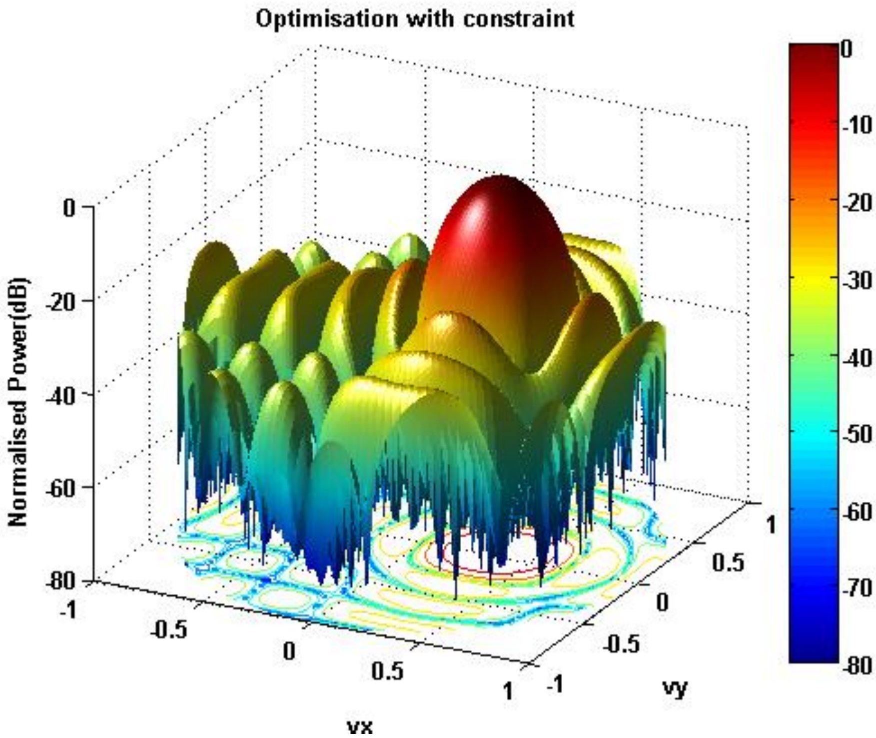

Figure 5. Planar antenna array pattern with main beam at (φ=5°,θ=20°) and one null at (φ=-155°,θ=80°)

The cut of the radiation pattern plot in figures 4-6 obtained by using Chebytshev method and genetic algorithm show respectively the radiation pattern of planar array antenna with main beam at (φ=5°,θ=20°) and one null imposed at (φ=-155°,θ=80°) and the radiation pattern of planar array antenna with main beam at (φ=-30°,θ=40°) and one null imposed at (φ=20°,θ=90°)and with maximum sidelobe levels of 27*dB*.

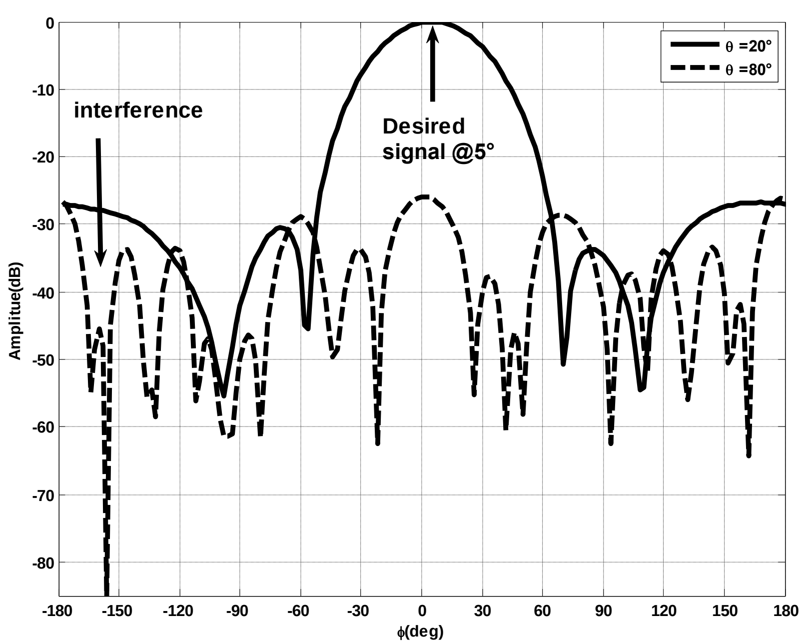

Figure 6. Planar antenna array pattern with main beam at (φ=5°,θ=20°) and one null at (φ=-155°,θ=80°)

Figure 7 shows a 3-D surface plot of the radiation pattern of the uniform planar antenna pattern obtained by controlling both the amplitude and phase with a main beam imposed at (φ=5°,θ=20) with maximum side levels is 27*dB*.

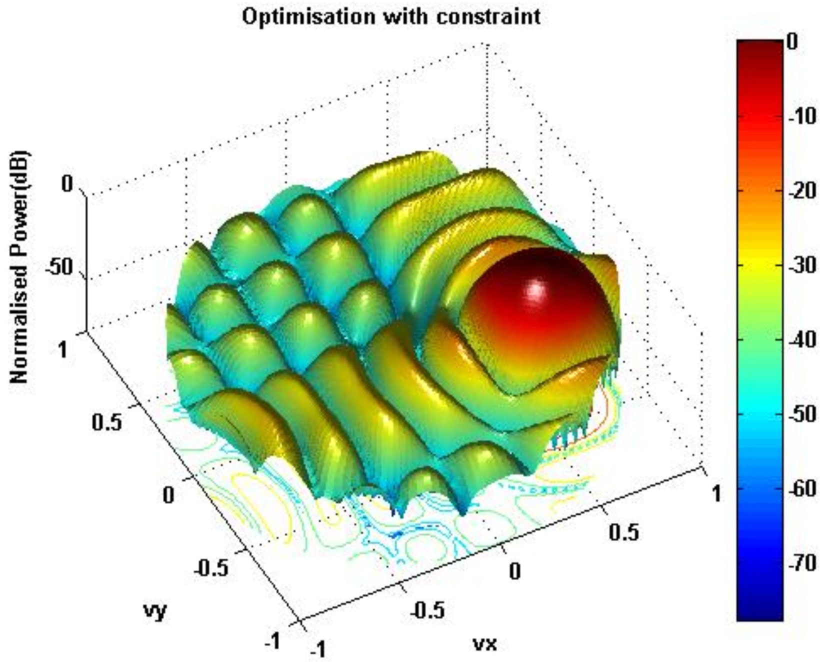

Figure 7. Planar antenna array pattern with main beam at (φ=-30,θ=40°) and one null at (φ=20°,θ=90°)

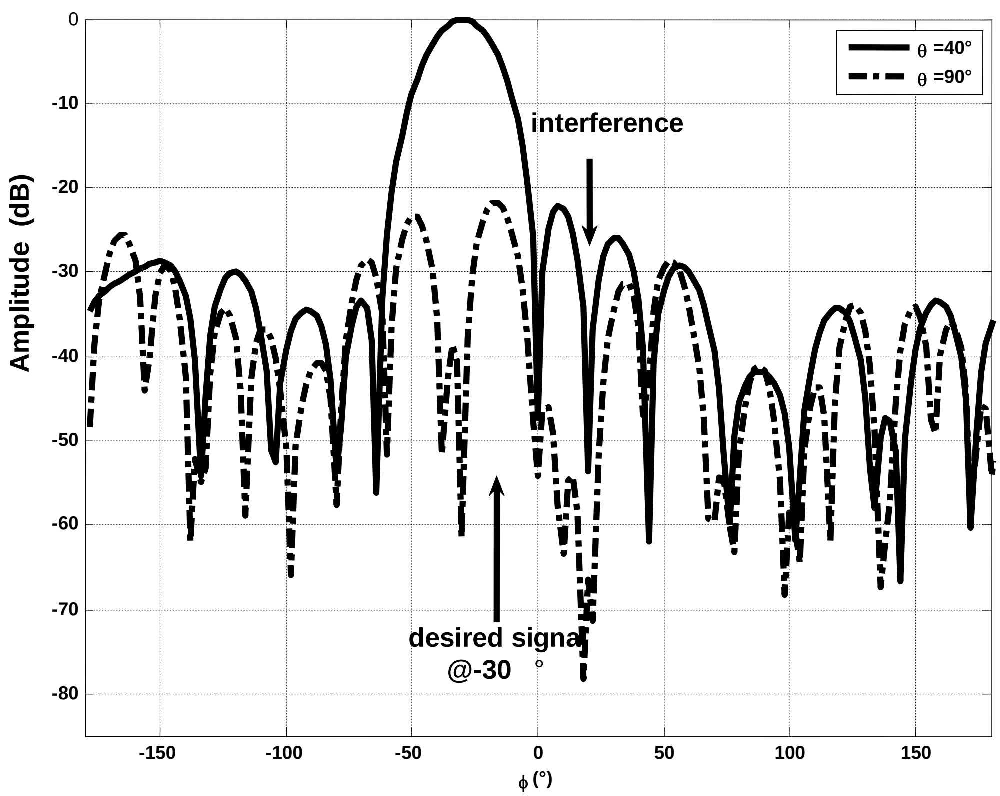

Figure 8. Planar antenna array pattern with main beam at (φ=-30,θ=40°) and one null at (φ=20°,θ=90°)

5. CONCLUSION

A method for Planar array *antenna* pattern synthesis based on the Chebytchev-Genetic Algorithm by optimizing both amplitude and phase excitation coefficients has been presented. A planar phased array antenna with 10×10 element was used, and several results showed that the proposed method is efficient and validity for synthesizing a planar array antenna pattern by amplitude and phase control; indeed, it is capable of forming nulls for any prescribed direction.

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