# Synthesizing Sectored Antennas by the Genetic Algorithm

Chien-Hung Chen and Chien-Ching Chiu
Department of Electrical Engineering, Tamkang University,
Tamsui, Taiwan, China

## Abstract

The genetic algorithm is used to synthesize the directional circular arc array as a sectored antenna. Based on the desired pattern and the topography of the antennas, the synthesis problem can be reformulated into an optimization problem and solved by the genetic algorithm. The genetic algorithm will always converge to global extreme instead of local extreme and achieves a good approximation to the desired pattern. Numerical results show that the synthesized sectored antenna is good and effective to combat the multipath fading.

## I. Introduction

To synthesize the sectored antenna, the excitation problems are reformulated as optimization problems. The current literature identifies three main types of search methods: calculus-based, enumerative and random methods, to find the extreme solution of the optimization problem [1]. The genetic algorithm is a well-known algorithm which uses random choice to search through a coding of a parameter space. This algorithm has achieved increasing popularity as researchers have recognized the shortcomings of calculus-based and enumerative schemes. Theoretically, the genetic algorithm and enumerative method converge to the global extreme of the problem, while calculus-based method often becomes trapped in a local extreme. On the other hand, the enumerative scheme lacks efficiency compared with the other two methods. As a result, the genetic algorithm is the most robust scheme among the three methods.

In this paper, the genetic algorithm is used to synthesize the sectored antenna. Section II describes the pattern synthesis by the genetic algorithm. Section III shows the numerical results. Finally, some conclusions are drawn in Section IV.

## II. Pattern Synthesis of Arc Array by the Genetic Algorithm

Circular arrays have a number of well-known advantages over linear arrays, because of their symmetry. For example, steering of a beam anywhere in the azimuth can be achieved simply by a circular shift of the weights used to form a beam. This property also carries over to arc arrays in which a small segment of the circular array is used to form the beam, and steering of the beam is now achieved by appropriately selecting a segment or arc and weighting the element signals independently of the chosen segment. Arc arrays also gain importance in view of the fact that with proper design, they are capable of giving nearly as good performance as circular arrays (of the same radius), and thus yielding considerable saving in hardware/signal processing.

The pattern synthesis procedure using the genetic algorithm begins with an array of fixed geometry with a set of starting excitations. The excitations are then changed until the desired pattern is achieved. We assume an array of M directional elements with equal space situated over an circle of radius R as shown in Fig. 1. The angular spacing between consecutive elements is $2\pi / M$. An arc region of L element is "turned on" and is used to synthesize the desired pattern. The radiation pattern of this arc array may be expressed in the form [2]

$$F(\theta,\phi)=\sum_{n=1}^{L} I_{\alpha} e^{j\alpha_n} e^{j\beta R\sin\theta\cos(\phi-\phi_n)} FE(\phi-\phi_n) \quad (1)$$

where $I_n$ and $\alpha_n$ are the magnitudes and phases of excitation respectively. $\beta$ is the wave number. The element pattern used in Eq. (1) that was considered by Jiao et al. [3] is as follows:

$$FE(\theta,\phi)=\frac{1}{3}\sin\theta\left[1+2\max\left(\cos\phi,-\frac{1}{2}\right)\right] \quad (2)$$

The genetic algorithm is a search algorithm based on the mechanics of natural selection and natural genetics. This algorithm has achieved increasing popularity as researchers have recognized the shortcoming of calculus-based and enumerative schemes. They find the global maximum of an objective function (or fitness function) of the problem by random search. The natural parameter set of the optimization problem is first coded as a finite-length string. Then three operators - reproduction, crossover and mutation – are employed to search the optimization of the problem through a coding of a parameter space. Reproduction is a process in which individual strings are copied according to their objective-function as some measure of profit, utility or goodness that we want to maximize. Copying strings according to their fitness values means that strings with a higher value have a higher probability of contributing one or more offspring in the next generation. After reproduction, simple crossover may proceed in two steps. First, members of the newly reproduced strings in the mating pooling are mated at random. Secondly, each selected pair of strings undergoes crossing over and then produces two new strings. Each bit value of the two new strings is chosen randomly from that of the two selected strings on the same bit position. After crossover, mutation operation is applied. Mutation is the occasional (with small probability) random alteration of the bit value of a string. In the binary coding of the parameter, this simply means changing a 1 to 0, and vice versa. The above three operations have proved to be both computationally simple and effective in attacking a number of important optimization problems. The flow chart for the genetic algorithm is shown in Fig. 2.

In the synthesis procedure, the genetic algorithm is used to maximize the following object function:

$$SF=\left[\sum_{i=1}^{J} a_i\left(D_{d_i}-D_{o_i}\right)^2\right]^{-1} \quad (3)$$

were $D_d$ is the desired value of a design parameter and $D_o$ is the obtained value of this parameter is each iteration. It is possible to include J design parameters in this function, each with a different weight $a_i$. The design parameters used in this work are sidelobe level (SLL), beamwidth and ripple level in the flat top beam region. The power of the genetic algorithm lies in its ability to avoid the local extreme and to converge to the global extreme of the object function.

## III. Numerical Results

Arc arrays are used to synthesis the six-sector antenna by the genetic algorithm. A circular array antenna with M elements distributed uniformly on the circumference is plotted in Fig. 1. Arc arrays of various size can then be constructed by considering the elements lying on a specified angular sector as active element, i.e., those actually used for forming the beam. In the examples given here, the number of active elements considered is $M/2$.

To synthesize the six-sector antenna, circular array located on xy plane with radius $R=2.392\lambda$ and $M = 30$ was considered. The spacing of elements on the arc is $\lambda/2$. Here $\lambda$ is the wavelength. The main beam is chosen to be flat in 60° range with a ripple level of $\pm 1/2$ dB and the sidelobe is chosen to below 10dB from the main beam. Note that the sidelobe level can be also chosen to below 30dB. However, the result is almost the same due to the size of this circular array. The excitation currents are computed by using the genetic algorithm via Eq. (3). The synthesis pattern is shown in Fig. 3. It is clean the synthesized pattern is good.

Next, let us consider a typical room with dimension $11m \times 12m \times 4m$ as shown in Fig 4. In this room, assume that the 25cm-thick walls, floor and ceiling are all concrete materials with a complex dielectric constant $\varepsilon_r = 6.5 - 0.43j$ at 57.5GHz [4]. The transmitting antenna is a half-wave dipole and vertically polarized. The transmitting antenna is located at the center of the room with coordinates (5.5m, 6m, 3.5m). The locations of the receiving antenna with a fixed height of 1.5 meters are uniformly distributed in the building and there are total 2000 receiving points. It is clear that the mean rms delay spread is reduced 20% for a typical room by using sectored antenna as shown in Fig 5. Numerical results show that is effective to combat the multipath fading.

## IV. Conclusions

Synthesizing directional arc array antenna as a sectored antenna by the genetic algorithm is presented. Based on the desired pattern, the synthesis problem can be reformulated into on optimization problem. The genetic algorithm maximizes the object function where we can control beam width, sidelobe level and other parameters of interest in design. This process avoids the local maximum of the object function and achieves a good approximation to the desired pattern. Numerical results show that the mean rms delay spread is reduced 20% for a typical room by using sectored antenna and is effective to combat the multipath fading.

## Acknowledgment

This work was supported by National Science Council, Republic of China, under Grant NSC-88-2213-E-032-011.

## Reference

[1] D. E. Goldgerg, *Genetic Algorithm in Search, Optimization and Machine Learning*, Addision-Wesley, 1989

[2] F. Ares, S. R. Rengarajan, J. A. F. Lence, A. Trastoy and E. Moreno, “Synthesis of antenna patterns of circular arc arrays,” *Electronics Letters,* vol. 32, pp. 1845-1846, Sept. 1996.

[3] Y. C. Jiao., W. Y. Wei, L. W. Huang, and H. S. Wu, ”A new low-side-lobe pattern synthesis technique for conformal arrays,” *IEEE Trans. Antenna Propag.*, Vol. 41, pp. 824-831, June 1993

[4] T. Manabe, Y. Miura and T. Ihara, "Effects of antenna directivity and polarization on indoor multipath propagation characteristics at 60 GHz," *IEEE J. Select. Areas Commun.*, vol. 14, pp. 441-448, April 1996.

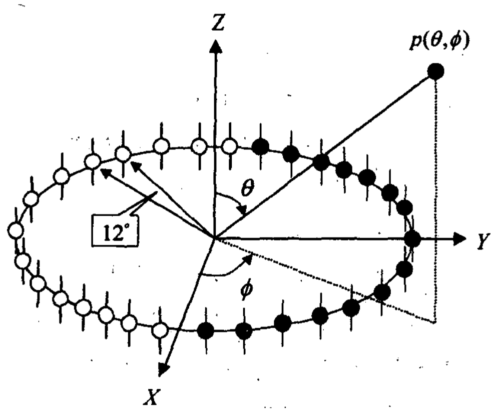


*Fig.1*

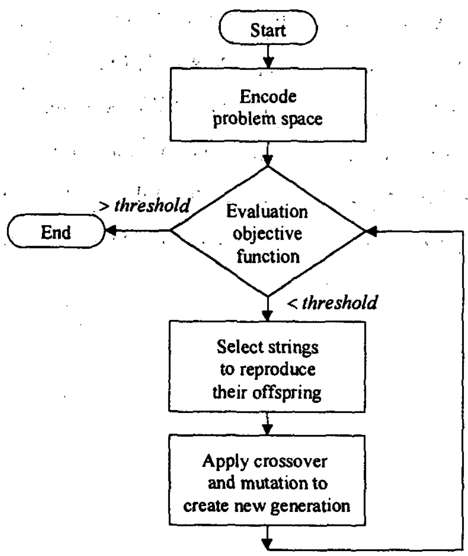


*Fig.2*

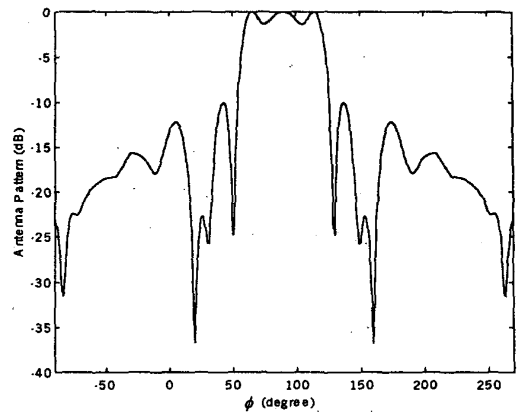


*Fig.3*

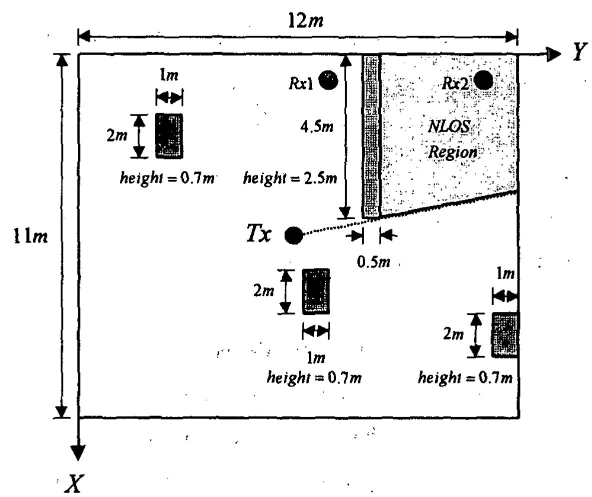


*Fig.4*

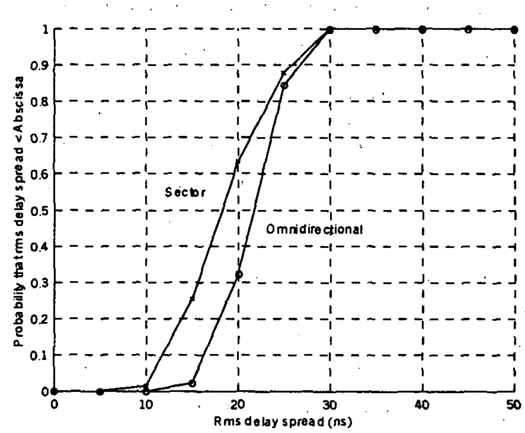


*Fig.5*