Antenna Array Beamwidth Widening with Phase Only Optimization Based on Genetic Algorithm

K.S. Beenamole, Sona O.K, Hemprasad Ghanta, Devaraj V, Ashish Meena, AK Singh.
Electronics and Radar Development Establishment, C.V. Raman Nagar,
Bangalore 560093, India.
ksbeena@yahoo.com

Abstract—
This paper reports about the beamwidth widening in active phased arrays using phase only synthesis. The phase only optimisation has been carried out using Genetic Algorithm. The simulations have been validated practically with an 8 element antenna array. The required phase shift values have been realized with stripline power dividers for demonstration purpose. The simulation and measured results are in good agreement and a beam broadening factor of ~2.4 has been achieved.

I. INTRODUCTION

Shaped beam synthesis using the combination of Genetic Algorithm(GA) and other synthesis methods and low sidelobe pattern synthesis have already been reported by many authors[1,3]. There are many kinds of shaped beams realized in antenna engineering. Among them beamwidth broadening is of particular importance because of its application in radar antennas especially in active phased arrays. In the present paper the GA has been used as a tool for the optimization of the phases of the array elements. The present method is useful for improving the search occupancy and reducing the search frame time for large active phased arrays. The phase only perturbation is useful in the transmit beam broadening for active phased arrays wherein the transmitted amplifiers are operated in saturation and amplitude adjustment is not practical during the transmit mode of operation.

The present paper describes a method for broadening the beam of an 8 element antenna array using phase only element weights synthesized using Genetic Algorithm. The simulated phase shift values have been realized using RF feed networks and fed to an 8-element linear array for practical validation of the results. The experimental results of the 8 element linear array integrated with a phase tapered power divider has been presented in comparison with a uniform amplitude, uniform phase power divider.

II. GENTIC ALGORITHM DEVELOPMENT

A simple Genetic Algorithm that yields good results in many practical problems is composed of three operators: Reproduction, crossover and mutation. Fig. 1 shows the crossover and mutation processes and the GA cycle developed for antenna design optimization is depicted in Fig. 2. Individual array radiation pattern is sampled to get Q sampling points and the fitness function for these sampled points is defined as Eqn. (1)

$$fitness = \frac{1}{1+\sum_{i=1}^{Q} P_0 |\left(S_{di} - S_{ci}\right)|} \qquad (1)$$

where P_0 is the penalty constant with the value within (0,1), S_{di} is the desired radiation pattern value and S_{ci} is the computed value using GA respectively. The optimisation is achieved by the suitable design of the fitness function for the shaped and other parts of radiation pattern.

The radiation pattern of an 8-element array has been calculated with an inter-element spacing of $d=0.5\lambda_0$, where λ_0 is the free space wavelength. The array gives a beamwidth of 12.8° with uniform amplitude/phase tapering. The Genetic Algorithm was developed for an initial population of 16, a discard rate of 50% and a mutation rate of 1% with P_0 to be 0.1 in Eq. (1). The array has been optimised to get a maximum beamwidth widening of 31° in this case resulting a beam broadening factor of 2.42. The optimised phase shift for the Eight elements of the array are as [0 -159 -128 -139 -148 -127 -156 0].

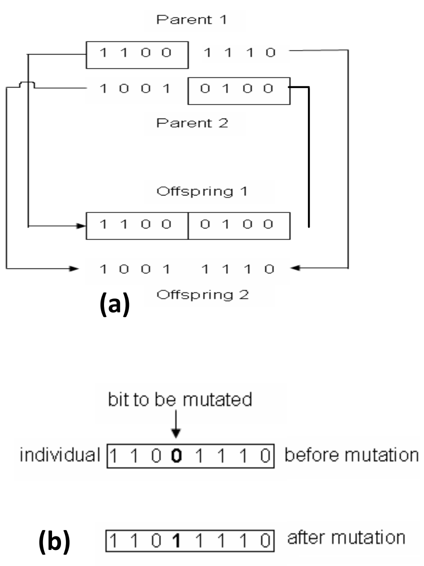

Fig. 1 Genetic Algorithm
(a) An illustration of the crossover process
(b) An illustration of the mutation process

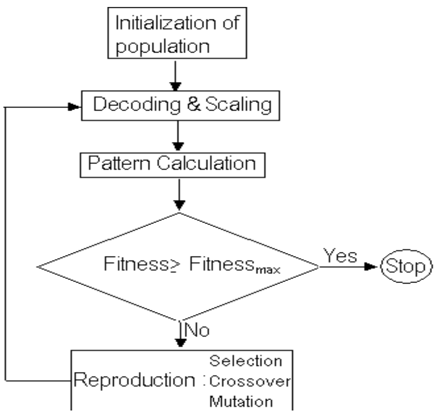

Fig. 2 The Genetic Algorithm cycle

III. DESIGN OF ANTENNA ARRAY AND RF FEED NETWORKS

An 8-Element linear array operating in S-band has been chosen here to validate the developed algorithm for beam broadening. The antenna array has been designed using microstrip meander line antenna elements [1]. The design has been done using EM Simulation package (IE3D) and the elements are arranged in a linear array with interelement spacing of 0.5λ to avoid grating lobes in the visible zone. Two types of RF Feed networks (A phase tapered Feed network and a uniform feed network) are considered in this case to evaluate the GA. The theoretical array beam width of the array with uniform amplitude/phase distribution has been compared with the beamwidth of the array fed with the phase tapered feed network. The phase tapered feed network has been designed with the optimised GA values required to get the necessary beam broadening. Both feed networks have been designed in stripline configuration using Advanced Design Systems (ADS) Software Package.

IV. FABRICATION OF ANTENNA ARRAY

A linear array of 8 elements has been fabricated employing the microstrip meander line antenna elements [2] as shown in Fig. 3. A glass epoxy substrate (FR4) with dielectric constant 4.4 and thickness 3.2 mm has been chosen for the fabrication.

Fig. 3 Photograph of 8-element meander line array inter element spacing d=0.5λ

V. FABRICATION OF POWER DIVIDERS

Two different types (phase tapered and uniform phase) of power dividers have been fabricated in stripline configuration for testing the meander line linear array. The substrate used is RT Duroid with thickness of 31 mil and dielectric constant of 2.2. The first one has been designed and realized with the tapered phase values and with uniform amplitude distribution. The fabricated power divider is shown in Fig. 4. An 8-element power divider with uniform amplitude/phase tapering has also been fabricated for comparing the results of the tapered feed network.

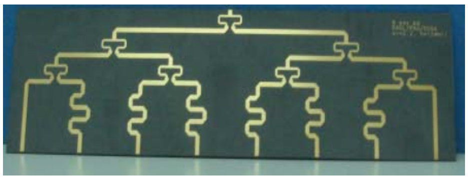

Fig.4 Photograph of the inside layout of the 1:8 way stripline power divider-exploded view.

VI. RESULTS

The radiation pattern of the 8-element array with uniform feed network is shown in Fig. 5. The radiation pattern of the array with tapered phase feed network is shown in Fig. 6. The phase tapering gives a beamwidth of 32° as against 13.1° with the uniform phase power divider. In this particular case a beam broadening factor of 2.44 has been achieved.

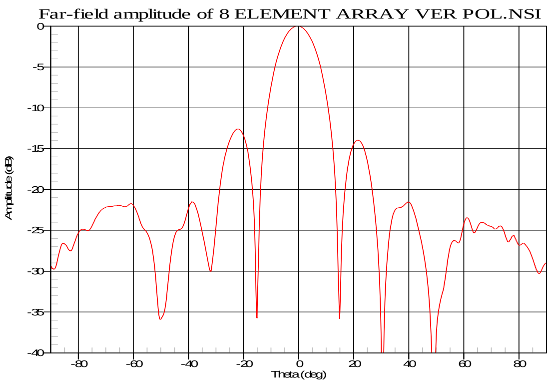

Fig.5 Radiation pattern of 8 element array with uniform feed network.

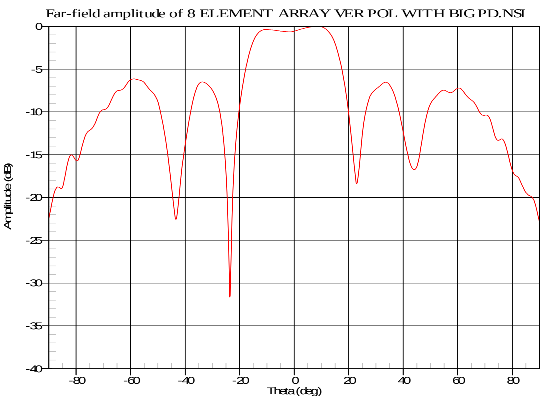

Fig.6 Radiation pattern of 8 element array with tapered feed network.

VII. CONCLUSIONS AND DISCUSSION

This paper reports a beam broadening method suitable for active phased arrays using phase only synthesis based on Genetic Algorithm. The optimised phase values have been implemented in an 8-element linear array through the required feed networks. A beam broadening factor of 2.44 has been achieved using this technique.

ACKNOWLEDGMENT

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