# Reduction of Side Lobe Level of Thinned Phased Array Antenna using Genetic Algorithm

P. Brahma, P. Nandi, A. Senapati and J. S. Roy
School of Electronics Engineering, KIIT University
Bhubaneswar 751024, Odisha, India

## ABSTRACT

Thinned phased array antenna is useful for Radar and satellite communications. Main drawback of phased array antenna is generation of side lobes and grating lobes when the beam is titled from broadside direction toward the end-fire direction. This paper reports the optimization of thinned phased array antenna using genetic algorithm (GA). By varying the tilt angle form broadside direction main beams of the phased are generated at different tilt angles and by GA optimization at different tilt angles side lobe levels (SLL) are reduced by thinning process. Variations of SLL and half-power beamwidth (HPBW), obtained using GA optimization, are compared with fully populated array.

## General Terms

Array Thinning, Phased Array Antenna, Genetic Algorithm, Side Lobe Reduction.

## Keywords

Phased array; thinning; genetic algorithm; side lobe level

## 1. INTRODUCTION

Antenna array is used to increase the overall gain of the array system and to control the radiation pattern (like, beam tilting, beam shaping etc.) of the array [1,2]. An antenna array produces main beam, nulls and side lobes. Side lobes consume power and causes interference in communication towards the undesired directions and therefore side lobe levels must be lowest in a practical antenna array. Phased array antenna is very useful for Radar and satellite and vehicular applications. In phased array main beam can be tilted in any desired direction by changing electronically the relative phase between the antenna elements [1, 2]. If in an array, all the antenna elements are excited (switched on), the array is called fully populated array. In a thinned array antenna [3-7] some of the antenna elements are kept switched off strategically and in this way narrowest beam can be produced with lowest side lobe level, without degrading the performance of the array. In the 'off' state the antenna element is either open circuited or terminated by a matched load. Various types of array synthesis methods are available to reduce side lobe levels keeping desired gain of the array constant. There are different methods of reducing side lobe level of an antenna array, some of which are, statistically tapered thinned arrays [8], thinning based on empirical or analytical formula [9], and thinning using optimization techniques [3-7,10-12]. Some of the popular optimization techniques, used for thinned array are genetic algorithm, particle swarm optimization, ant colony optimization.

In this paper, genetic algorithm (GA) is used to design thinned linear arrays with tilted beam at different directions from the broadside direction. Genetic algorithm is used to optimize the 'on' and 'off' states of the array to produce lowest side lobe level of the linear phased array. Numerical results show that lowest side love can be obtained using this technique. The results are compared with the fully populated array.

## 2. THINNED ARRAY ANTENNA

Thinning an array means strategic elimination of some elements in a uniformly spaced array to produce a radiation pattern with low side lobe level (SLL), where the positions of the elements are fixed. Due to turning off the elements, there is no large degradation in performance. All the elements have two states either "on" or "off", depending on whether the element is connected to the feed network or not. In the "off" state, the element is passively terminated to a matched load and therefore effectively the elements from the array are removed. Fully populated array and thinned array are shown in Figure1.

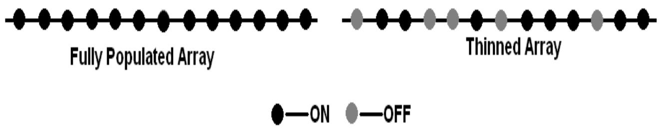


**Fig 1: Fully populated array and thinned array**

## 3. THINNING OF PHASED ARRAY ANTENNA USING GENETIC ALGORITHM

Genetic algorithm (GA) is a search procedure using random selection for optimization of a function [13] and has been used for robust searches in complex spaces and this method can be used for electromagnetic problems also [14]. Here, genetic algorithm is used to optimize lowest side lobe level of the linear array by optimizing the "on" and "off" positions of antenna elements in the array.

The diagram for the linear array with 'n' number of elements with inter-element spacing 'd' and progressive phase shift 'α' is shown in Figure 2.

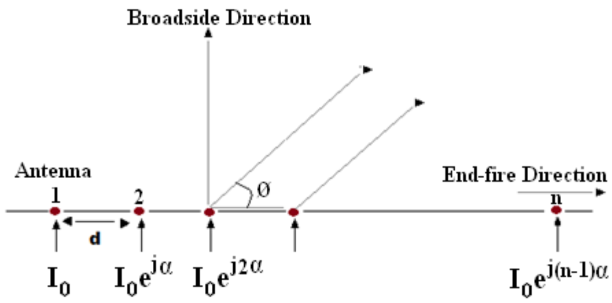


**Fig 2: Antenna array with 'n' number of elements**

Array Factor of the antenna array is expressed as [2]

$$\mathbf{AF} = \sum_1^n \mathbf{I_n} . \mathbf{e}^{\mathbf{jn2\pi d}(\cos\theta - \cos\emptyset)} \tag{1}$$

This equation for array factor is used as cost function in GA optimization.

All the antennas are considered isotropic and the uniform separation between the antenna elements is (d) 0.3λ, where λ is the free-space wavelength. In order to avoid grating lobes during beam tilting, the inter-element separation between the antenna elements is kept less than the maximum value of 'd', given by [1,2]

$$d_{max} = \frac{\lambda}{1+\sin\Phi} \tag{2}$$

Here normalized array factor is $|AF|/|AF|_{max}$. Number of antenna elements is 10. Thinned array combination, for which best result is found (best chromosome), is 1 1 1 1 1 1 1 1 0 1. Here '1' means the antenna is 'on' and '0' means the antenna is 'off'.

The GA optimized results for normalized array factors for thinned phased array antenna are compared with the results obtained for fully populated array at different tilt angles in Figure 3, Figure 4 and Figure 5.

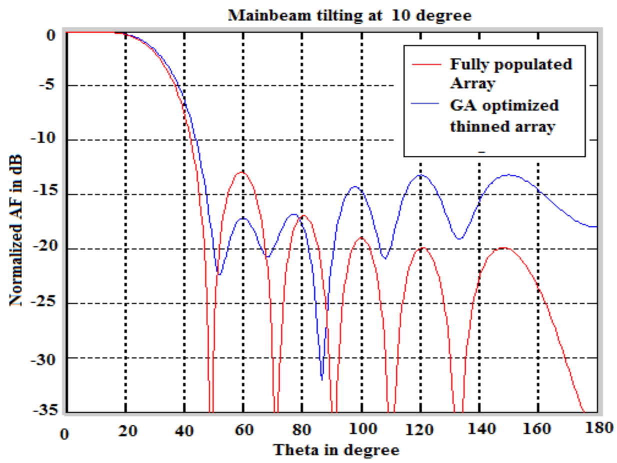


**Fig 3: Normalized array factor using GA and without using GA when main beam is tilted at 10 degree**

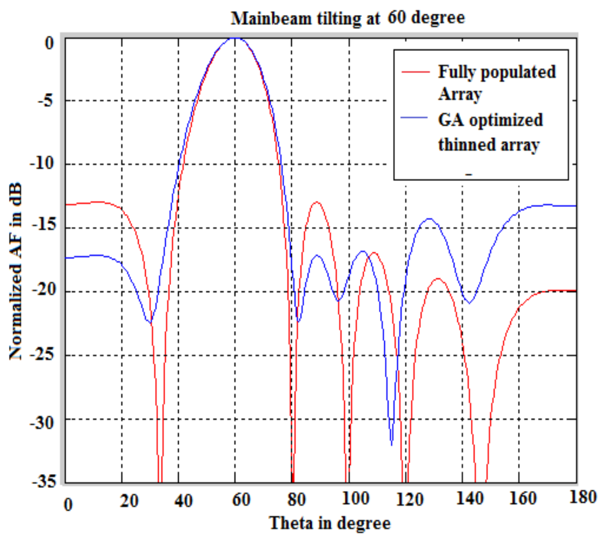


**Fig 4: Normalized array factor using GA and without using GA when main beam is tilted at 60 degree**

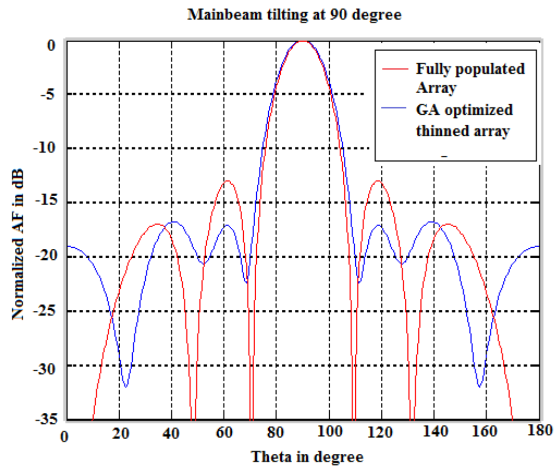


**Fig 5: Normalized array factor using GA and without using GA when main beam is tilted at 90 degree**

The comparison of side lobe level and half-power beamwidth, between GA optimized thinned array and fully populated array are tabulated in Table 1.

**Table 1. Comparison of SLL and HPBW between fully populated array and GA optimized thinned array**

| Angle | SLL | | HPBW | |
|---|---|---|---|---|
| | Fully populated array | GA optimized thinned array | Fully populated array | GA optimized thinned array |
| $0^0$ | -12.97 dB | -13.2 dB | $54^0$ | $60^0$ |
| $10^0$ | -12.98 dB | -13.2 dB | $48^0$ | $50^0$ |
| $20^0$ | -12.98 dB | -13.21 dB | $35^0$ | $40^0$ |
| $30^0$ | -12.98 dB | -13.21 dB | $27^0$ | $30^0$ |
| $40^0$ | -12.97 dB | -13.21 dB | $23^0$ | $25^0$ |
| $50^0$ | -12.97 dB | -13.22 dB | $22^0$ | $22^0$ |
| $60^0$ | -12.98 dB | -13.22 dB | $20^0$ | $20^0$ |
| $70^0$ | -12.97 dB | -14.29 dB | $16^0$ | $18^0$ |
| $80^0$ | -12.97 dB | -14.3 dB | $12^0$ | $15^0$ |
| $90^0$ | -12.98 dB | -16.88 dB | $10^0$ | $12^0$ |

Variations of side lobe levels and half-power beam widths with tilt angle are compared in Figure 6 and Figure 7 respectively.

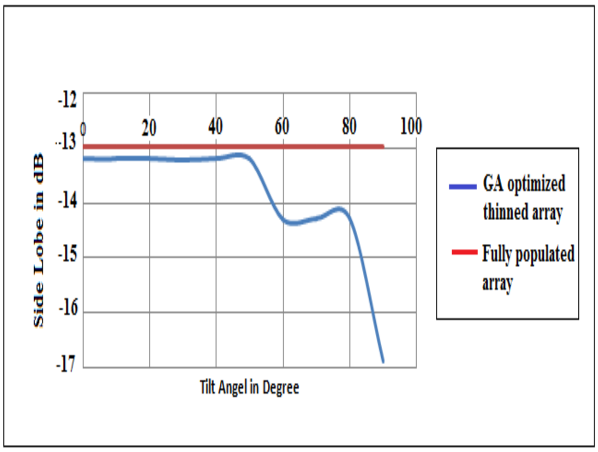


**Fig 6: Variation of side lobe level with tilt angle for GA optimized thinned array and fully populated array**

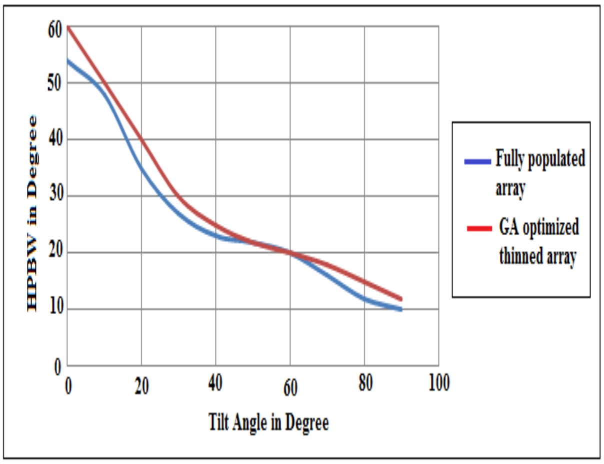


**Fig 7: Variation of half-power beamwidth (HPBW) of main beam with tilt angle for GA optimized thinned array and fully populated array**

## 4. DISCUSSION AND CONCLUSION

Genetic algorithm is applied to the thinning of phased array antenna. In GA optimization program is run for 40 generations. In Table 1, the variation of results for HPBW between fully populated array and GA optimized thinned array is due to the fact that for less number of ‘on’ elements in thinned array, gain of the thinned array is less than the fully populated array where all the elements are ‘on’. Even after maintaining the condition (2), grating lobes may appear and those results are eliminated in optimization. As shown in Figure 6, as beam is tilted toward the end-fire direction, reduction of side lobe level using GA optimization is more. Side lobe may be reduced further using array synthesis technique along with optimization method which is a task for future research work.

## 5. REFERENCES

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