



Thinning of Semi-Elliptical and Quarter-Elliptical Antenna Array Using Genetic Algorithm Optimization

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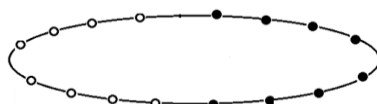
Abstract: Design of thinned semi-elliptical and quarter-elliptical antenna arrays, with uniform excitation and uniform spacing using genetic algorithm (GA) optimization, is presented in this paper. Thinned arrays produce narrow directive beam without causing major degradation of fully populated antenna arrays. Semi-elliptical array contains antenna elements along half of the elliptical geometry and quarter-elliptical array contains antenna elements along one-fourth of the elliptical geometry. Optimization is employed on these array arrangements to reduce side-lobe level (SLL) of the arrays. Simulation results of the GA optimized thinned arrays are compared with a fully populated arrays for all the cases to illustrate the effectiveness of the proposed method.

Keywords: Thinning; semi-elliptical array; quarter-elliptical array; genetic algorithm optimization; array factor; side-lobe level

I. Introduction

An antenna array is arrangement of similar antennas oriented similarly to get greater directivity in a desired direction. Antenna array is used to increase the overall gain of the antenna system and to control the radiation pattern (like, beam tilting, beam shaping etc.) of the array. Antenna arrays have been widely used in different applications including direction finding, scanning, radar, sonar, and wireless communications [1]. Thinning an array means switching 'off' some elements in a uniformly spaced or periodic array to generate a pattern with low side lobe level [2]. In this paper, the locations of the elements are fixed and all the elements have two states either "on" or "off" (similar to Logic "1" and Logic "0" in digital domain), depending on whether the element is connected to the feed network or not. In the "off" state, either the element is passively terminated to matched load or open-circuited [3]. If there is no matching between the elements, it is equivalent to removing them from the array. Thinnings may have 2^Q combination, where Q is the number of array element [4]. When many antenna elements are arranged in the form of ellipse it called elliptical arrays. Elliptical array has one extra parameter 'eccentricity' as compared to other geometry which helps to reduce side-lobe level [5]. The geometry of semi-elliptical array and quarter elliptical array is same as that of elliptical array (Figure 1). In semi-elliptical antenna arrays configuration, half of the antenna element in an elliptical array are permanently kept 'off' and other half are 'on' to radiate in the desired direction. In quarter- elliptical array, one-fourth antenna elements of a elliptical array are kept 'on' and rest of the elements are 'off'.

Figure 1 Geometry of semi-elliptical antenna arrays

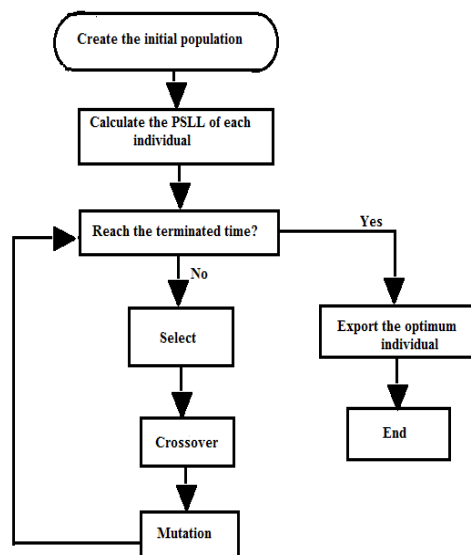


Application of semi-elliptical array antenna can be seen in mobile tower, where radiation is required to radiate in particular direction. In this paper thinning has been optimized using GA to reduce SLL without causing significant degradation in antenna performance. Also, investigation of optimized thinned elliptic array with various inter-element spacing is presented in this paper.

II. GENETIC ALGORITHM

Optimization refers to the selection of a best element from some set of available alternatives. GA's are search algorithms based on the mechanics of natural selection and natural genetics [6-9]. With combined innovative flair of human search, GA's are based on the theory "Survival of the Fittest" among string structures with a structured yet randomized information exchange. In every generation, a new set of creatures (strings) is created using bits and pieces of the fittest of the old; an occasional new part is tried for good measure. A flow chart for GA optimization is shown in Figure 2:

Figure 2 Flow chart of genetic algorithm



III. THINNING OF SEMI-ELLIPTICAL AND QUARTER-ELLIPTICAL ARRAY USING GA

The SLL is defined as $SLL(dB) = 20 \log_{10}(\text{amplitude of side-lobe} / \text{amplitude of main lobe})$. SLL changes with different 'on' 'off' condition of antenna elements [11]. The maximum amplitude of SLL for particular combination is termed as SLL_{max} . Overall radiation pattern changes when many antenna elements are combined together in an array due to array factor (AF). If the value of array factor is large, it causes radiation in undesired direction [12-13]. Therefore, GA optimization is used as GA controls the value of array factor.

The cost function for calculating array factor of semi-elliptical arrays and quarter-elliptical arrays are same as that of elliptical arrays and can be expressed as [11,13]:

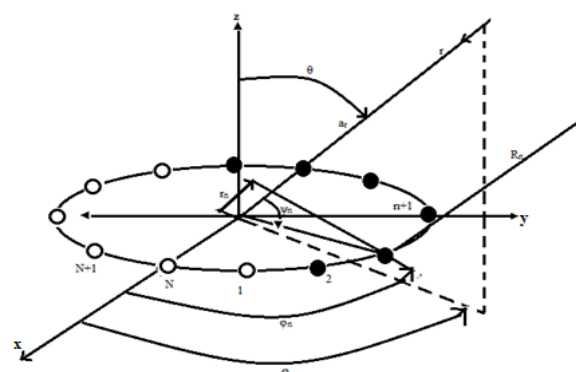
$$AF(\theta, \varphi) = \sum_{n=1}^N A_n (\exp(jk \sin \theta (a \cos \varphi_n \cos \varphi + b \sin \varphi_n \sin \varphi))$$

Where, a, b are semi-major and semi-minor axis respectively, eccentricity, $e = \sqrt{1-a^2/b^2}$.

$\varphi_n = 2\pi (n-1)/N$ is the angle in the x-y plane between the x axis and the n-th element, φ is the azimuth angle measured from positive x-axis and θ is the elevation angle measured from positive z-axis. A_n is the excitation amplitude of n-th element and k is the wave number. Normalized array factor in dB can be expressed as follows:

$$AF (dB) = 20 [\log_{10} |AF| / |AF|_{max}]$$

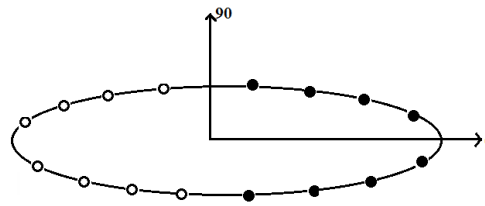
Figure 3 Geometry of semi-elliptical antenna array in xy plane



In this paper, thinned optimized results of semi-elliptical array is presented for 3 cases, for N=100, N=200 and N=400 with variation of inter-element spacing.

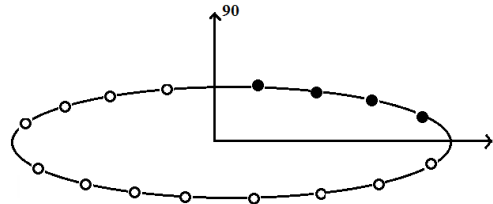
In case 1: All antenna elements of semi-ellipse are 'ON' as shown in Figure 4. Optimized thinning is applied on this pattern using GA.

Figure 4 Semi-elliptical antenna array



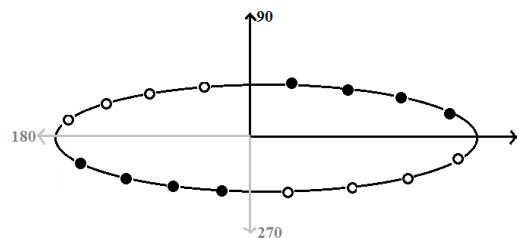
In case 2: One-fourth of the antenna elements of ellipse are 'ON' as shown in Figure 5. Optimized thinning is applied on this quarter-elliptical configuration using GA.

Figure 5 Quarter-elliptical antenna array



In case 3: Here, vertically opposite quarter-elliptical portions of the array are 'ON', as shown in Figure 6. Optimized thinning is applied on this pattern using GA.

Figure 6 Vertically opposite populated quarter-elliptical antenna array



IV. OPTIMIZED RESULTS

GA optimized result of thinned semi-elliptic array is compared with that of fully populated semi- elliptic array in each case. The following plots (Figure 7(a) & 7(b)) are simulated for Figure 4 geometry of semi-elliptical array for $N=100$. Here, $\phi = 0^\circ$ is considered.

Figure 7(a) Plot of optimized radiation

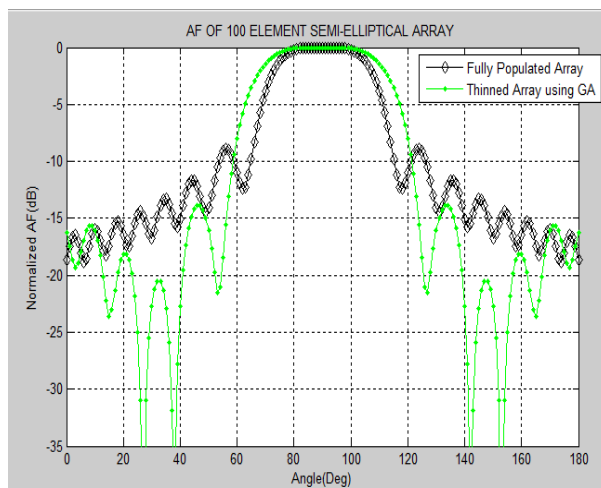
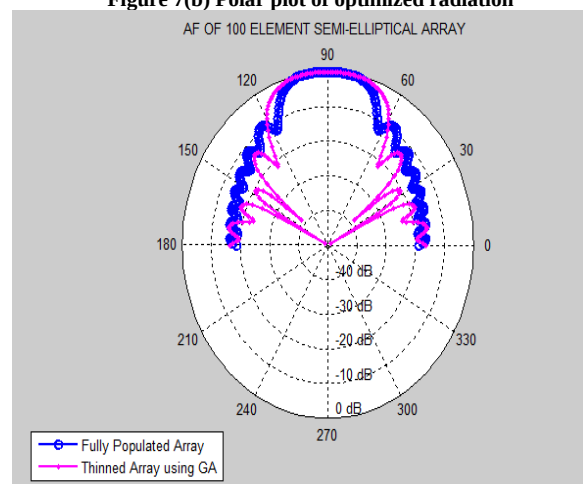


Figure 7(b) Polar plot of optimized radiation



The following plots (Figure 8(a) & 8(b)) are simulated for quarter-elliptical array (Figure 5) for $N=100$. Here, pattern is plotted at $\phi = 0^\circ$ plane.

Figure 8(a) Plot of optimized radiation

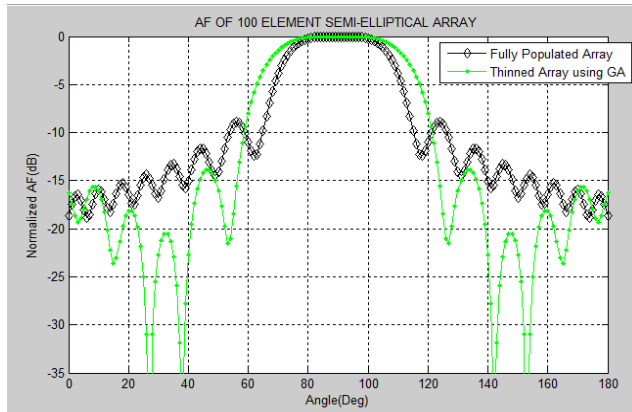
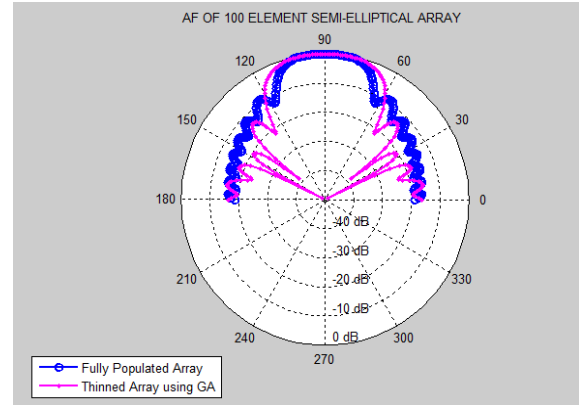


Figure 8(b) Polar plot of optimized radiation



The following plots (Figure 9(a) & 9(b)) are simulated for vertically opposite quarter-elliptical array (Figure 6) for $N=100$ at $\phi = 45^\circ$ plane.

Figure 9(a) Plot of optimized radiation

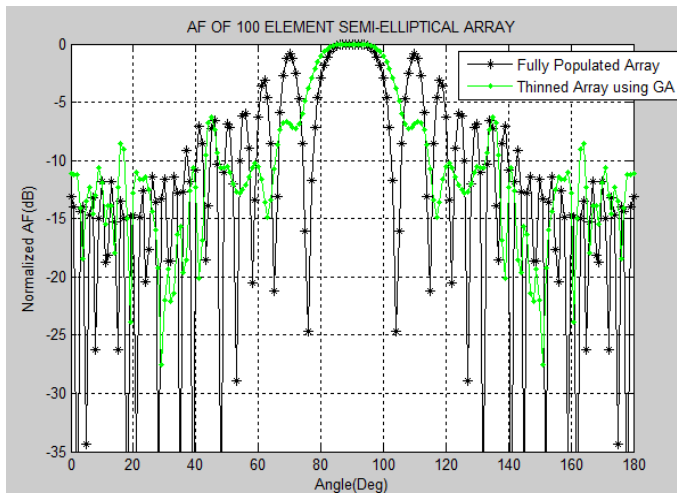
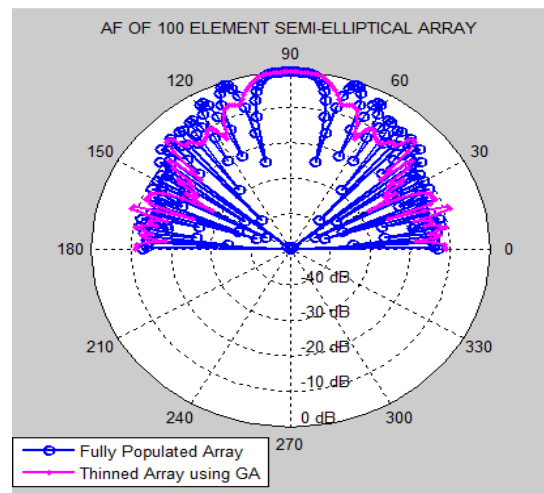


Figure 9(b) Plot of optimized radiation



Similarly, GA optimized results for different number of antenna elements are tabulated below:

Table I Results of Optimized Thinned Semi-Elliptical/Quarter-Elliptical Array using GA

Sl. No.	No. of elements in fully populated ellipse	No. of elements in semi-ellipse/quarter-ellipse	Spacing (λ)	No. of 'ON' elements on semi-ellipse/quarter-ellipse	Filled Ratio (%)	Maximum SLL(dB)	HPBW (Deg)
1.	100	50	0.5	22	44	-14.68	140
2.	100	25	0.5	14	56	-13.88	115
3.	100	50	0.8	21	42	-6.63	104
4.	200	100	0.2	48	48	-13	103
5.	200	50	0.2	29	58	-14	136
6.	200	100	0.95	47	47	-3.71	166
7.	400	200	0.2	85	42.5	-12.81	105
8.	400	100	0.2	48	48	-13.46	106
9.	400	200	0.95	93	46.5	-5.95	190

For all the above cases wave number, $k=8.75 \text{ m}^{-1}$ is kept constant.

V. CONCLUSION

In the present work, element excitation is kept uniform. Inter-element spacing and eccentricity are adjusted in each case to reduce SLL. A significant reduction in SLL after GA optimization is observed, for all the given

geometries. However, for 200 & 400 antenna elements for geometry of Figure 6, doesn't gave good optimized result as radiation from opposite located antennas produce undesired grating lobe. Wide beam-width is observed in all the cases because less number of antenna elements is making up the array. GA optimization is used only to find the optimal antenna position to reduce SLL.

VI. REFERENCES

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