Optimization of Symmetric Linear Antenna Array Using Multiobjective Genetic Algorithm

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Abstract— Themultiobjectivegenetic algorithm (GA) optimization method is used for realizing a symmetric linear antenna array. Multiobjective Genetic algorithm is a high performance stochastic evolutionary algorithm is employed to reduce the side lobe level (SLL) of an antenna array. Objective function is applied to optimize the amplitude, spacing and phase variation of the elements. The simulation analysis using MATLABis performed on 16 element arrays. Better SLL and nulls are observed in case of amplitude optimization. Case of amplitude optimization for realization of antenna array is further studied for different number of elements.

Keywords—Genetic algorithm, objective function, linear antenna array, side lobe level.

1. INTRODUCTION

THE Overall radiation pattern of an antenna array is determined by the array factor and it depend on geometrical configuration (linear, rectangular etc.), inter-element spacing, current excitation amplitude and phase. Side lobe reduction and interference suppression can be obtained by controlling these parameters. The methods used for the synthesis of antenna arrays: deterministic include analytical methods, neural networks and stochastic include genetic algorithm (GA), simulated annealing (SA), and differential evolution (DE). Stochastic methods have many advantages over deterministic methods like ability to deal with large number of optimization parameters, easy to implement on computers[1-3].

In the past, multiobjective optimization techniques were used in the antenna array analysis in different ways to optimize the parameter of the array. A multiobjective genetic algorithm (GA) technique is employed in [4] to suppressing the fixed interference, to minimize SLL and avoiding the rise of maximum side lobe level (MSLL) of non-uniform linear phased arrays. Circular antenna arrays are optimized using multiobjectivememetic optimization (MOMO) approach which provide simultaneous SLL suppression and directivity maximization [5]. A multiobjective differential evolution (MODE) technique is used to design reconfigurable antenna array [6]. A memeticmultiobjective evolutionary algorithm approach is employed for SLL minimization of sub arrayed linear antenna array design [7]. Various optimization techniques for antenna arrays is discussed in [8] to minimize SLL, a brief introduction on GA and particle swarm algorithm (PSO) is done. In [9] design of non-uniformly excited symmetric linear array with optimized techniques of real coded genetic algorithm (RGA) is done.

In this paper, it is assumed that array is uniform utilizing objective function to individually optimize three parameters of the array namely the amplitude, phase of the excitation and separation between the array elements using the GA technique to achieve both low side lobes and nulls in cyclic manner to find out the case in which we get better results. GA is used to minimize the non-derivable objective function, so there is no need to compute the auxiliary functions. In this paper, we are presenting the optimization of symmetric linear antenna array using genetic algorithm (GA). In this paper, effect of increases in the number of antenna elements on the performance and computational cost is also analyzed. The rest of the paper is arranged as follows: Section II problem formulation is presented. Simulation results are presented in Section III followed by conclusions in Section IV.

2. Problem Formulation

The multiobjective optimization is applied to synthesize the linear antenna arrays with maximum SLL and nulls reduction using the GA. The first objective function is formulated for optimizing the distance, while the phase and amplitude of the array element will be kept constant. The second objective is formulated for optimizing the phase, while amplitude and distance of the array elements will be kept constant. The third objective function is formulated for optimizing the amplitude, while phase and distance of the array elements will be kept constant.

The array factor of a linear antenna array with uniform element spacing d is given by:

$$AF(I, d, \emptyset) = 2\sum_{n=1}^{M} In\cos(kdn\cos(\theta) + \emptyset n) \quad (1)$$

Where k =2*pi/λ is the wavenumber, n is the number of element, and In, $\emptyset$n and$\boldsymbol{d}$n are amplitude, phase excitation and distance of the nth element from the origin, respectively. The absolute value of this array factor and its square are then calculated, then its value is integrated over all the values of theta and the resultant function is optimized by GA. A MATLAB program is developed for performing this optimization and GA is presented next.

The problem is formulated on an array consisting of 16 elements, the initial values for amplitude excitations are taken as unity, phase excitation are taken as zero for all elements, the value of distance are taken in terms of λ/2. Each optimization is run with the following GA parameters:

Maximum number of generation "g"= 500, Population size "p"=20, Spacing between the elements should be greater than 0.35λ and amplitude excitation should be less than 2.8[10].

3. Simulation Results

The antenna array consists of 16 elements, with an inter element spacing of λ/2. A Genetic Algorithm with a population size 20, 500 generations as in using MATLAB program and the best result was found for each iteration. The side lobes band is from [1 88] and [94 181] and nulls directions be at 80 and 100 in all optimization techniques.

A. **Optimization by adjusting the element spacing**

In this deep nulls of -37.6dB occur at 80 and 100 angle. Also two bands of SLL are there in which near lobes are at -28.43 dB and from [66 74] and [106 114] are at -40.43 dB and far lobes from [40 60] and [120 140] are at -46.37 dB.

The array pattern obtained are as follows:

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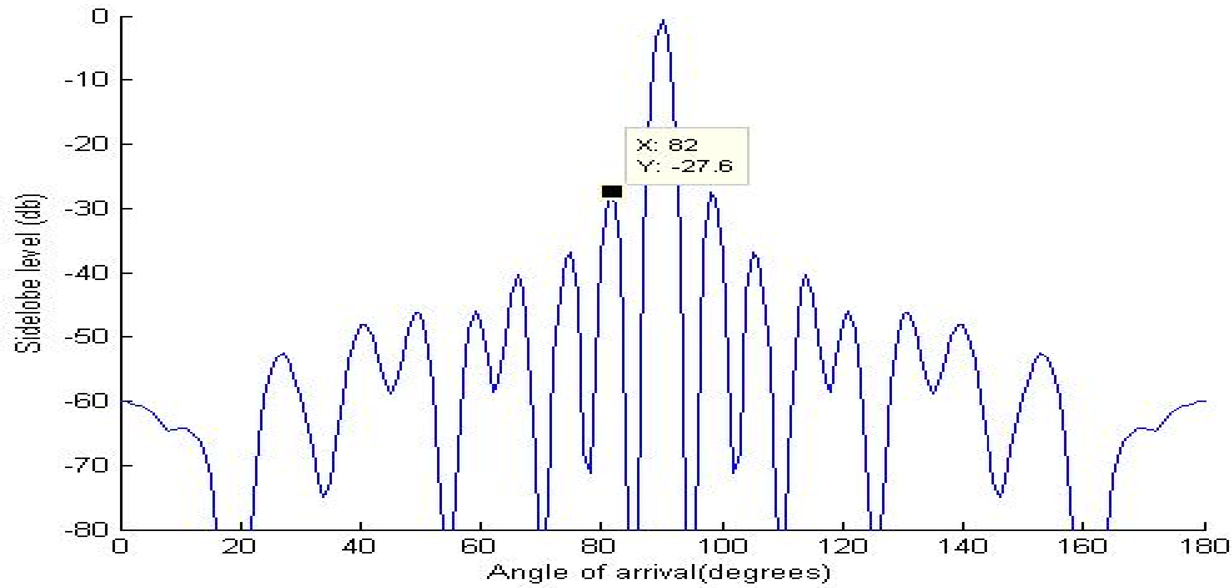

Fig. 1 indicates the radiation pattern obtained by optimizing the distance of elements from origin.

Table 1: Results obtained by optimizing the element spacing of the elements

d_n	d_1	d_2	d_3	d_4	d_5	d_6	d_7	d_8	d_9	d_{10}	d_{11}	d_{12}	d_{13}	d_{14}	d_{15}	d_{16}
Distance (element spacing)	0.58	1.63	2.57	3.49	4.49	5.49	6.55	7.58	8.35	9.42	10.43	11.49	12.61	13.77	14.77	15.81

B. **Optimization by adjusting the feed current phase**

Here deep nulls of -34.15dB occur at 80 and 100 angle. Also SLL are there in which near lobes are at -27.5 dB from [75 81] and [99 105] and far lobes from [40 66] and [115 141] are below -45.76 dB.

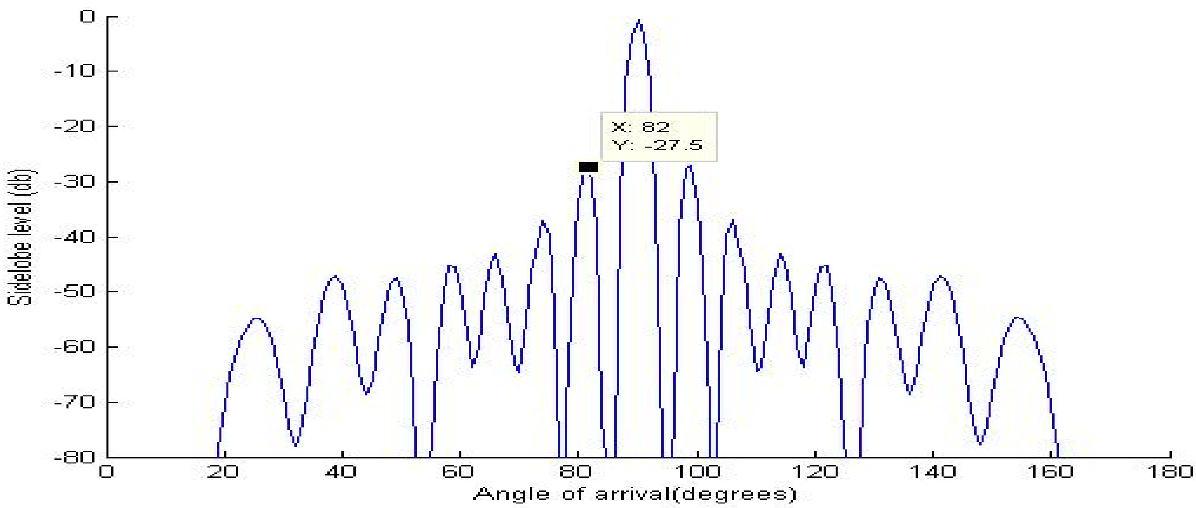

Fig. 2 indicates the radiation pattern obtained by optimizing the phase of 16 elements.

Table 2: Results obtained by optimizing the phase excitation of the element

Ø$_n$	Ø$_1$	Ø$_2$	Ø$_3$	Ø$_4$	Ø$_5$	Ø$_6$	Ø$_7$	Ø$_8$	Ø$_9$	Ø$_{10}$	Ø$_{11}$	Ø$_{12}$	Ø$_{13}$	Ø$_{14}$	Ø$_{15}$	Ø$_{16}$
Phase	0.013	0.062	0.11	0.13	0.09	0.12	0.18	0.15	0.19	0.20	0.34	0.53	0.44	0.35	0.35	0.29

C. **Optimization by adjusting the feed current amplitude**

Here deep nulls of -40.26 dB occur at 80 and 100 angle. Also SLL are there in which near lobes are at -31.5 dB from [75 81] and [99 105] and far lobes from [40 66] and [115 141] are below -39.25 dB.

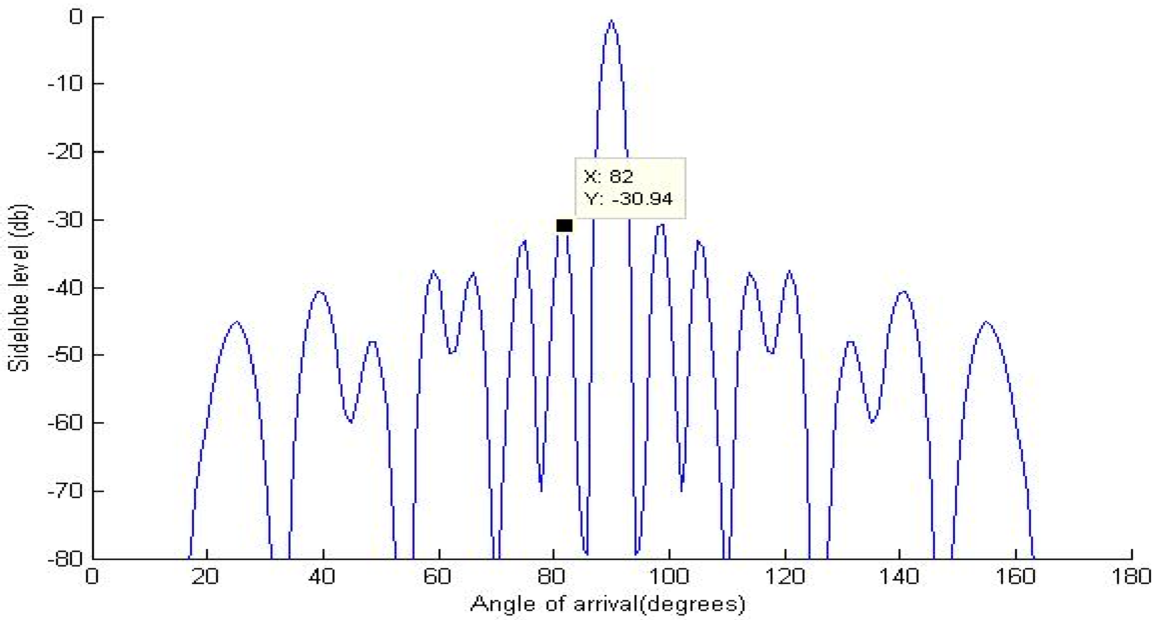

Fig. 3 indicates the radiation pattern obtained by optimizing the amplitude excitation of the elements.

Table 3: Results obtained by optimizing the amplitude excitation of the elements

I_n	I_1	I_2	I_3	I_4	I_5	I_6	I_7	I_8	I_9	I_{10}	I_{11}	I_{12}	I_{13}	I_{14}	I_{15}	I_{16}
Current amplitudes	0.68	0.79	0.75	0.58	0.78	0.70	0.50	0.50	0.53	0.50	0.50	0.50	0.50	0.50	0.50	0.58

From these figures we can observed that nulls in the desired directions are at -37.6 dB, -34.15 dB, -40.26 dB in case of fig. 1, fig. 2, fig. 3 respectively. These three optimization are carried out for a specific number of cycles. It can be seen that better nulls are obtained in case when the amplitude excitation is optimized, while keeping phase and spacing of the elements constant. The nulls obtained in amplitude excitation is -40.26 dB better than from spacing and phase optimization. Also, from figures we can observed that SLL is better in case of amplitude optimization is optimized. So from figures we included that we go for the amplitude excitation for better nulls and SLL.

D. **Performance analysis of linear antenna array for different array element for amplitude optimization**

Best radiation pattern for the 24 element array by adjustment of feed current amplitude

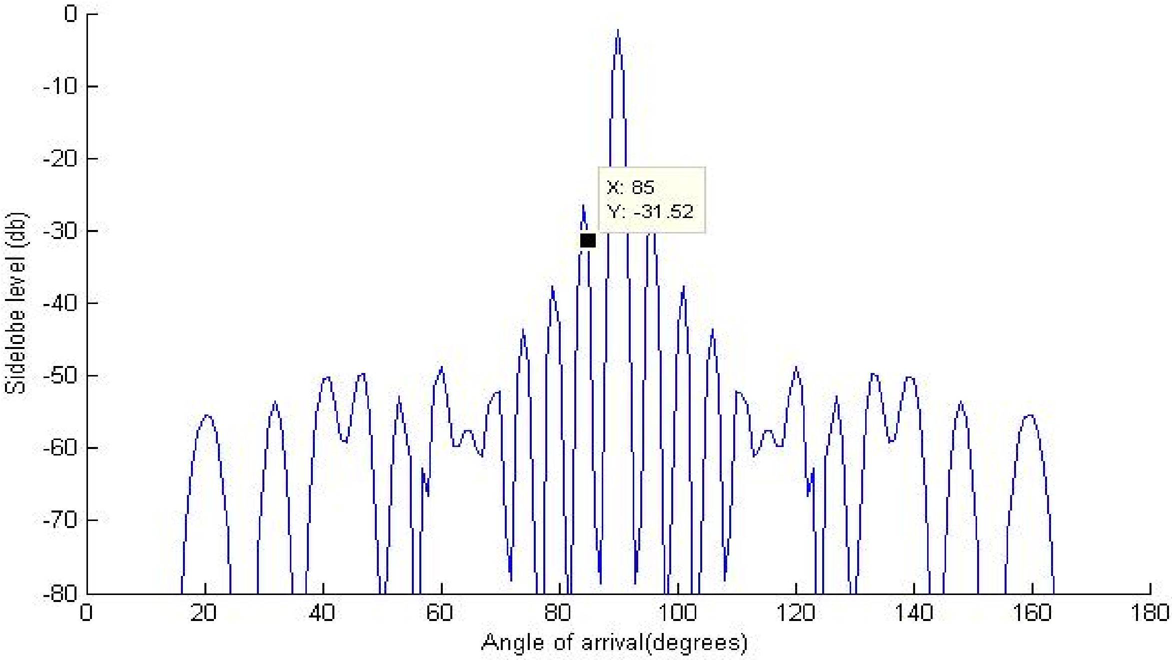

Fig. 4 indicates the radiation pattern obtained by optimizing the amplitude excitation for 24 element array.

Best radiation pattern for the 32 element array by adjustment of feed current amplitude

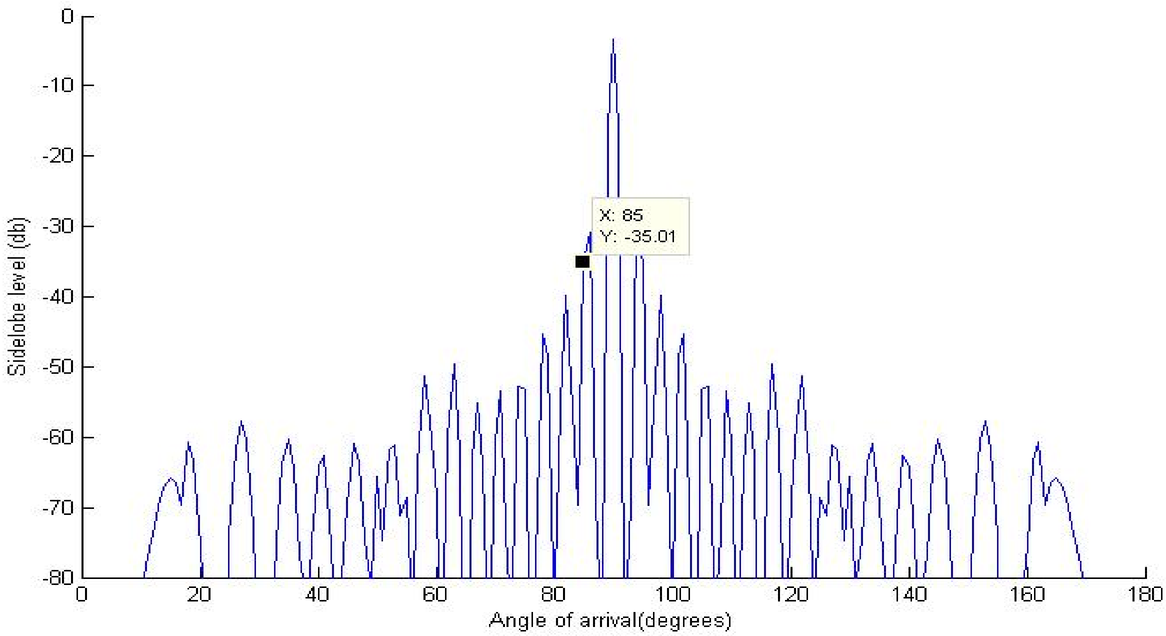

Fig. 5 indicates the radiation pattern obtained by optimizing the amplitude excitation for 32 element array.

From above figure 4 and figure 5 we observed that the radiation pattern obtained by optimizing the amplitude excitation, the SLL is reduced by more than 3.49 dB from -31.52 dB to -35.01 dB, when we increase the array elements from 24 to 32 and the best result was found for each iteration.

Table 4: Results obtained by optimizing the amplitude excitation of the elements

No. of elements	SLL(dB)	Nulls(dB)
16	-30.94	-40.26
24	-31.52	-43.19
32	-35.01	-88.03

The computational cost for each cycle is as follows [10]:

Computational cost= 3* K *p*(n-1)*g

Where K is angle at which the magnitude of array factor is calculated and was taken as 180.Factor "3" indicates that three separate optimizations.

Table 5: Computational cost for each cycle

Cn	Computational Cost(computation per cycles)
C16	81000000
C24	124200000
C32	167400000

When we increase the array element from 16 to 24 then the increase in computational cost is 55.3%. Also when array element increase from 24 to 32, the increase in computational cost is 55.3%. So we can say that as "n" increases, the computational cost "C" also increases. Also, as we increase the array elements it showed the performance improvement by reducing the side lobes and null levels.

4. Conclusion

A multi-objective genetic optimization algorithm is applied to individually optimize the three parameter of the array namely amplitude, phase, separation between the array elements. Here, amplitude optimization outperforms the other two parameters optimization in terms of SLL reduction and nulls. The effects of number of elements on performance and computational cost are also studied in this paper. This technique can be also be applied for two dimensional arrays, simultaneously optimization of two or more parameter, and also for the optimization of nonlinear antenna array.

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