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Antenna Array Synthesis for Suppressed Side Lobe Level Using Evolutionary Algorithms

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Abstract: - Antenna performance was greatly reduced by the presence of the side lobe level (SLL) in the radiation pattern which is undesirable. The large antenna arrays have the ability to provide interference reduction and increases the range of signal coverage. In this paper binary genetic algorithm (BGA), multi point crossover GA (MPXGA) algorithms and real coded GA (RGA) are employed to reduce the side lobe level of an antenna array. The aim is to produce the desired radiation pattern which exhibits the minimum SLL. The above algorithms are successfully implemented to find the optimum excitation levels of antenna array with greater performance i.e. < -40dB reduction in SLL over the conventional methods.

Key words: **Side Lobe Level (SLL), Genetic Algorithms (GA), real coded GA (RGA), Multipoint Crossover GA (MPXGA)**

I. INTRODUCTION

Antennas array synthesis is widely used in different communication systems phased array radar applications, satellite and wireless communication applications in which high power gain is required in the given direction. Several studies have been made on the antenna arrays where the array pattern of an antenna should have high power gain in the given direction, minimum side lobe level and variable band width .The desired array pattern can be realized by choosing the physical placement of the antenna elements, amplitude and phase of excitations. There are several mathematical techniques are adapted in the design of array to have the required side lobe level of an antenna. But the mathematical techniques usually converge to local values rather than global optimum values. Hence there is need of evolutionary techniques that are applied to the phased array antenna synthesis to minimize the side lobe level of an array and these techniques produces best results than differential techniques. The new Stochastic techniques [3] like Genetic algorithms [4][5] and swarm intelligence algorithms produce better results than the differential methods. In the present application binary genetic algorithms (BGA), real coded GA (RGA) and multipoint cross over Genetic algorithms (MPXGA) techniques are employed to find the excitations of the antenna array for minimum side lobe level. These algorithms yield better results than the conventional techniques. The comparison of these three methods are shown at the end and is observed that BGA in all cases gives better performance of about < -40 dB SLL is achieved than real coded GA and MPX GA.

II. FORMULATION OF FITNESS FUNCTION

In the antenna array synthesis and design it is often desired to achieve the minimum side lobe level (SLL) apart from the narrow beam and efficiency. In the process of formulation for the fitness function for minimizing the Side lobe level the antenna array[13][14][16], the array factor for '2N' number of elements were considered and assumed that the elements of an array are spaced linearly and separated by $\lambda/2$ where λ is the wave length. The array factor for '2N' number of elements for the geometry shown in the Fig. 1 is given by the equ.(1)

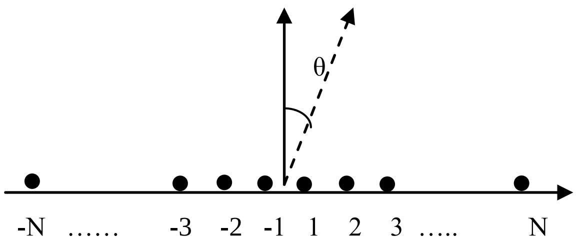

Fig. 1: Geometry of Array Elements of Size 2N

$$(AF)_{2N} = a_1 e^{j(1/2)kd\cos\theta} + a_2 e^{j(3/2)kd\cos\theta} + \dots + a_1 e^{-j(1/2)kd\cos\theta} + a_2 e^{-j(3/2)kd\cos\theta} + \dots + a_M e^{-j[(2M-1)/2]kd\cos\theta}$$

(1)

$$(AF)_{2N} = 2\sum_{n=1}^{N} a_n \cos\left[\frac{(2n-1)}{2} kd\cos\theta\right] \quad (2)$$

a_n is the excitation coefficient
d is the distance between the elements
k is wave number
θ is the angle between the line of observer and source position.

The normalized array factor is give by the Equ. (3)

$$(AF)_{norm} = \left[\frac{AF}{\max(AF)}\right] \quad (3)$$

The power gain or voltage gain of antenna in db is given by Equ. (4) and Equ.(5) respectively.

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$$(AF)_{norm} = 10[\log AF - \log(\max(AF))] \qquad (4)$$

$$(AF)_{norm} = 20[\log AF - \log(\max(AF))] \qquad (5)$$

$$Cost = SLL_{max} = AF_{max} - Max(AF != AF_{max}) \qquad (6)$$

The side lobe level is calculated by using the mathematical method i.e. finding the differentiation at each point and if there is any change in sign appears then that point is stored in the memory for further processing of the array. If there is a change in the sign and is the peak value then store the corresponding array factor belongs to particular value of θ. Among all the stored values the maximum value except the main lobe value corresponds to the maximum side lobe level of the array. Earlier mathematical methods like binomial distribution, Dolph Tschebyscheff array and Taylor polynomial [13][14] are used to evaluate for minimum side lobe level. These mathematical methods needs some initial conditions and if these selected initial conditions are good, then it yields good results. Because of the limitations in mathematical techniques, there is a need to change over to the new techniques or stochastic methods. In the present application Genetic Algorithms are applied on 16, 24 and 32 elements to find the Array Factor and hence the side lobe level. The algorithms presented in this paper will utilize BGA, RGA and MPXGA. Among the three algorithms the binary GA (BGA) will yield good results i.e. up to <-44dB side lobe level. All these algorithms are compared and the results are depicted at the end of the paper..

III. EVOLUTIONARY ALGORITHM

The evolutionary algorithms refer to a powerful search and optimization methods are influenced by biological mechanisms of evolution. These algorithms involves selection, recombination and competition of the individuals in population adequately represents the potential solutions. Genetic algorithms are the one of the powerful algorithms among the evolutionary algorithms. For the above described problem the three models of GA i.e. multi point crossover (MPXGA), real coded (RGA) [9][10] and binary genetic algorithms (BGA) are used to find the optimum values for excitation coefficients of an antenna array. In all the three methods of GA [9][10] initial population or chromosomes are selected randomly and given as input to the cost function.

IV. COST FUNCTION

In the given problem the cost i.e. side lobe level is evaluated using the Equ. (6). for every population and perform the following GA operations on the population i.e. selection, crossover and mutation to generate new population.

V. SELECTION

The chromosomes that are selected in each iteration are such that they produce better cost values among all. Normally 50% of the population which produces better results is selected in each iteration.

VI. CROSSOVER

Once the selection process is completed we need to separate the resultant population such that part of the population acts as mother chromosomes and part of it acts as father chromosomes to generate the offspring. Keeping the selected chromosomes as it is we generate new population by means of crossover technique. Once the new population is generated then we make use of them to mutate and produce new population.

VII. MUTATION

Once the cross over is completed then these new chromosomes are mutated and generate new population for next generation, which is used to for evaluating the cost function. The evolutionary cycle of GA is represented by the flow chart shown in the Fig.2.

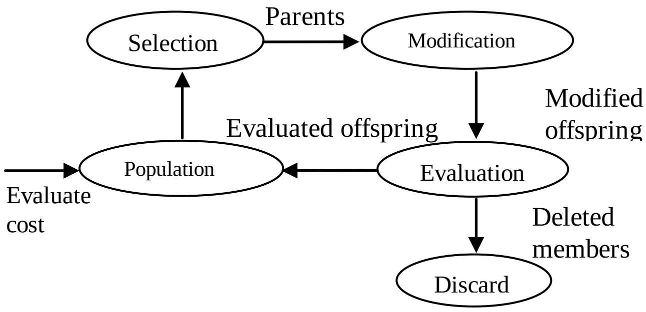

Fig. 2 Evolutionary Cycle of GA

The following are the steps to implement Genetic algorithm.

Step 1: Start by generating the random population of *n* chromosomes.

Step 2: Evaluate the cost function for each chromosome in the population.

Step 3: Create a new population by repeating the following steps.

Step 4: Select two parent chromosomes from a population according to their fitness.

Step 5: With a crossover probability to cross the parents and to form a new offspring. If no crossover was performed, offspring is a copy of parent itself.

Step 6: With a mutation probability mutate new offspring at each locus to generate new chromosomes.

Now place new offspring in the population and use this newly generated population to evaluate the cost function and repeat these steps until required condition is satisfied. The following is the flow chart Fig. 3 representing the above algorithm.

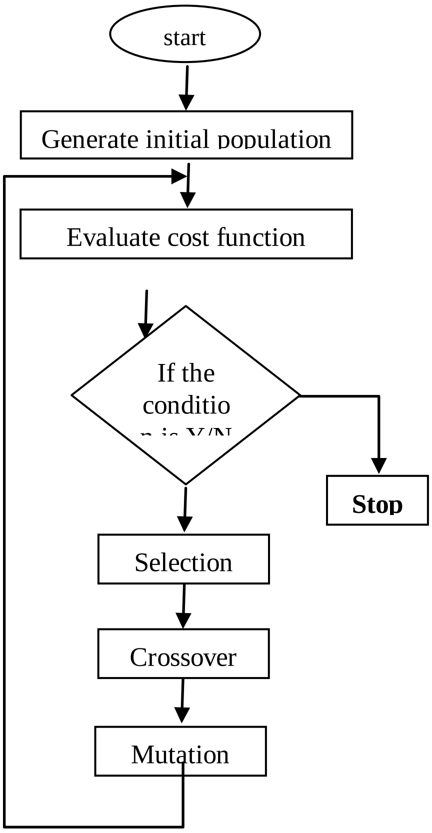

Fig. 3: Flow Chart to Implement GA.

VIII. RESULTS

The general representation for the half of the symmetric array is shown in the fig.1 for '2N' number of elements. The selected algorithms will optimize the excitation coefficients for 16, 24 and 32 elements of an array for minimum side lobe level. The optimization results are presented in the Table 1, Table 2, Table 3 for 16, 24 and 32 elements of the antenna array respectively. For each set of elements of the array Side lobe levels are calculated and the results are given at the end of the table. The excitation obtained through the algorithms are used in the calculation array factor and plotted for 16, 24 and 32 elements respectively. The radiation patterns for each set of elements are shown in the figures fig4, Fig. 5and Fig. 6 respectively. These plots show the smooth reduction in the side lobe level in each case.

IX. CONCLUSION

In all the three cases using 16, 24 and 32 elements of array antenna, binary genetic algorithm (BGA) produces better results than RGA, MPXGA. The side lobe level decreased up to -44.627 dB down the main lobe which represents the high reduction in the side-lobe level which is very much desirable. The side lobe reduction is more useful in radar , wireless and sonar applications. Particularly in radar application it is very much useful to reduce the side lobe level to avoid interference from other sources.

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Table 1: Excitation of elements of an array of size 16

El.No.	BGA	RGA	MPXGA
±1	1.0000	0.9793	0.9323
±2	0.9216	0.8975	0.8646
±3	0.7843	0.7077	0.7552
±4	0.6000	0.5390	0.6184
±5	0.4078	0.3805	0.4226
±6	0.2471	0.2601	0.2636
±7	0.1255	0.1457	0.1488
±8	0.0588	0.0922	0.0834
SLL in dB	**-44.6710**	**-36.2900**	**-35.8400**

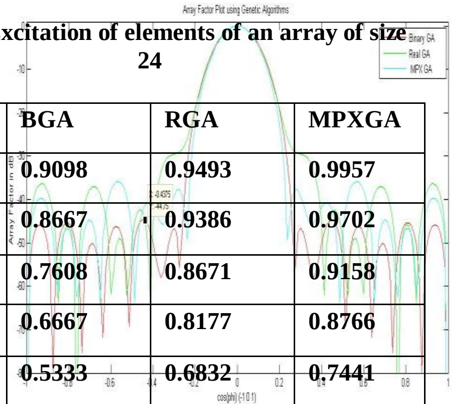

Table 2: Excitation of elements of an array of size 24

El. No.	BGA	RGA	MPXGA
±1	0.9098	0.9493	0.9957
±2	0.8667	0.9386	0.9702
±3	0.7608	0.8671	0.9158
±4	0.6667	0.8177	0.8766
±5	0.5333	0.6832	0.7441
±6	0.4431	0.6334	0.7097
±7	0.3020	0.5094	0.5565
±8	0.2196	0.3933	0.4543
±9	0.1725	0.3021	0.3801
±10	0.0941	0.2406	0.2651
±11	0.0431	0.1636	0.2369
±12	0.0235	0.1172	0.1456
SLL in dB	-40.9400	-35.9710	-33.3520

Fig.4 Array Factor for 16 Elements

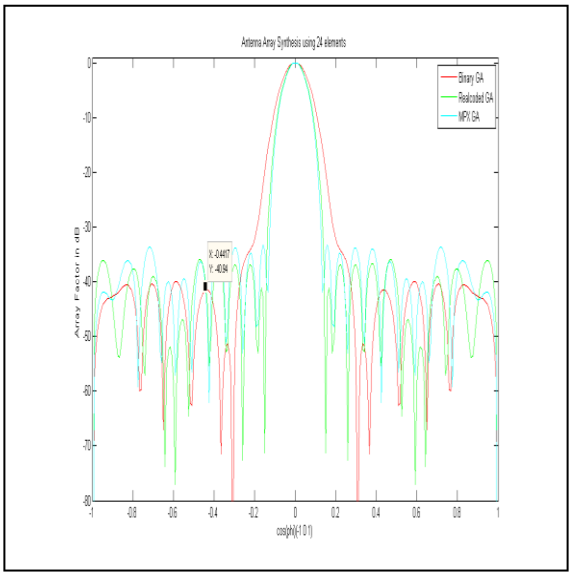

Fig.5 Array Factor for 24 Elements

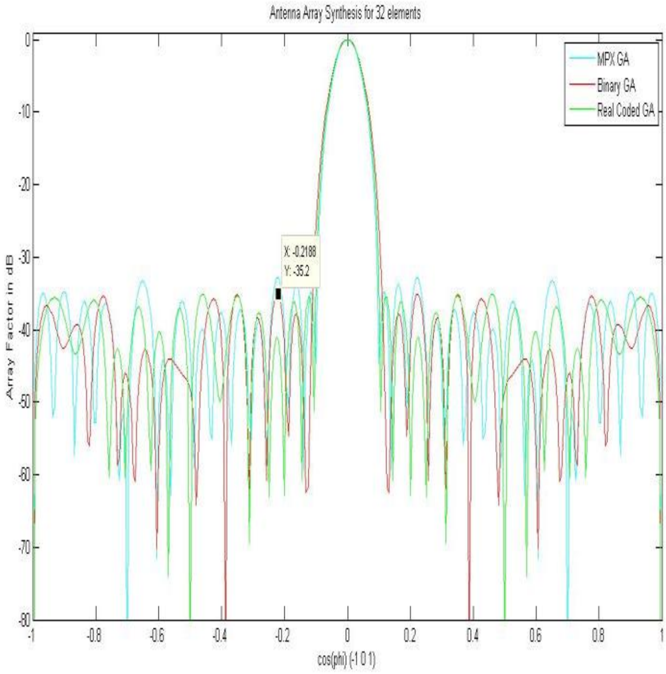

Fig. 6 Array Factor for 32 Elements

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Table 3: Excitation of elements of an array of size 32

El.No.	BGA	RGA	MPXGA
±1	0.9608	0.9628	0.8864
±2	0.9412	0.9303	0.8274
±3	0.9137	0.9815	0.8518
±4	0.8824	0.8546	0.8273
±5	0.7961	0.8263	0.7511
±6	0.7725	0.7229	0.7130
±7	0.6157	0.7207	0.6495
±8	0.5882	0.6332	0.5661
±9	0.4941	0.5545	0.5174
±10	0.4392	0.4545	0.4444
±11	0.3333	0.3853	0.3781
±12	0.2392	0.3205	0.3342
±13	0.2353	0.2680	0.2570
±14	0.2000	0.1603	0.2277
±15	0.1255	0.1772	0.1467
±16	0.0980	0.1124	0.1815
SLL in dB	-35.06	-35.00	-32.096