Synthesis Of Optimized Patterns from Thinned Arrays

G.S.K.Gayatri Devi

Abstract -- Difference patterns find their applications in radar tracking. There rises a need to generate such patterns with minimum sidelobes to reduce clutter and interference in accurate target tracking. A popular technique used for low sidelobe pattern generation is thinning. It reduces the number of elements active in the overall system. In addition to reducing sidelobes, it also reduces cost and weight. In the current presentation, low sidelobe difference patterns are generated from thinned linear assortments. Differential Algorithm is made use of for the pattern generation. Optimized patterns are portrayed for different number of elements. The results computed show good sidelobe level reduction without enhancing beamwidth between first nulls.

I. INTRODUCTION

In target tracking radar systems, it is essential to trace the target with great accuracy. This can be done with a simple sum pattern. The location of the target is specified by the position of main beam. But the accuracy of detection depends on where the target falls within the main beam region. Hence patterns with narrow beam width or high directivity must be generated. Instead difference patterns can be employed in such cases where high angular accuracy is required.

Difference patterns are characterized by a profound sharp insignificant in the bore sight direction in addition to the two foremost lobes on either side. Target detection mainly utilizes this deep null. Placing the target accurately at the null position amid the principal lobes, the target location can be resoluted exactly. This method is more exact as the angular width of null is very narrow compared to a broad beam sum pattern.

One of the main fields which employ difference patterns is Monopulse tracking system. This system employs both sum and difference pattern. The sum beam reveals the presence of target and difference pattern determines its angular position. Conventional methods for generating difference pattern generally use Bayliss aperture distribution [1]. Several works were reported on generation of difference patterns. Elliot [2] developed a method to generate difference patterns with arbitrary side lobes from line source antennas. A Bayliss pattern is taken as initial pattern and an iterative method is applied to produce desired pattern. Mc Namara [3] presented a method for generation of optimum difference patterns. The method uses zolotarev polynomials to find the element excitations, given number of elements and desired side lobe ratio. Lopez [4] et al. employed sub-array configuration and obtained optimum sub array weights for generating difference patterns with minimum change in the feed network. Morabito [5] employed an analytical procedure based on a density taper approach to generate difference patterns from equally excited linear arrays for the simplification of receiving chain and to improve antenna efficiency. Satyanarayana [6] proposed suitable amplitude and phase distributions for generating asymmetric difference patterns useful for marine radar applications.

Generation of optimized difference patterns became somewhat easier with the advent of global optimization techniques. Asim [7] made use of particle swarm optimizer to design a simple feed network for generating difference patterns for monopulse radar system. The optimum weights were obtained by including mutual coupling effects. Salvatore et al. [8] employed sub array configuration for generating difference patterns with desired side lobe level requirement. The optimization was carried out using a hybrid Real Integer-coded Differential algorithm. Varma et al. [9] employed optimization techniques like GA, PSO and Simulated Annealing methods to find optimum amplitude distribution for generation of low side lobe difference patterns. Mohammad [10] described a method for generating difference patterns from sum patterns using a simple beam forming network. Two external edge elements are used for the generation. Yanchang et al. [11] proposed a method which extracts the aperture coefficients from Taylor distribution. The method offers good control over peak side lobe level. A new method for easily computing difference patterns from Dolph-Chebyshev distribution is given by Yanchang et al. in [12].

The main objective of the work is to generate low side lobe optimum difference patterns by the method of thinning. Thinning selectively turns off certain elements without disturbing the system performance. It results in optimum design of arrays with a reduction in cost and weight. Moreover, all the elements are excited uniformly which requires a simple feed network. It is simpler than aperiodically placing the elements because the latter has infinite possible ways of placing the elements. Thinning an ‘n’ element array has only 2^n possible combinations. Hence it reduces time and laborious work on part of the designer. But this is true only for small arrays. For large arrays, as ‘n’ increases the number of combinations also increases. It is impossible to check all possible combinations for best solution. This situation arises a need for methods that give faster solutions. Global optimization techniques satisfy this requirement. Many techniques like GA[13-14], PSO[15], ACO[16] etc. were implemented successfully for solving numerous complex optimization methodology in antenna design. A systematic Differential Evolution algorithm is

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utilized in the current demonstration to obtain optimum antenna configuration.

The paper is organized like this: Introduction is conferred in section I. Section II illustrates operating principles of Differential Evolution algorithm. Section III describes formulation of the problem. Presentation of results is carried in sub division IV. Conclusions and inferences are depicted in article V.

II. DIFFERENTIAL EVOLUTION

DE belongs to evolutionary algorithms family. It was first put forward by Scientist Storn and Research scholar Price [17]. It is a very dominant stochastic erch algorithm accepted globally across the researchers and scientists for solving many complex global optimization problems which also population based systematic approach. Its efficiency was proved in many scientifically predominant arenas like communications sectors, pattern recognition sectors etc., as the abovementioned algorithm offers extemporaneous advantages like few control parameters, satisfactory convergence speed and ease to handle a variety of complex fitness functions

The different stages of the algorithm are depicted in the below flowchart:

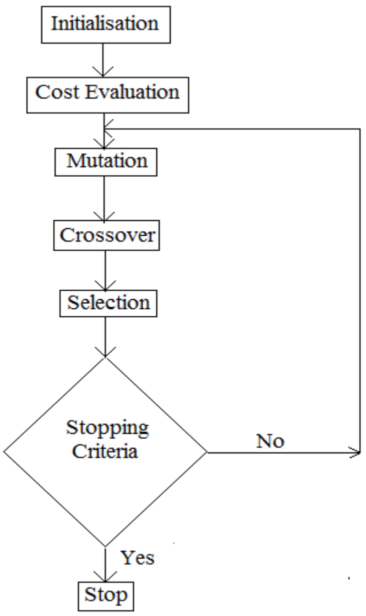

Fig 1. Flowchart for DE

Initialization: An initial number of 'N' population vectors are considered. Target vector is the name assigned to the initialized vectors. The population size remains unchanged throughout the entire course of the algorithm. Let '$a_{i,G}$' e designated as the i^{th} parametric variable vector where i=1, 2, 3, … N. And 'G' represents the generation variable. These parametric variable vectors are unsystematically initialized in a random fashion. Then the vectors are systematically estimated for their cost factor using the corresponding appropriate fitness function.

During the intermediate distinct mutation process, new parametric variable vector functions are created simultaneously by adding a meagre weighted difference between the respective two of the target vectors to the succeeding third target vector, i.e. for any given systematic target vector '$a_{i,G}$', three consecutive parameter vectors such as $a_{r1,G}$, $a_{r2,G}$, $a_{r3,G}$ are selected such a manner that the functional constants i, r1, r2, r3 are different in the way of values and directions to establish new parameter vectors called as the 'donor vectors'.

$$b_{ji,G+1} = a_{r1,G} + F\left(a_{r2,G} - a_{r3,G}\right)$$

At this point r1, r2, r3 ∈ {1, 2, 3, …, N}

At the moment the Mutation process increases the room for exploring optimum solution. Here a constant called mutation factor, 'F' is chosen between 0 to 2.

Parameter vectors with good fitness can be included from earlier operations using crossover operation. Formation of new vectors called as 'trail vectors' ($c_{i,G+1}$) takes place by mixing together the selected target vectors ('$a_{i,G}$') and synthesised donor vectors ($b_{i,G+1}$).

$$c_{ji,G+1} = b_{ji,G+1} \; if \; rand \leq CR \; or \; j = I_{rand}$$
$$= a_{ji,G+1} \; if \; rand > CR \; and \; j \neq I_{rand}$$

Here i϶{1,2,…} and j϶{1,2,3,….D}.

The variable D represents numerous parameters in one of the significant population vector. I_{rand} is random numerical usually selected between 1 to D. Inclusion of this factor makes sure that not less than one vector is selected from donor vector set into trail vector set. CR is another constant chosen between 0 and 1.

Next stage is selection process. Based on the fitness values of the individual vectors, those which satisfy a certain selection criteria will be selected for the next succeeding generation. This current process is mathematically represented in the trigonometric equation as:

$$a_{i,G+1} = c_{i,G+1} \; if \; cost\left(c_{i,G+1}\right) \leq cost\left(a_{i,G}\right)$$
$$= ax_{i,G} \; otherwise$$

The above equations clearly indicate that a newly generated trail vector substitutes parent population vector and passed on to next generation only if it results in reduced cost.

The above operations will continue to repeat until it meets some stopping feasibility criteria. In overall formulation a fixed number of specific generations or predefined cost factor etc. is taken as stopping criteria.

A number of variations in DE are put forward by Storn and Price [17]. A DE//rand//1//binary scheme is formulated in the presentation work.

III. FORMULATION

Consider a symmetric linear array of 2M isotropic elements placed along z-axis as shown in fig.1. All elements have an equal inter element spacing of 'd'.

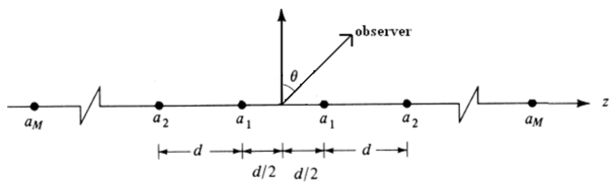

Figure 1 Geometry of linear symmetric array

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Further assume that the amplitude distribution is symmetric about array axis. The resultant array factor can be given as [18]:

$$E(u) = 2j \sum_{m=1}^{M} I_m \sin[(m-0.5)kdu]$$

where $u = \sin\theta$

k= $(2\pi/\lambda)$

d= spacing between two elements, $(\lambda/2)$

λ= operating wavelength

I_m=Excitation coefficient of m^{th} element in the array.

Now the array is thinned with an objective of finding the optimum configuration that results in lowest possible peak side lobe level. Hence I_m takes the value of either 0 or 1.

A DE algorithm is applied to get the optimum array configuration. The parametric variable selection plays the most substantial role in the procedure of convergence of the algorithm to the best solution. The control parametric setting variable function for a DE algorithm with the usage of DE//rand//1//binary systematic stratagem is as given in Table 1.

Table 1: Parameter selection

Parameters for DE	
Population size	30
Mutation	0.7
Crossover ratio	0.8
Number of generations	100

All results are simulated using Matlab software.

IV. RESULTS

A brief description of results obtained has been substantiated in this sub division. An isotropic linear array of 30 elements is considered initially. The assortment is subjected to gradual thinning process. The resulting pattern has a definite peak side lobe level evaluated as -14.91dB. Prior to the process of thinning, it is only -10.44dB. An improvement of 4.5dB can be observed. The pattern is shown in figure 2.

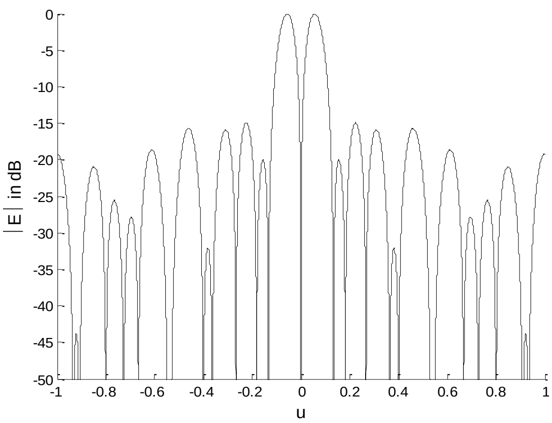

Figure 2. Radiation pattern for 30 element array

The corresponding thinning weights for right half of the array is depicted in figure 3.

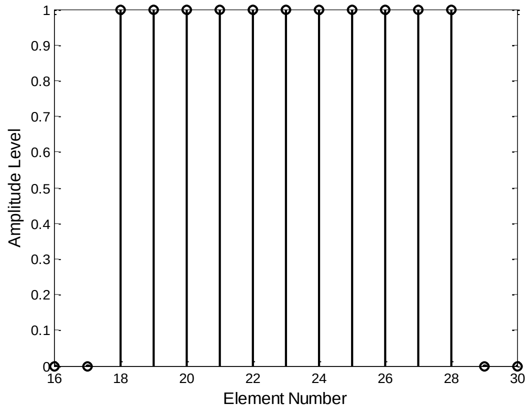

Figure 3. Half the thinning weights for right half of 30 element array

The same process is repeated for different number of elements. As an example, for a 100 element array, a distinct height of peak SLL of -20.17dB is obtained after the gradual procedure of thinning. An improvement of around 9.5dB can be observed. The consequential pattern structure is shown in figure 4.

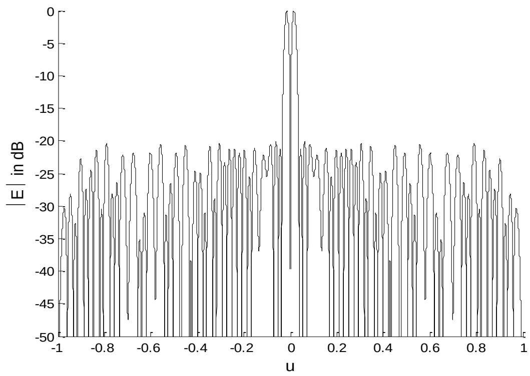

Figure 4. Radiation pattern for 100 element array

The corresponding thinning weights for right half of the array are depicted in figure 5 given below:

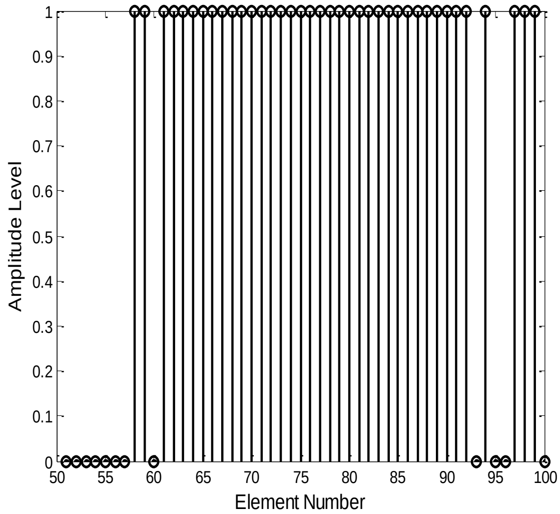

Figure 5. Half the thinning weights for right half of 100 element array

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Figures 6 and 7 show the radiation pattern and the corresponding right half thinning weights for a 200 element array. The peak SLL obtained in this case is -21.9dB. It is only -10.56dB before the array is thinned. An improvement of around 11dB can be observed.

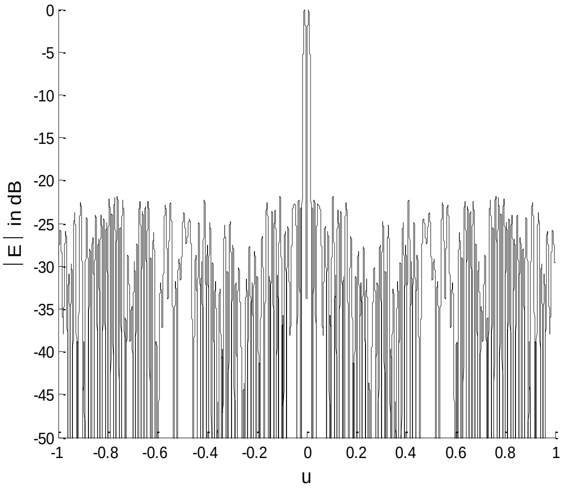

Figure 6. Radiation pattern for 200 element array

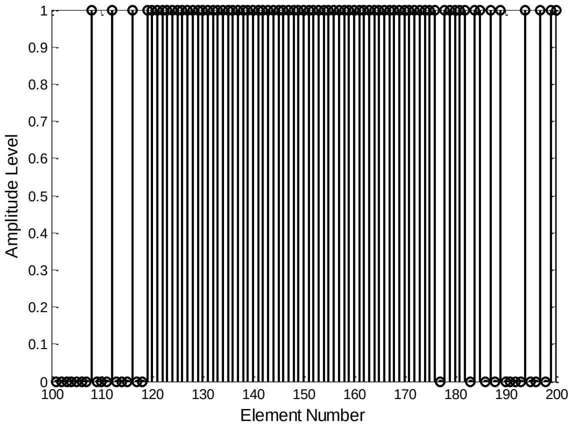

Figure 7. Half the thinning weights for right half of 200 element array

A comparison table for peak SLLs obtained before and after thinning is given below for the sake of convenience.

Table 2: Comparison of PSLLs before and after thinning

Number of Elements	PSLL(dB) before thinning	PSLL(dB) after thinning
30	-10.438	-14.91
40	-10.495	-16.37
50	-10.521	-17.2
60	-10.535	-17.78
70	-10.543	-18.41
80	-10.549	-19.12
90	-10.552	-19.63
100	-10.555	-20.17
150	-10.562	-21.22
200	-10.564	-21.9

V. CONCLUSIONS

A linear array of 'n' isotropic element array is taken and thinning is carried out with an intention of reducing peak side lobe level. Such patterns with low side lobes find wide applications in radar target tracking. A Differential Evolution algorithm is applied to obtain the best optimum thinning configuration. The results clearly show that thinning results in better side lobe reduction with minimum number of active elements. Results have been illustrated for different numerous elements of the lobes. The work can be extended for thinning arrays of practical elements.

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