Side Lobe Level Reduction in Circular Antenna Array Using DE Algorithm

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Abstract -*In this paper, we make use of the differential evolution algorithm in order to reduce the side lobe level in a circular antenna array. The differential evolution algorithm uses iteration method in order to get the best required solution. The algorithm is loaded using the MATLAB software and by varying the parameters, different outputs are observed, noted and also compared with the normal radiation pattern of the circular antenna array. The output tables and radiation patterns are given to show the performance of the differential evolution algorithm.*

Key Words: Differential Evolution Algorithm, Side Lobe Level Reduction, Circular Antenna Array,MATLAB,iteration,radiation pattern

1.INTRODUCTION

Antenna arrays are used in order to improve the effectiveness during long distance communication. A single antenna cannot fulfill all te requirements during long distance communication, since its directivity, side lobe level and other factors may not be as per the requirements. And so in order to do so we make use of an antenna array. The circular antenna array is used because it compensates the effect of mutual coupling by breaking down the excitation given to the array into a symmetrical series of components.

Due to the large usage of antennas in modern day communication, the study of its efficiency and usage has proven to be very vital to us. We make use of different techniques in order to improve its efficiency, directivity, to reduce its side lobe level and many other factors. Various optimization techniques have been designed in order to do so.These optimization techniques are mostly based on varying few vital parameters of the antenna, they can be either the number of elements, amplitude excitation or the phase.

In this paper, the side lobe level is reduced by varying the amplitude excitations and by making use of the differential evolution algorithm. This algorithm has proven to be very stable and produces accurate results without getting stuck at the local maxima when compared to the older algorithms such as the genetic algorithm.

2.DIFFERENTIAL EVOLUTION ALGORITHM

The differential evolution algorithm basically consists of four main parts; they are the initialization of the population, mutation, crossover or recombination, and finally the selection part. The iteration consists of the last three parts. This iteration continues till we get the best solution in the end.

2.1 Initialization

In case we want to optimize a function with D number of real parameters, then let us consider a vector having the form of $X_{i,G}=[x_{1,I,G}, x_{2,I,G}, \ldots x_{D,I,G},]$ i = 1, 2,…N. and G is the generation number. We then need to define upper and lower bounds for each parameter as $x_{max}=[x_{max1},x_{max2,\ldots,}x_{maxD}]$ and $x_{min}=[x_{min1},x_{min2,\ldots,}x_{minD}]$.The initial parameter values should be randomly selected from these minimum and maximum bounds. This process here doesn't need to undergo much iteration.

2.2 Mutation

This consists of the main part in which a new vector is formed by making use of the previously defined vectors. We randomly select three vectors and by making use of this process we create the new vectors. In this, it makes use of the differential evolution formula where the difference of two vectors is multiplied with a factor and then added to another vector. The formulas is given as

$V_{i,j}=X_{min,i}+ U(0,1)[X_{max,i}-X_{min,i}]$. Using this mutation takesplace and a new vector is created. This vector is termed as the donor vector.

2.3 Recombination

The process of recombination has iterations and makes use of the previous vectors in order to create new vectors here trial vector Ti,j is developed using this method. It makes use of the donor vector and the target vector. The elements of the donor vector enter the trial vector with a probability. This probability decides which vector is finally selected. This recombination takes place by the formula as

$$T_{iG}^{j}=\begin{cases} V_{i,G}^{j} \text{ if } U(0,1) \leq CR \text{ or } j = j_{rand} \\ X_{i,G}^{j} \quad otherwise \end{cases} \quad (1)$$

2.4 Selection

This selection process is done in order to keep the population size constant throughout the subsequent generations. The selection process can be done in two ways one is for the maximization problem and the other for the minimization problem. In the maximization process, if the objective function of the trial vector is greater than the target vector then, in that case the trial vector is selected, if not so then the target vector is selected. In the minimization process, the opposite is the case. The selection process depends on the objective function values of the different vectors; it follows the following formula as

$$X_{i,G+1} =\begin{cases} T_{i,G} \text{ if } f(T_{i,G}) \geq f(X_{i,G}) \\ X_{i,G} \quad otherwise \end{cases} \qquad (2)$$

Where f (.) is the objective function and it decides which vector gets selected to the next generation.

3. FORMULATION

In this article, we consider a circular antenna array, having N number of variables. The Array Factor is calculated in this case, and it is formulated as

$$AF(\emptyset) = \sum_{n=1}^{N} I_n \exp\left[j\left\{kr\left(\cos\left(\emptyset - \emptyset_{ang}^{n}\right) - \cos\left(\emptyset_o - \emptyset_{ang}^{n}\right)\right) + \beta_n\right\}\right] \qquad (3)$$

In the above formula, I_n is the normalized amplitude excitation, β_n is the phase excitation of the nth element, $\emptyset$ is the angle of incidence of the plane wave. These three are mainly required in order to formulate the array factor. In the above formula $\emptyset_{ang}^{n} = \frac{2\pi(n-1)}{N}$ is the angular position of the nth element in the antenna array in the x-y plane. kr=Nd is where k is the wave number, r is the radius of the circle of the circular antenna array, d is the angular spacing between elements and N is the number of variables. The amplitudes are varied between range of (0, 1).

4. NUMERICAL SIMULATION RESULTS

To show the usage of differential evolution algorithm in the reduction of side lobe level for a circular antenna array, different outputs have been taken by varying the number of elements as shown below

Table 1: After applying differential evolution algorithm

No of elements	Side lobe levelin dB	Null –null beam widthin degree	Half power beam widthin degree
15	– 19.56	26.3	10.4
20	– 19.8	20	8.1
30	– 20.01	16	6.3
40	– 20.12	10.5	4.2
50	– 20.30	8.8	3.6
70	– 20.46	5.8	2.48
100	– 20.57	3.7	1.8

Figure 4.1. Table showing element number and their corresponding side lobe levels and beam widths

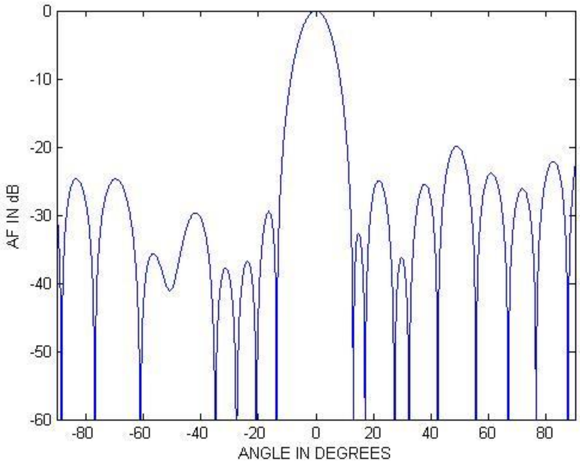

Fig 1: Radiation pattern found by DE for element number=20

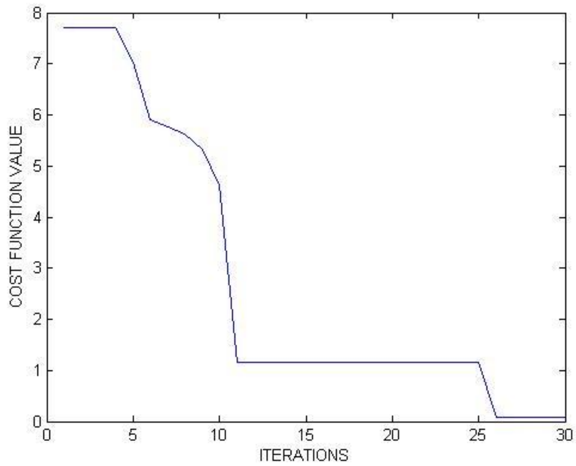

Fig-2 :convergence plot of DE for number of elements=20

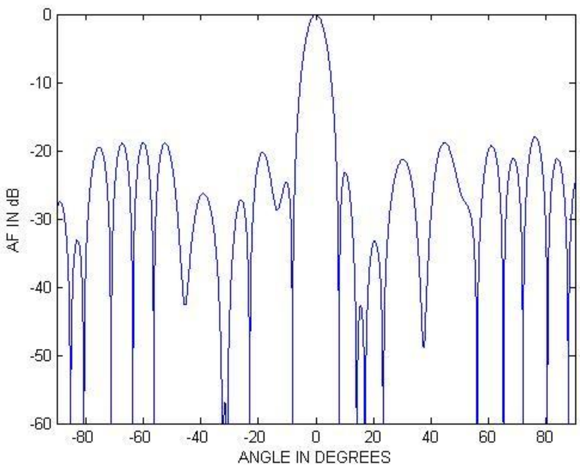

Fig-3 : Radiation pattern found by DE for element number=30

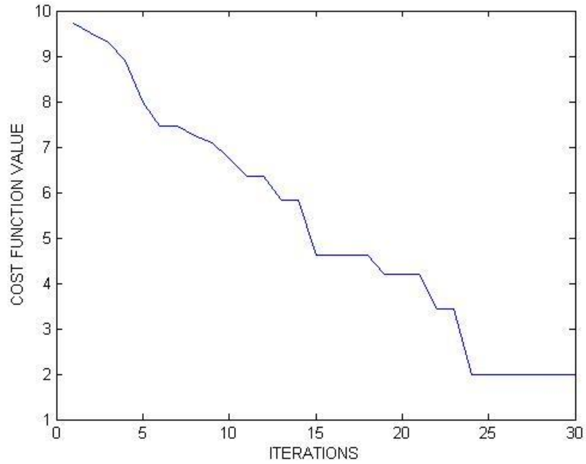

Fig-4: convergence plot of DE for number of elements=30

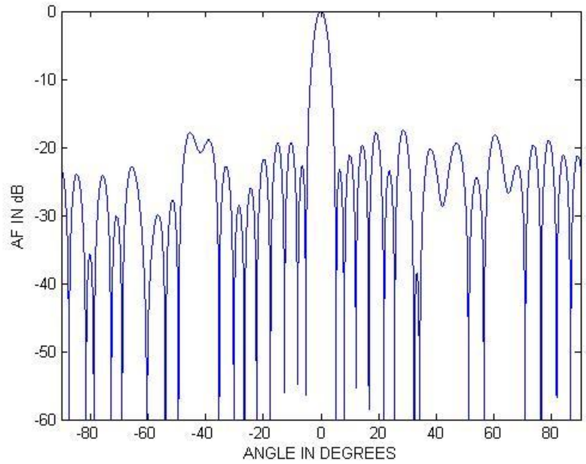

Fig-5: Radiation pattern found by DE for element number=40

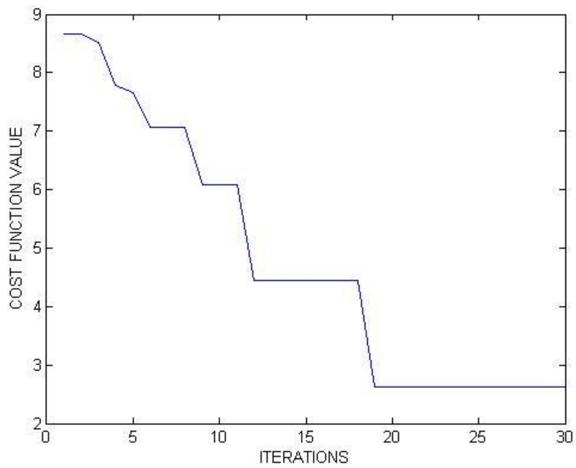

Fig-6: convergence plot of DE for number of elements=40

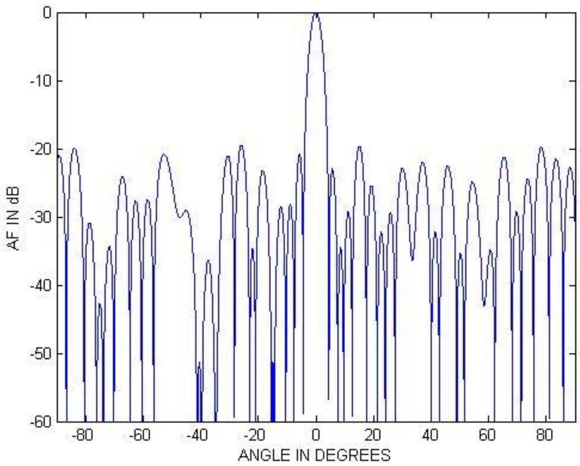

Fig-7: Radiation pattern found by DE for element number=50

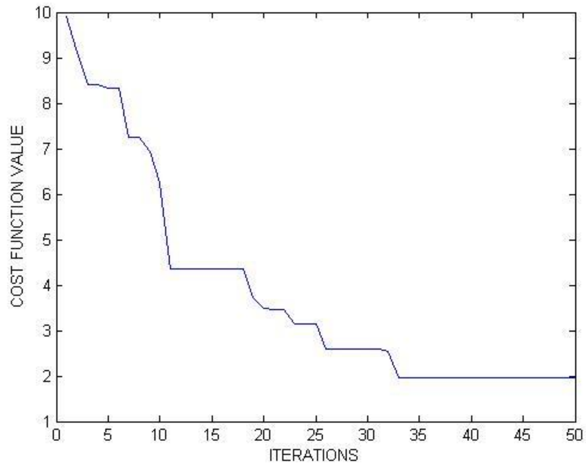

Fig-10 convergence plot of DE for number of elements=70

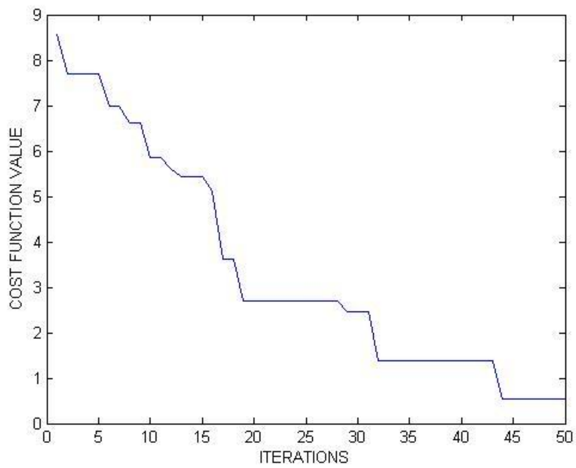

Fig-8: convergence plot of DE for number of elements=50

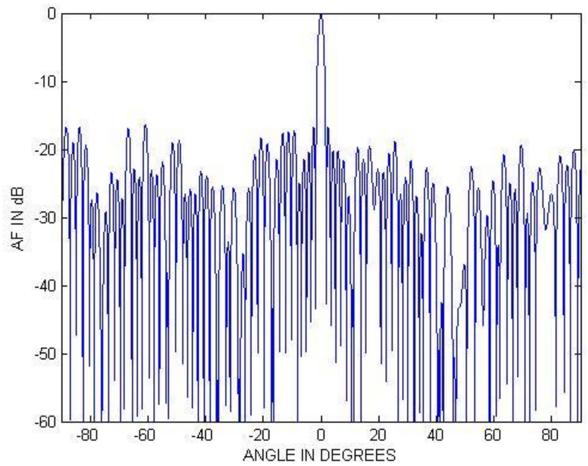

Fig-11 Radiation pattern found by DE for element number=100

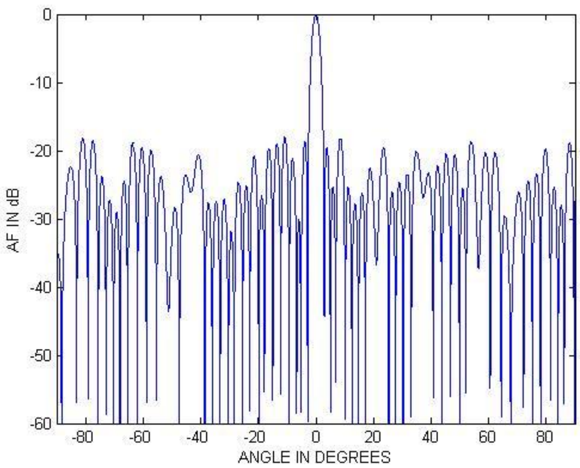

Fig-9: Radiation pattern found by DE for element number=70

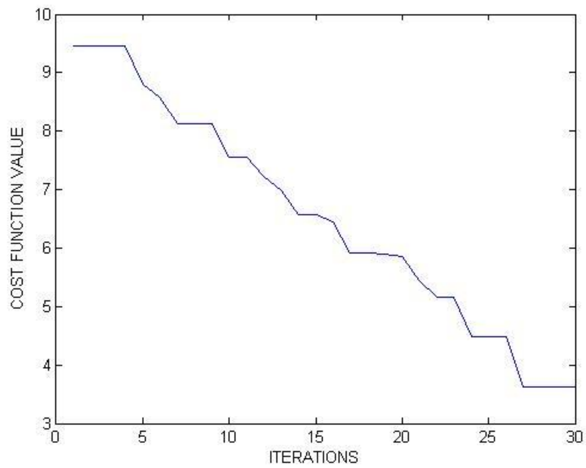

Fig-11 convergence plot of DE for number of elements=100

5. CONCLUSION

In this paper, the differential evolution algorithm has been used for the reduction of side lobe level of a circular antenna array by varying the amplitude excitations. The results show that the algorithm is capable of reducing the side lobe level to about -20 dB.The algorithm can also easily be implemented for arrays with many elements as well. It is easy to implement and provides a better accuracy.

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