Optimal Design and Synthesis of Linear Antenna Array Using Social Group Optimization Technique

Abdul Rahiman Sheik, Kalva Sri Rama Krishna

Abstract: ***In the recent past many evolutionary computing algorithms are proposed for linear array synthesis with several objectives adopting many available synthesis techniques. Every synthesis technique has its unique performance on each objective. It is evident from the literature that incorporating newly proposed heuristic approaches which are widely accepted in other disciplines for antenna array synthesis is a predominant part of research in electromagnetics. This consistently helped antenna engineers to take on the challenges of pattern synthesis for wireless applications. Accordingly in this paper a new algorithm namely Social Group Optimization Algorithm (SGOA) has been chosen and applied for optimally designing linear array synthesis. Further a comparative study is performed to analyze the performance of this algorithm over existing popular numerical technique called Chebyshev technique. Several objectives are considered for synthesis of LA in this work. Obtaining a very low SLL of -50dB with narrowest possible BW that is equal to the Chebyshev BW (TBW) for the same SLL is one of the major objective of investigation. The other objectives are to study the synthesis process using both amplitude only and amplitude-space techniques. Symmetrical LA is considered in all the cases mentioned in this paper.***

Index Terms: ***SLL, SGOA, BW, ARRAY FACTOR***

I. INTRODUCTION

Efficient design of LA is an important issue in the field of array antenna engineering. LAs are characterized by simple geometrical description ie; all the elements in the array are oriented on a straight line as shown in Fig.4.1. More detailed description of the LAs is given in the previous Chapter along with the formulation of the array factor (AF). These LAs have wide applications in wireless communications. It is concerning fact that any new approach or technique in array synthesis is first applied to LAs.

LA synthesis involves in finding coefficients or weights for amplitude, spacing or phase distribution of the elements of the array that yields the required specifications of the radiation patterns. Proper determination of the non-uniform amplitude distribution for the linear array elements produces suppressed SLL while maintaining main BW unaltered . Evolutionary computing algorithms like the GA are used to solve several multi-objective problems involving conflicting objectives like the SLL minimization while observing beam scanning in

a LA synthesis using amplitude-position technique. Similarly PSO is applied to greatest advantage in many electromagnetic problems especially for LA synthesis [137-140] with the most concerned objectives of SLL reduction and BW control using amplitude only technique. Each technique employed exhibits specific characteristics in achieving the desired beam patterns.

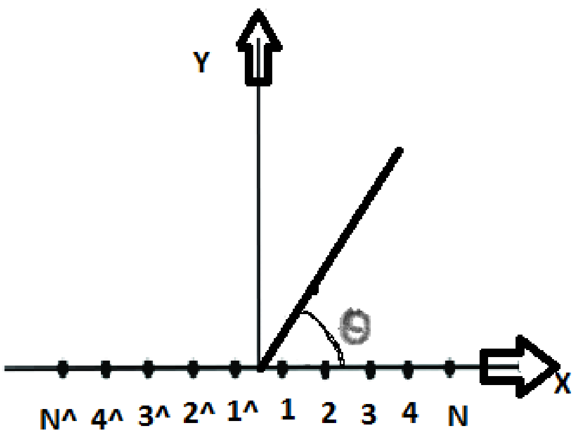

Fig.1.1: Linear array geometry

In this work, a novel algorithm called the FPA is applied to LA synthesis problem with objectives like the SLL reduction and BW control and compared with an improved version of PSO known as APSO. In brief, the objective of the work presented in this Chapter is to suitably use the novel algorithm known as SGOA that have lesser complexity in arriving at the optimal solution. To assess the suitability, the radiation patterns obtained for SGOA is compared with patterns obtained using the conventional numerical technique for LA synthesis known as "Chebyshev technique". The conventional Chebyshev technique goes through many computational steps to optimize the LA and considered to be the best numerical optimizer that could produce lowest possible BW for desired lower SLL.

The rest of the paper is organized as follows. Fitness function formulation is given in the next section, followed by brief discussion on the "Chebyshev" method of linear analysis. The simulation based experiment referring to performance study of SGOAare presented. These results and analysis is mentioned in the subsequent sections. The LA synthesis using amplitude

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only technique with main beam positioned at 0^0 mentioned as initial study in the previous Chapter. Similarly, proposed work in this Chapter isto synthesize LA with non-uniform distribution using Amplitude-Spacing technique.

II. FORMULATION OF THE FITNESS FUNCTION

The formulation of fitness function incorporates the objective of SLL reduction and BW control. The radiation pattern is the distribution computed AF values for every interval of azimuthal angle (θ) over a range of -90^0 to 90^0. Hence the fitness is formulated as a function of AF values in order to obtain the desired patterns.

$$SLL_{diff} = SLL_{des} - \max[\,|\,AF(\theta)\,|_{-90}^{\theta_0 - \frac{BW_{obt}}{2}}\,]$$

$$BW_{diff} = |\,BW_{Cheb} - BW_{obt}\,|$$

$$f_1 = SLL_{diff} \quad \text{if } SLL_{diff} > 0$$
$$= 0 \quad \text{otherwise}$$
$$f_2 = SLL_{diff} \quad \text{if } SLL_{diff} > 0$$
$$= 0 \quad \text{otherwise}$$
$$f = c_1\, f_1 + c_2\, f_2$$

Where SLL_{diff} is the difference between the desired SLL (SLL_{des}) and the obtained SLL (SLL_{obt}) BW_{diff} is the difference between the desired Chebyshev beamwidth (BW_{Cheb}) and the obtained beamwidth (BW_{obt}).

In this case f_1 is responsible for SLL reduction and f_2 controls the BW of the array.

The final fitness *f* value calculated as summation of f_1 and f_2. where c_1 and c_2 are two constant biasing weighting factors such that

$$c_1 + c_2 = 1$$

However, in the current work no biasing is applied and the objectives are provided with equal weight, such that $c_1 = c_2$.

A. Array Factor Formulation

The structure of the circular array lies on the XY planar surface as given in the Fig. (1). the array factor of the array is

$$AF(\phi) = \sum_{n=1}^{N} I_n \exp(j(kr\cos(\phi - \phi_n) + \beta_n)) \quad (7)$$

Where,
n is element number
I_n amplitude of source current of n^{th} element
N is total number of elements in the array
β_n is the phase of the source current of n^{th} element

$$kr = \frac{2\pi r}{\lambda} = \sum_{i=1}^{N} d_i$$

$$\phi_n = \frac{2\pi}{kr} \sum_{i=1}^{n} d_i$$

The pattern of the radiation of the array is obtained from product of antenna element factor and the corresponding antenna array factor. As the elements in the array are isotropic in nature the element factor is considered as '1'. Hence, the array factor completely delineates the radiation pattern of the array.

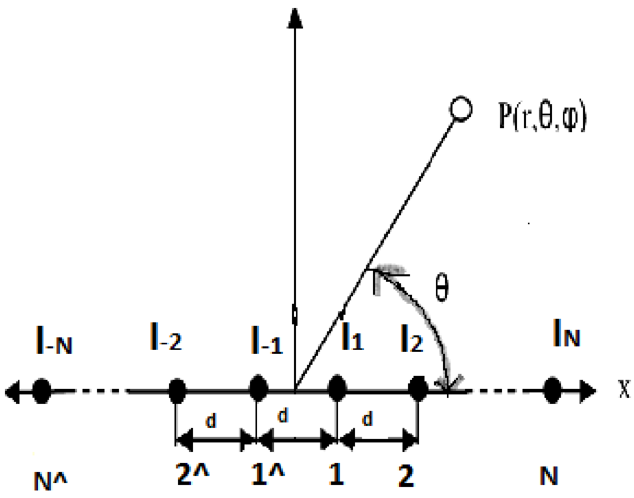

Fig.2.1: Geometrical configuration of Symmetric Linear Array

It can be understood from the that the array factor is a function of element current excitation amplitude, its corresponding phase, and inter-element spacing. Modifying these parameters the corresponding radiation pattern can be controlled. Basing on this, in brief, the design problem can be described as determining proper array configuration that produces the desired radiation pattern.In amplitude only technique the array configuration is solely defined by the amplitudes of the element's current excitation which is also known as non-uniform amplitude distribution Symmetric Linear Array.

III. DEGIGN USING SGOA

The proposed antenna is designed using the HFSS (High Frequency Structure Simulator) software 14.0 version.

Social Group Optimization Algorithm [8, 9] is novel metaheuristic population based Algorithm inspired by the social conduct of the general public. The general population having a place with a general public share a few highlights and interests for all intents and purpose and some totally clashing. They frequently express these highlights basing on the overarching conditions around them. Some time they experience some unpredictable issues which must be comprehended. At stake of taking care of these issues they may apply their inborn abilities or may share the encounters of the other individual people in the general public. This is called bunch learning sharing. Singular endeavors to take care of the issue are regularly considered as the neighborhood seek method while the gathering movement might be alluded as the worldwide pursuit. The SGOA procedure of critical thinking is partitioned in totwo stages. They are upgrading stage and getting stage. Amid the previous stage, the information source is the most proficient individual of the general public or gathering. This is given as the accompanying articulation. $Inew_{ij} = c * Iold_{ij} + r * (gbest(j) - Iold_{ij})$

Amid the later stage there is common communication

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that improves the arrangement. This shared cooperation is arbitrarily performed. At long last, the person with wide learning is develops as the best in that cycle. The execution of these calculations is explicit to the amalgamation procedure as the cluster components of both direct and roundabout exhibit are correspondingly an element of plentifulness (I), entomb component dispersing (d) and component excitation stage (Ø).

IV. RESULTS AND DISCUSSIONS

The reults relating to the simulation accomplish on linear array combination utilizing amplitude-spacing technique is introduced in this paper.

The linear array has characteristic symmetric nature by which the Array is energized at the focal point of the Array and the Array is isolated into two sections. The left side components are in symmetry with the right-side components. In the same manner, the coefficients of sufficiency excitation on the left-hand side of the array are replicated to right hand side part. This in fact and computationally productive element of Linear Array apparatus. It is not required to decide the coefficients of synthesis variable of the considerable number of components in the array. In any case, it is adequate to acquire the dissemination of the just a single side components and as needs be which the rest of the component amplitudes are mapped to.

The simulation of the synthesis of linear array antenna includes in delivering the radiation designs with wanted SLL and BW. The ideal SLL should be always less than the the SLL of the Chebyshev appropriation case. The Chebyshev technique can be utilized to plan radiation designs with wanted SLL. Be that as it may, the BW is the ideal BW that is conceivable with the ideal SLL. Subsequently this Method is taken as the benchmark and as needs be, the SLL is taken as the parameter to be enhanced for a similar BW as that of the Chebyshev (Cheb-BW).

The results in terms of radiation pattern plots along with their corresponding element amplitude distribution plot is given for n=8, n= 16 are Presented.

A. Case 1:

For this case, substituting the non-uniform amplitude and separating appropriation(space) in the array factor for the geometry talked about in the presentation yields radiation designs from which the SLL and the BW can be acquired for that amalgamation of amplitude and spacings.. The radiation pattern and convergence plots for n=8 are given below.

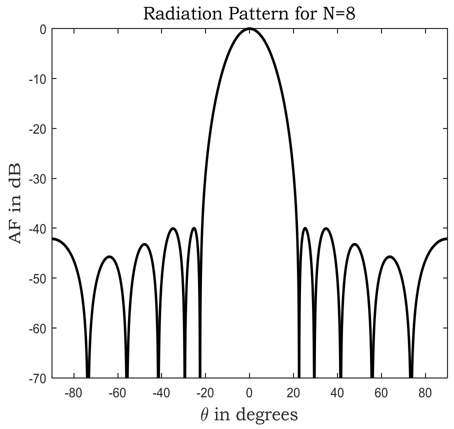

Fig.4.1: Radiation pattern of Non-Uniform Amplitude distribution and Spacing of 8 element Linear Array (LA)

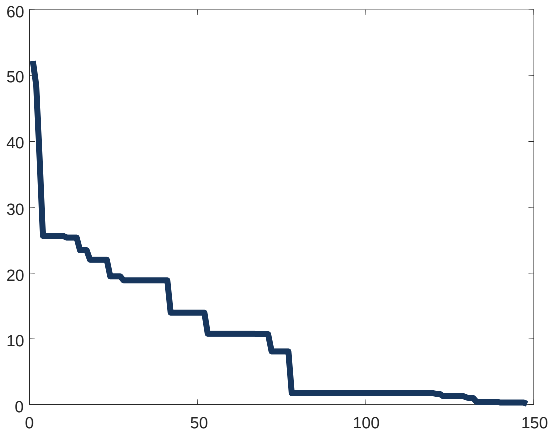

Fig.4.2: Convergence plot of Non Uniform Amplitude distribution and Spacing of 8 element Linear Array (LA)

Table: 4.1 Non Uniform Amplitude distribution and Spacing of 8 element Linear Array (LA)

Element No.	Chebyshev method		SGOA method	
	Amp	Space (λ)	Amp	Space (λ)
1&1^	1.0000	λ/2	0.92207	0.30567
2&2^	0.8120	λ/2	0.68575	0.60649
3&3^	0.5187	λ/2	0.37751	0.60248
4&4^	0.2622	λ/2	0.12646	0.60675

In above table the amplitude distribution and spacing of individual elements of 8 element linear array using Chebyshev method and SGOA method are given. In non uniform linear array , each element is excited with different cuttent amplitude . By using Chebyshev method, elemts in the array excited with current sources of non uniform amplitudes with equal spacing. But by using SGOA method elemts in the array excited with current sources of non uniform amplitudes with unequal spacings for getting desired SLL and with suitable Beam Width(BW).

With reference to the above deliberation, the simulation experimentation is performed for length of linear antenna array starting from N=8 . The SGOA is utilized in every one of the cases to decide the relating adequacy of current excitation with in the range (0-1) and the comparing between component separating. The resolved non-uniform amplitudes and component spacings are arranged for the length of the n=8 length array as referenced above in the Table 4.1

B. Case 2:

In this case, substituting the non-uniform amplitude and separating appropriation(space) in the array factor of the length n=16, for the geometry talked about in the presentation yields radiation designs from which the SLL

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and the BW can be acquired for that amalgamation of amplitude and spacings.. The radiation pattern and convergence plots for n=16 are given below.

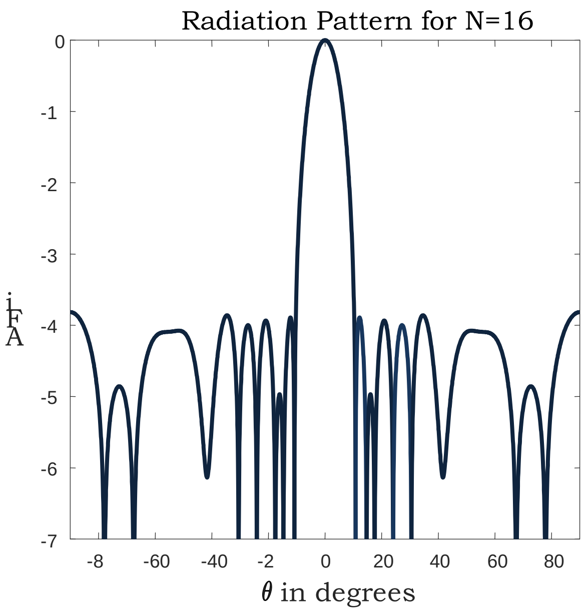

Fig.4.3: Radiation pattern of Non-Uniform Amplitude distribution and Spacing of 16

In the given table the amplitude distribution and spacing of individual elements of 16 element linear array using Chebyshev method and SGOA method are listed. In non uniform linear array , each element is excited with different cuttent amplitude . By using Chebyshev method, elemts in the array excited with current sources of non uniform amplitudes with equal spacing. But by using SGOA method elemts in the array excited with current sources of non uniform amplitudes with unequal spacings for getting desired SLL and with suitable Beam Width(BW).

Table: 4.2 Non Uniform Amplitude distribution and Spacing of 16 element Linear Array (LA)

element No.	Chebyshev method		SGOA method	
	Amp	Space (λ)	Amp	Space (λ)
1&1^	1.0000	λ/2	0.99804	0.30063
2&2^	0.95279	λ/2	0.6615	0.5159
3&3^	0.86366	λ/2	0.63162	0.34496
4&4^	0.74239	λ/2	0.87872	0.56293
5&5^	0.60176	λ/2	0.74478	0.70141
6&6^	0.45569	λ/2	0.49706	0.75801
7&7^	0.3173	λ/2	0.27456	0.79912
8&8^	0.29099	λ/2	0.10197	0.74079

With reference to the above deliberation, the simulation experimentation is performed for length of linear antenna arrays of n=8 and n=16 . The SGOA is utilized in every one of the cases to decide the relating adequacy of current excitation with in the range (0-1) and the comparing between component separating. The resolved non-uniform amplitudes and component spacings are arranged for the length of the n=16 length array as referenced above in the Table 4.2

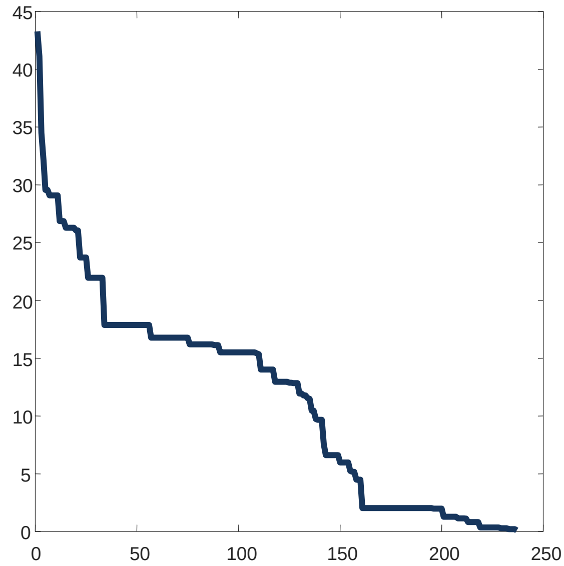

Fig.4.4: Convergence plot of Non Uniform Amplitude distribution and Spacing of 16 element Linear Array (LA)

V. CONCULSION

The robustness of the SGOA is studied in terms of its efficiency in suppressing the SLL while the BW constant as a constraint in the optimal synthesis of linear array antenna. The algorithm presented its consistency through out several examples in which the length of the linear array is varied at several intervals.

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