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Research Article

Sector Beam Synthesis in Linear Antenna Arrays using Social Group Optimization Algorithm

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ABSTRACT
The sector beam based radiation patterns have almost flat top in a two dimensional pattern. It is always a challenging task to synthesize such patterns. In this paper, the sector beams are generated using recently developed evolutionary computing tool known as social group optimization algorithm (SGOA). The technique involving both the amplitude and phase as design parameters is used and both the parameters of 20 elements of linear antenna array (LAA) are determined using the algorithm. The results are analysed in terms of radiation pattern plots. The simulations are carried out in Matlab.

Keywords: Linear antenna array, SGOA, flat top beam, sector beams, radiation pattern.

Introduction

In radar applications, several shaped beams like flat top (sectoral) beams [1], stepped positive and negative ramp [2-5] shaped beams are used for efficient scanning of the target and to interact with the target for long period of time. Among these, the sectoral beam is one that favours direction finding along with several other features like range finding and proper realization of radar cross section. However, it is not possible to accomplish this task with single element antenna that require additional circuitry to mechanically steer the antenna. Hence the solution lies in adopting antenna arrays.Radar systems are equipped with phased array antenna technology. This type of antenna array are capable of steering the beam to any scanning angle. As a result, it may be considered that there is need for array development for synthesizing sectoral beams.

Considering the above in this paper, linear array synthesis for sectoral beam generation is proposed [6-15] using latest evolutionary computing tool known as social group optimization algorithm. The technique known as amplitude-phase involving in determining both amplitudes and the corresponding phase of the element for optimal synthesis of the sectoral beams using FPA. Sectoral beam observing a flat top in the main beam over a range of 180^0, and $90^0$are presented.

Formulation of the fitness function

The proposed generalized fitness function corresponding to the above discussion is formulated as,

For $\theta_l \leq \theta \leq \theta_h$

$$f_1 = \sum_{\theta=\theta_l}^{\theta_h} |E(\theta)| \quad \text{if } E(\theta) \geq E_{sec} \qquad (1)$$

For $\theta_h \leq \theta \leq \theta_l$

$$f_2 = \sum_{\theta=-\frac{\pi}{2}}^{\theta_l} (E(\theta)+SLL_{opt}) + \sum_{\theta=\theta_h}^{\frac{\pi}{2}} (E(\theta)+SLL_{opt}) \text{ if}$$

$E(\theta) \geq -SLL_{opt}$ (2)

Finally, cost functionis now written as

$f_{sec}=f_1+f_2$ (3)

Where SLL_{opt} and E_{sec} represent the desired maximum sidelobe level and ripple in main beam respectively. The total sector pattern angular range is from θ_l to θ_h. For SLL_{opt} = 25dB and E_{sec} = 1.5dB are used. The vector c consists of both amplitude and phase variables. E_{sec} acts as a control parameter to achieve the desired flat beam. More the value with E_{sec}, less the number of generations and vice versa. On the other handSLL_{opt} plays a major role in establishing a control over the beamwidth. The values of SLL_{opt} and E_{sec} are selected such that trade-off between the beamwidth, SLL and ripple magnitude in the trade in regions is observed.

Formulation of design problem

Consider 2N elements aligned along a straight line to form a linear array geometry as shown in the Fig.1. The corresponding array factor is given as (4)

$$AF(\phi) = 2\sum_{n=1}^{N} I_n \cos[kx_n \cos(\phi) + \varphi_n] \qquad (4)$$

Where, the symbols I, φ and x are the corresponding elements current excitation amplitude, phase and the position of the element in the array respectively. In the current problem of interest the x is uniform ie; the array is uniformly spaced with x=λ/2.

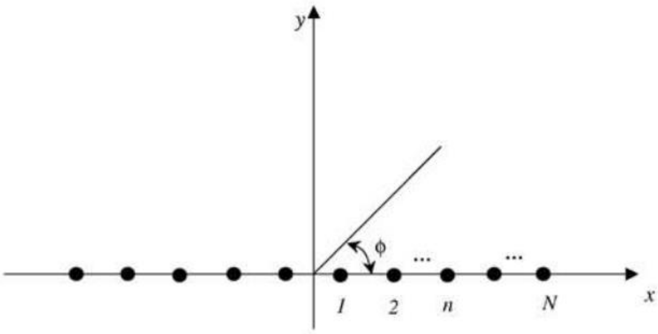

Fig.1: Geometry of symmetric linear array

Social group optimization algorithm

SGOA mimics the social behavior of human beings [16-21]. Every human inherently possesses some coefficient of intelligence and skill to get aware of the problem and instantly provide a solution. An individual with the highest degree of knowledge or skill set can provide best solution to a problem. Further, it is possible to subsequently improve his /her solution finding skills. This exchange of knowledge in the quest to find a solution to individuals' problem is formulated and structured in the Social Group Optimization Algorithm.

For a population of N individuals, each individual referred as Xi can provide a solution to a design problem of dimension 'd'. The same as given as population

X = $[X_1,\ X_2, X_3 \ldots\ldots\ldots\ldots. X_N]$ (5)

$x_i = [x_1, x_2, x_3 \ldots\ldots\ldots.. x_d]$where i = 1,2…..N. (6)

The algorithm progresses in two phases namely improving and acquiring phase.

In the improving phase, every individual tries to improve his solution with respect to the best in the society or group. This formulated as

$X_{new\ i} = cX_i + r\ .(X_{best} - X_i)$ (7)

$X_{new\ i}$is the improved version of i^{th}individual and $X_{best}$is the best individual in the group and r is a random number.

Similarly, the following formulation is used to update individual in acquiring phase.

$X_{new\ i} = X_i + D.r_1.(X_i - X_r) + r_2(X_{best} - X_i)$ (8)

Here

D = 1 if f(X_i) < f(X_r). (9)

= -1 if f(X_i) > f(X_r).

Here r_1 and r_2 are two random numbers with uniform distribution within the range (0,1), while D is a determinant factor. Similarly, $X_r$another individual such that i ≠ r.

Results and discussions

Results pertaining to the objectives of the work proposed in this Chapter are given in this Section. The sectoral beams are synthesized by determining amplitudes and the corresponding phase of the elements using SGOA. The amplitudes and the phase values for 180^0, and 90^0wide sector beams are determined. The range of amplitude distribution is (0,1)and the corresponding phase is (-180^0,180^0). The radiation patterns for the above said beam widths for sector beams are presented in Figs. 2(a)and Fig.3(a) respectively. For all the cases the SLL is maintained below -25dB.. For all the patterns presented are accompanied with corresponding stem plots of amplitude distribution and the phase distribution as presented in Fig.2(b) and Fig.3(b) respectively for 180° and 90° sectoral beams. The phase distribution stem plot has both +ve and -ve axis. An admissible ripple on the flat top is allowed to level of -1.5dB. This is observed in all the radiation pattern plots.

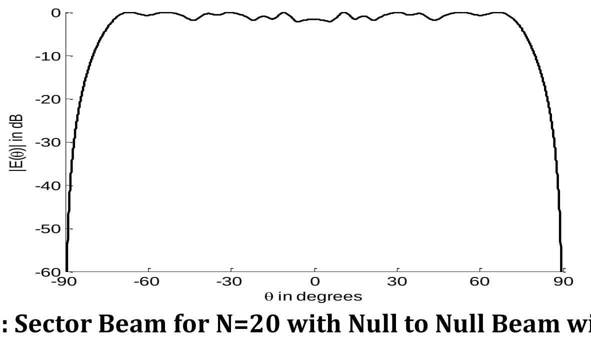

Fig. 2 (a): Sector Beam for N=20 with Null to Null Beam width=180^0

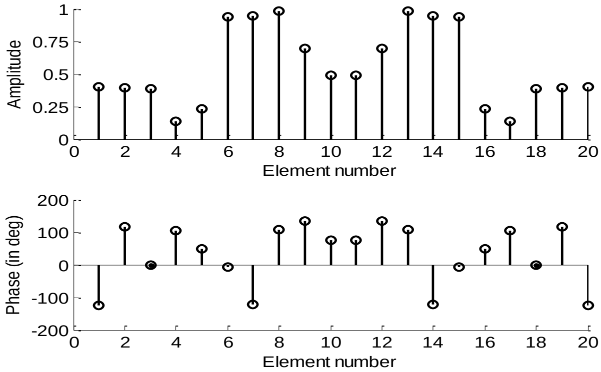

Fig.2(b): Amplitude and Phase Excitations for an array of 20 Elements

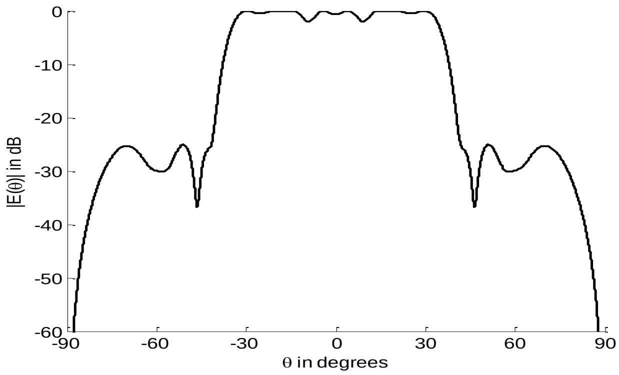

Fig. 3(a): Sector Beam for N=20 with Null to Null Beam width=90^0

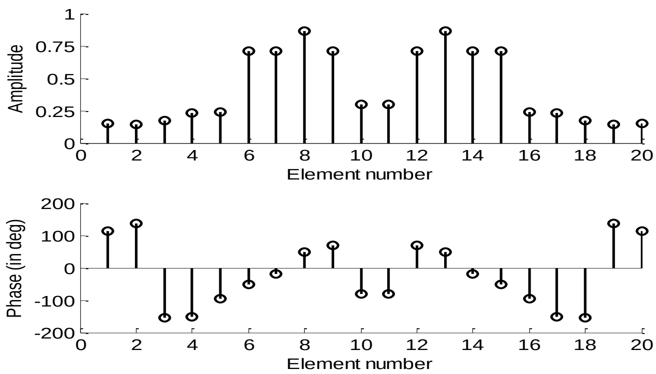

Fig. 3(b): Amplitude and Phase Excitations for an array of 20 Elements

Conclusion

The SGOA for linear arrays is applied to obtain the Sector Beams. The merit of the algorithm is that it can optimize a large number of discrete parameters. The genetic algorithm intelligently searches for the best amplitude and phase excitations that produce the desired pattern. It is evident from the results, that the sector beams are really optimum using the present technique. The ripples are well controlled and the sidelobe levels are maintained within the acceptable limits. The SGOA is found to be useful for the synthesis of the specified sector beams for different angular sectors. The method can be extended to the other shapes also.

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