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Deployment of the meta heuristic Colonial Competitive Algorithm in synthesis of unequally spaced linear antenna array

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Abstract: In this paper we re-call a recently developed meta heuristic optimization algorithm based on socio-political process of imperialistic competition. This Colonial Competitive Algorithm (CCA) has shown its efficient capability in comparison to convenient optimization algorithms like GA, PSO. In this study we investigate the synthesis problem of unequally linear space antenna using CCA and show the efficient convergence to obtain a pattern with acceptable Side Lobe Level.

Keywords: unequally-spaced antenna, Colonial Competitive Algorithm, genetic algorithm, legendre method, pseudo least mean square method

Classification: Other communication hardwares

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1 Introduction

Over the last decade synthesis of the non uniformly spaced array antennas (NUSA) have received a lot of attention. Adjusting the amplitude or/and the position of elements has became an interesting category, because it reduces the size, or the number of elements in array antennas. This is mainly due to the fact of the degree of freedom that such arrays provide [1, 2, 3].

In [4] the density of elements located within a given array length is made proportional to the amplitude distribution of the conventional equally-spaced array. Mailloux et al. used statistical thinning of arrays with quantized element weights to reduce the SLL considerably in large circular arrays [5]. Genetic algorithm has been exploited in optimizing the array spacing [6]. This method is used for thinning a large linear array of uniformly excited isotropic antennas to provide the SLL equal to or below a fixed level while the percentage of thinning is always kept equal to or above a given value. Some randomized algorithms were used to synthesize the unequally-spaced arrays such as Tabu search [7] and Particle Swarm [8]. In a more recent work, the authors used Pseudo Least Mean Square (LMS) and Fourier methods to minimize the SLL. These methods used matrix form to solve the system of M equations and N variables with M > N [9, 10, 11].

In this paper we deploy an efficient meta heuristic algorithm based on socio-political process of imperialistic competition. Colonial Competitive Algorithm is a novel global search heuristic that uses imperialism and imperialistic competition process as a source of inspiration [12]. This paper is

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organized as following: section 2 briefly discuss about unequally-spaced array antenna and Pseudo LMS method to synthesize the unequally-spaced arrays antenna. Section 3 presents the meta heuristic search CCA algorithm and the synthesis problem of unequally-spaced array antenna is derived. Simulated results are presented in section 4 and the contribution of this work is presented in section 5.

2 Synthesis of unequally spaced arrays

The structure of unequally-spaced linear array with $2N+1$ elements is shown in Fig. 1 (a). The goal is to calculate the current distribution I_n, and the element spacing d_n. So that the resulted pattern is close to desired pattern at every θ for the prescribed geometry about 3 dB better than LMS method. The desired pattern has a main lobe at θ_0 (usually at zero) with The array factor (resulted pattern) of the array is given by:

$$E(\theta) = \sum_{n=0}^{N} I_n cos(k_0 d_n cos\theta) \tag{1}$$

We sample the array factor at M points:

$$E(u_m) = \sum_{n=0}^{N} I_n cos(k_0 d_n u_m) \tag{2}$$

where:

$$U_m = cos(\theta_m) = \frac{m}{M-1} \qquad m = 0, 1, ..., M-1 \tag{3}$$

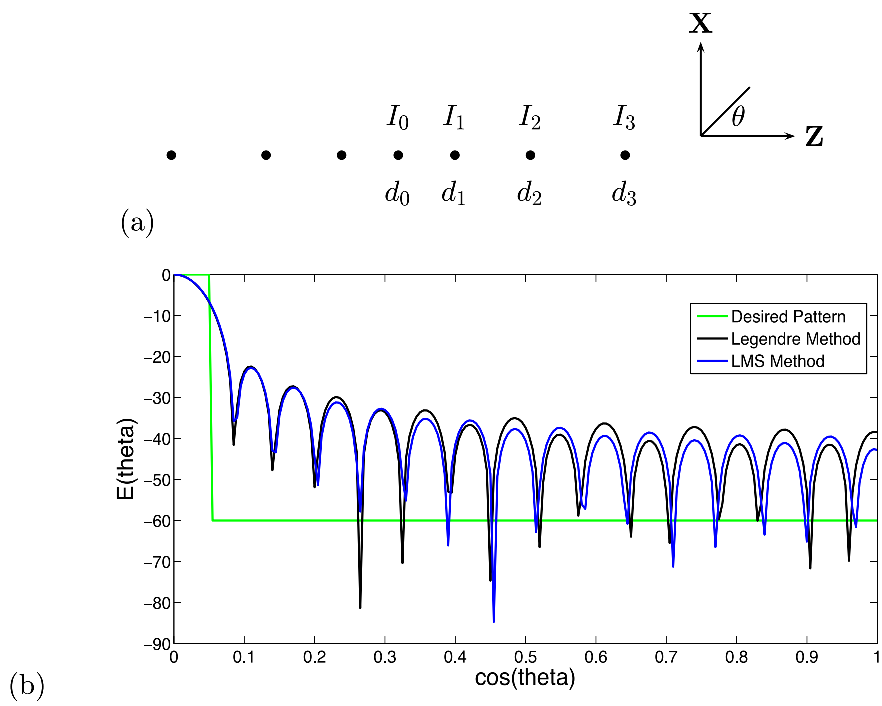

Fig. 1. (a) structure of unequally-spaced linear 2N + 1 element array antenna (b) Desired pattern and the simulated patterns for pseudo LMS and Kumar methods, N = 9.

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This pattern is equal to the desired pattern at the quantized points:

$$E(U_m) = E_d(U_m) \tag{4}$$

which can be represented in a matrix form:

$$\begin{pmatrix} E(u_0) \\ E(u_1) \\ \vdots \\ E(u_{M-1}) \end{pmatrix} = \begin{pmatrix} 1 & 1 & .. & 1 \\ cos\beta_1 & cos\beta_2 & .. & cos\beta_N \\ \vdots & \vdots & .. & \vdots \\ cos(M-1)\beta_1 & cos(M-1)\beta_2 & .. & cos(M-1)\beta_N \end{pmatrix} \begin{pmatrix} I_0 \\ I_2 \\ \vdots \\ I_N \end{pmatrix} \tag{5}$$

that β_n is defined as

$$\beta_n = \frac{k_0 d_n}{M-1} \qquad n = 0, 1, \ldots, N \tag{6}$$

In [7] we obtained the current distribution using Pseudo LMS method. Fig. 1 (b) compares the radiation patterns obtained from LMS with the Kumar's one [13].

We define the function Z as the difference between the desired and quantized pattern and we aim to use CCA optimization algorithm [12] to minimize $(Z(u_m) = E(u_m) - E_d(u_m))$ at M points. This one N dimension problem with N unknowns is studied briefly in the section 3.

3 Colonial competitive meta hueristic algorithm

Imperialist competitive algorithm (ICA) or Colonial Competitive Algorithm (CCA) is a new evolutionary algorithm for optimization [12]. This algorithm starts with an initial population called country. Countries are divided in two groups: imperialists and colonies. In this algorithm the more powerful imperialists, have the more colonies. The initial colonies belong to imperialists in convenience with their powers. The total power of each imperialist is determined by the power of its both parts, the empire power plus percents of its average colonies power.

$$TC_n = cost(imperialist_n) + \xi mean(cost(colonis\ \ of\ \ empire_n)) \tag{7}$$

where TC_n is the total cost of the n^{th} empire and ξ is a positive number which is considered to be less than one. When the competition starts, imperialists attempt to achieve more colonies and the colonies start to move toward their imperialists. The initial colonies belong to imperialists in convenience with their powers. The imperialist countries absorb the colonies towards themselves using the absorption policy.

The absorption policy makes the main core of this algorithm and causes the countries move towards to their minimum optima. So during the competition the powerful imperialists will be improved and the weak ones will be collapsed.

At the end just one imperialist will remain. In this stage the position of imperialist and its colonies will be the same and all the empires except the

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most powerful one will collapse and all the colonies will be under the control of this unique empire. The flowchart of this algorithm is shown below [12].

1. Start
2. Initialize the empires
3. Move the colonies toward their relevant imperialists
4. Is there a colony dominating its relevant imperialist?
5. If no go to 7
6. If yes Exchange position of an imperialist and its best colony
7. compute total cost of empires
8. give a colony of the weakest empire to a stronger empire
9. Eliminate empires with no colonies
10. Are stop condition satisfied?
11. If no go to 3
12. If yes STOP

4 Simulation results

CCA is used to determine I_n's distribution in synthesis of an unequally array antenna with $N = 9$, 19 elements. We determine N unknowns to minimize the difference between the desired pattern, $E_d(\theta)$ and the obtained pattern (1). CCA is initialized with 80 *Countries* and 8 *Empires* and iteration is done in 30 decades as shown in Fig. 2.

$$Cost\ Function : abs(E_d(\theta) - E(\theta)) \tag{8}$$

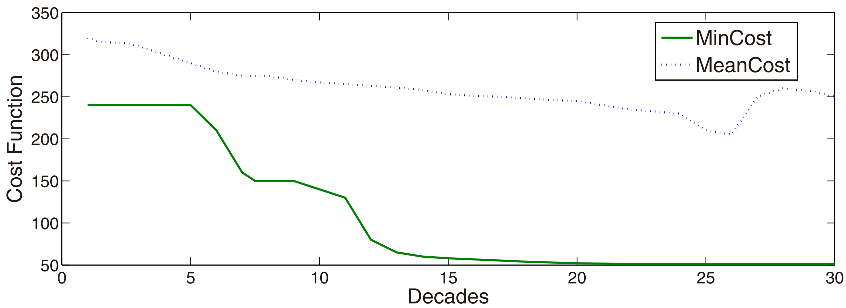

Fig. 2. (a) Cost function related on decades, Min(Cost) (green), Mean(Cost) (blue).

The desired pattern is assumed to be a pulse function at $\theta = 0$ direction. After applying the CCA, the optimized patterns for $N = 9$ and $N = 19$ are obtained, as shown in Fig. 3 (a) and Fig. 3 (b) respectively. It is shown that the resulted pattern from obtained current distribution I_n's, have very good performance in the peak and side lobe levels.

Table 1 compare the achieved cost function for LMS, CCA [12] and GA [14] methods. The minimum cost function is achieved with CCA and $N = 19$.

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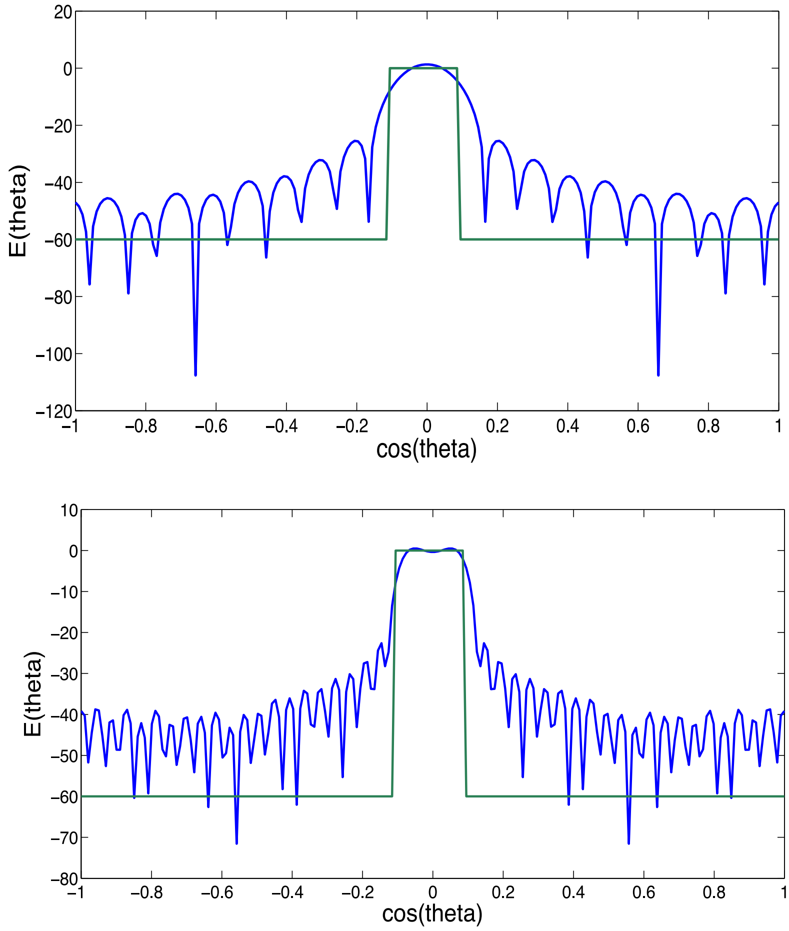

(a) (b)

Fig. 3. Optimized Pattern using CCA, Desired pattern (green), Obtained Pattern (blue) (a) $N = 9$, (b) $N = 19$.

Table I. Performance comparison of the proposed VCO.

	Costfunction (PseudoLMSmethod)	**Costfunction (CCA)**	**GA**
N = 9	64	51	57
N = 19	62	47	54

5 Conclusion

The current distribution of an unequally-spaced array are optimized with the desired CCA (colonial competitive algorithm), to minimize the cost function between the radiated pattern and an ideal endfire pattern (with a pulse shape). It is shown that the results are about 4 dB much better than GA, Legendre and LMS methods.

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