Synthesis of Thinned Square Array Using Modified Teaching-Learning-Based Optimization Algorithm

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***Abstract* - This paper proposes a modified teaching-learning-based optimization (TLBO) algorithm for synthesis of thinned square array with low side lobe level (SLL). A local search method based on status switch of elements is imposed to speed up the convergence of the TLBO algorithm and enhance the global searching ability of TLBO. Numerical results of thinned square array synthesis show that the performance of the proposed modified TLBO algorithm outperforms other methods through comparison.**

***Index Terms* — Thinned arrays, TLBO, beam pattern, SLL reduction.**

I. INTRODUCTION

The synthesis of thinned antenna arrays is a vital issue in electromagnetics and antenna engineering. Many techniques have been proposed over the last decades to synthesize such arrays [1-3].

The teaching-learning-based optimization (TLBO) is a newly proposed optimized technique, which based on the natural phenomenon of teaching and learning, is recently being used as a new reliable, accurate and robust global optimization technique [4]. Since the TLBO was proposed by Rao et. al in 2011, it has been successfully applied in many engineering optimization fields [5]. In the original TLBO algorithm, learners can improve their results by two basic modes of learning: by learning from the teacher (known as teacher phase) and learning from the other learners (known as learner phase), while the teacher gets no improvement from the class. Therefore we added a local search method based on status switch of elements to the original TLBO algorithm for the purpose of improving the result of teacher during the teaching-learning process.

In this paper, a modified TLBO algorithm is proposed to synthesize square antenna array. The proposed optimization procedure determines the number of active elements and the corresponding excitation amplitudes to synthesis the 20×10 square array. Optimized results show that the satisfactory beam pattern of antenna array has been successfully achieved.

II. THE BEAM PATTERN AND OPTIMIZATION PROCEDURE

Let us consider a square array of $M \times N$ elements placed symmetrically on the plane with equidistance d=0.5λ. The beam pattern of this antenna can be expressed as:

$$BP = 4\sum_{i=1}^{M/2}\sum_{j=1}^{N/2} I_{ij} k \cos\left(x_{ij}\sin\theta\cos\phi + y_{ij}\sin\theta\sin\phi\right) \tag{1}$$

where I_{ij} is the excitation of element which locate at $\left(x_{ij}, y_{ij}\right)$. The main purpose of this study is to design low SLL beam pattern for thinned antenna arrays with minimum number of elements. The objective function of can be expressed as the function of element excitation I and the number of active elements Na by:

$$F(I) = Na^2 + \sum_{s}\left(BP - BP_d\right) \tag{2}$$

where BP_d is the desired side lobe levels, S is the side lobe region, which satisfies the relation of $BP > BP_d$.

The main modification to the original TLBO is performed by importing a local search method based on status switch of elements to improve the result of teacher. Implementation steps of the modified teaching-learning-based optimization algorithm are summarized as below:

Step 1: Initialize the population in a searching space bounded by a matrix with Pz (number of learners, i.e. class size) rows and $M \times N$ columns.

Step 2: Evaluate the class and select the best learner as the teacher for that iteration.

Step 3: Local search. The teacher tries to improve his or her knowledge by self-learning with the local search method. During the local search procedure, all the elements are randomly selected based on an ergodic sequence. If the chosen element is inactive, it will be activated with a random weight; whereas, if the chosen element is active, it will be switched to inactive. Once the switched status of element gives a better solution, the teacher will be updated with the new solution. In addition, if the active element fails in state transition, then a perturbation will be added to it for searching a better solution.

Step 4: Teacher phase. Class members learn from the teacher. T_F is the teaching factor, which can be either 1 or 2 with the equal possibility. X_{new} will be accepted if it gives a better value of objective function.

$$X_{new} = X_i + r \cdot (X_{teacher} - T_F \cdot X_{mean}) \tag{3}$$

Step 5: Learner phase. Learners increase their knowledge by interacting with each other. The learner X_i who has the bigger value of objective learns from others according to (4).

$$X_{new} = X_i + r \cdot (X_j - X_i) \tag{4}$$

Step 6: If the population meets termination criterion, then search method stops, otherwise goes to step 2.

III. Optimization Results

The modified TLBO method was applied to thin a 20×10 uniform square array with a λ/2 element spacing. One of the optimal results is a 78-element array with SLL=-20dB. The beam pattern of the thinned array is shown in Fig.1. Figure 2 shows the configuration of a quarter of symmetric thinned square array optimized by modified TLBO. Detailed data of excitation amplitudes of elements are listed in Table I. Compared with the results shown in [6], it can be found that there are 88 elements used in the same square array to achieve the same desired goal by a hybrid GA algorithm. The reduction in number of array element is 10, which shows that the optimization performance of the proposed modified TLBO is better in this problem.

The convergence curves of proposed modified TLBO and original TLBO synthesizing the above array are shown in Fig.3. The modified TLBO converges to optimal minimum after 16 iterations, while the original converges to a worse solution after 38 iterations.

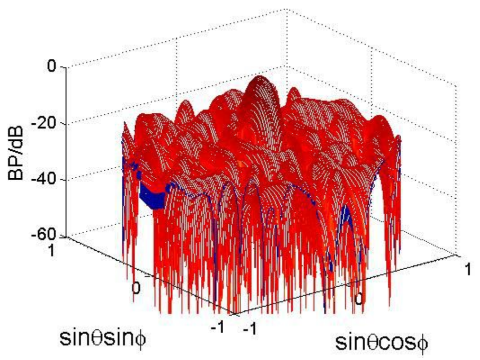

Fig.1. Optimized array beam pattern obtained by the modified TLBO.

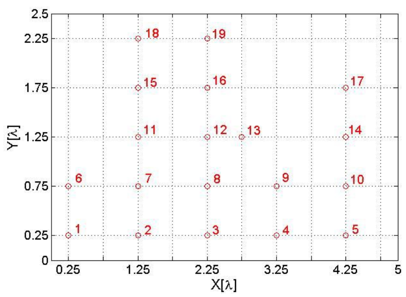

Fig.2. Configuration of a quarter of symmetric thinned square array.

IV. Conclusion

This paper proposes a modified TLBO for synthesizing a 20×10 uniform square array. The proposed optimization method is easy to implement, and it converges to the optimal result quickly with few numbers of iterations. Results of the optimization comparison show that ten array elements reduction and less number of required iterations can achieve the same goal by the proposed modified TLBO algorithm.

TABLE I
Optimized excitation amplitudes of the active elements

Element	Excitation	Element	Excitation
1	0.521	11	0.672
2	0.518	12	0.645
3	0.705	13	0.530
4	0.715	14	0.835
5	1	15	0.505
6	0.365	16	0.520
7	0.855	17	0.8
8	0.751	18	0.567
9	0.749	19	0.597
10	0.979		

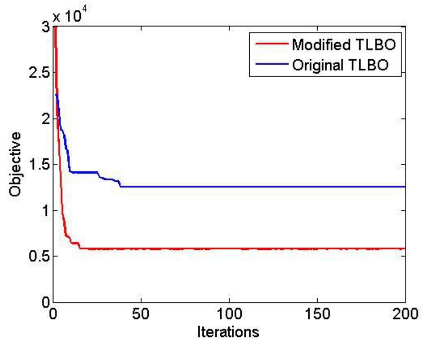

Fig.3. The convergence curves of modified TLBO and original TLBO.

Acknowledgment

The work was supported by the Research Fund for the Doctoral Program of Chinese Higher Education (No. 20110142130010), and the Chinese Ministry of Public Security State Research Projects (No. 2011ZDYJHJXY012).

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