Novel Technique of Synthesizing and Optimizing Linear Antenna Array having Minimal Side Lobes and Null Control Using Invasive Weed Concept

D.Rajitha, G.Karunakar, Rudra Pratap Das

Abstract: In this paper, a special optimization technique called Invasive weed optimization (IWO) has been initiated to synthesize linear variety of antenna arrays. IWO is applied to optimize amplitude excitations for performance improvement such as a reduced level of side lobes as well as control of null. A design example is considered and the amplitude weights are optimized with and without considering a specific beam width. In comparison with the conventional linear array antenna radiation pattern, this approach yields diminished levels of side lobe coupled with nulls positions in specific lines of choice.

Keywords: Antenna Array, Low side lobe level, Null control, Invasive weed optimization

I. INTRODUCTION

For long distance operation and communication devoid of interference, the antennas must have high directivity and minimal levels of side lobe. However, generally arrays having less bandwidth do not produce result in lower levels of side lobe. The above mentioned requirements are conflicting because narrow width of beam does not result in reducing side lobe. The converse is also true. Thus, a compromise has to be obtained by controlling levels of side lobe and synchronously keeping beam width at a suitable value. Novel algorithms such as genetic algorithm (GA)[1] and particle swarm optimization (PSO) [2] are effective in optimizing the gap between elements as well as excitation of the elements in the course of synthesizing the array.

For the objective of achieving a compromise between width of beam and level of side lobes, a highly effective evolutionary algorithm IWO has been selected for discussion in this paper. It is noted that Mehrabain and Lucas introduced IWO [3].

II. FORMULATION

1. Linear Antenna array

Taking an array of antenna placed on line of X-axis, the array factor for the azimuth plane can be expressed in [2].

$$AF(\theta) = \sum_{n=1}^{2N} I_n \cos[kx_n \cos(\theta) + \varphi \qquad (1)$$

Revised Manuscript Received on May 8, 2019.

D.Rajitha, Electronics & Communication Department, Chaitanya Engineering College, Visakhapatnam, India.

Dr.G.Karunakar, Electronics & Communication Department, GITAM Deemed to be University, Visakhapatnam, India.

Dr.Rudra Pratap Das, Director R&D, NSRIT, Visakhapatnam, India.

Here k represents the wave number, θ gives the angle of azimuth. I_n , φ_n and x_n are the amplitude, phase position of excitation of element n respectively. Assuming uniformity in phase part of excitation ($\varphi_n = 0$), by controlling nulls the reduction of side lobe is feasible by variation of I_n.

So the resultant fitness for [2] can be described as

$$Fitness = \sum_i \frac{1}{\Delta\theta_i} \int_{\theta_{li}}^{\theta_{ui}} |AF(\theta)|^2 \, d\theta + \sum_k |AF(\theta_k)|^2 \qquad (2)$$

Here θ_{li} *and* θ_{ui} are related to spatial regions corresponding to reduction of level of side. Null's direction is given by θ_k , the difference $\Delta\theta_i = \theta_{ui} - \theta_{li}$. Reduction of side lobe level and positioning of nulls are altered by solving the first and second terms of the above equation.

2. Novel Technique of Optimization (Invasive Weed):

The main steps of IWO are a) to Initialize, b) to Reproduce & disperse spatially and c) Competitive exclusion.

a. Initialization

In a solution space of N dimension, random initialization of seeds of finite number is carried out by its irregular positions.

b. Reproduction & Spatial dispersal

This step is similar to growth of seed to flower of the weed. The reproductive capacity of each seed is given by the magnitude of fitness function. Individual fitness value as well as the minimum & maximum values of the specific colony is required to determine the number of seeds reproduced from each seed. The produced seeds follow a random dispersion defined by Gaussian type having zero mean & changing standard deviation. This implies that location search can be carried out by scattering the produced seeds in neighborhood of mother weed. The value of σ reduces non linearity with the progress of generations. Initial value is given by $\sigma_{initial}$ & final value is given by σ_{final}. The relationship can be expressed as

$$\sigma_{gen} = \frac{(gen_{max} - gen)^n}{(gen_{max})^n} \left(\sigma_{initial} - \sigma_{final}\right) + \sigma_{final} \qquad (3)$$

Here gen_{max} represents the highest figure of generations.

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The measure of non linear modulation is n.

c. Competitive Exclusion

With passage of time, the new seeds thus created the level of flowering. These are kept with previous batch. Those of with minimum fitness are tarred in phases upto maximum point which proceeds next batch. The P_{max} value progresses to the next generation-S_{max}, S_{min}, $\sigma_{initial}$, σ_{final}, P_{max} and n are chosen as 4, 0, 0.015, 0.00015, 20 and 3 respectively.

III. DESIGN

For a thorough study, 28 elements linear array has selected the effective IWO for optimizing the amplitude excitations for least side lobe level coupled with control of nulls. The element spacing for these arrays along x axis is assumed to be $\lambda/2$. IWO algorithm is implemented using MATLAB. The total number of fitness function evaluations is taken as 500. Table I shows the optimized non-uniform amplitude excitations for each of the elements of the symmetric linear array.

IV. RESULTS

a. Case 1

Here we have considered the problem of minimizing the peak side lobe level without considering fixed first null beam width (FNBW). The example illustrates the synthesis of 28 element system of reduced level of side lobe placed in the positions of $\theta = [0^0,\ 84^0]$ & $\theta = [96°, 180°]$ with desired nulls at $\theta = 55^0, 57.5^0, 60^0, 120^0, 122.5^0$ & 125^0. In figure 1, It may be observed that IWO gives marked improvement in compressing the first side lobe level by around 9 dB in comparison with conventional system of array geometry. The first null beam width (FNBW) has gone up from 8^0 to 12^0 after applying optimization. Moreover broad nulls of approximately -65 dB have been attained at desirable directions.

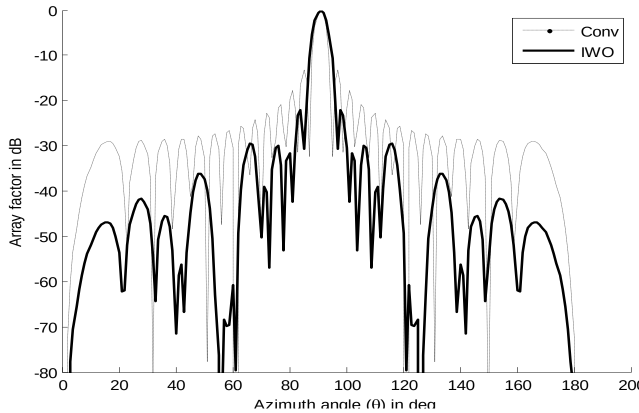

Fig 1. Normalized array factor of 28 element optimized linear array with desired nulls at $^{\prime}, 57.5^0, 60^0, 120^0, 122.5^0$&$125^0$ maintain without specific beam width

b. Case 2

Here we have considered the problem of minimizing the peak side lobe level with considering fixed FNBW. The obtained array pattern from the IWO algorithm is shown in figure 3, compared with the conventional optimized array pattern. It is seen from figure 3, suppression of first side lobe level by around 5 dB and broad nulls around -65 dB are achieved at the desired directions.

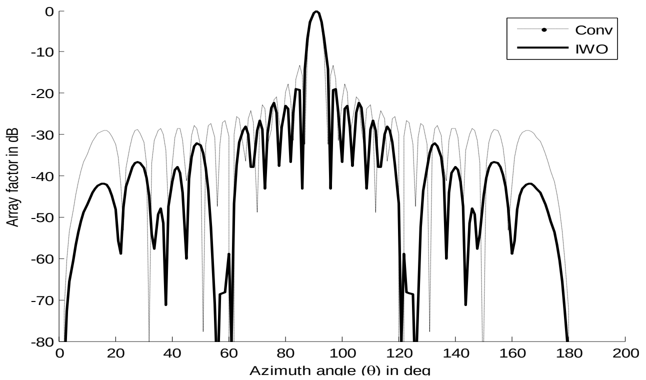

Fig 2. Rationalized factor of arrangements of twenty eight element linear array with desired nulls at $57.5^0, 60^0, 120^0, 122.5^0$&$125^0$ maintain with specific beam width.

Array Type	*Optimized Amplitude Weights*			
28 Element Antenna Array	*With Specific B.W*	0.5392 0.5444 0.4943 0.3748 0.2663	0.5911 0.5632 0.4674 0.4355 0.1573	0.5952 0.5165 0.3835 0.4014
	Without Specific B.W	0.5887 0.6046 0.5144 0.3256 0.1640	0.6486 0.5754 0.4749 0.3034 0.091	0.6429 0.5207 0.3861 0.2544

Table 1. Design Optimized Variables Obtained With IWO

V. CONCLUSION

In this paper, IWO is successfully utilized to attain reduced side lobes and correct placement of nulls. The obtained results are compared with data from conventional linear array geometry. The results confirm that substituent improvement has been achieved by IWO without disturbing strong nulls in specific directions. It is found that IWO is well suited for different type of array synthesis problems and also well suited for electromagnetic applications. This type of designs will enhance the performance of the communication systems by reducing the interference.

REFERENCES

1. J. Johnson and Y. Rahmat-Samii, "Genetic algorithms in engineering electromagnetics", IEEE transactions on antennas and propagation magazine, vol. 39, No. 4 , pp. 7-21, Aug. 1997.
2. Majid M. Khodier and Christos G. Christodoulou, " Linear array geometry synthesis with minimum side lobe level and null controlling using particle swarm optimization"., IEEE transactions on antennas and propagation, vol. 53, no. 8, pp. 2674-2679, August 2005.
3. A. R. Mehrabian and C. lucas, "A novel numerical optimization algorithm inspired from weed colonization", Ecol. Inform., vol. 1, no. 4, pp. 355-366, Dec. 2006.
4. Shaya Karimkashi and Ahemd A. Kishk, "Invasive weed optimization and its features in Electromagnetics", IEEE transactions on antennas and

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propagation, vol. 58, no. 4, April 2010
5. G.Karunakar and GSN Raju, "Influence of Dipole Length on Radiation Characteristics", IEEE Xplore, May - 2006, Article number . 5419770, Publisher: IEEE.
6. Oliveri, G. and A. Massa, \Genetic algorithm (GA)-enhanced almost difference set (ADS)-based approach for array thinning,"IET Microwaves, Antennas & Propagation, Vol. 5, 305{315, 2011.
7. Mahanti, G. K., N. Pathak, and P. Mahanti, \Synthesis ofthinned linear antenna arrays with fixed sidelobe level using real-coded genetic algorithm," Progress In Electromagnetics Research,Vol. 75, 319{328, 2007.
8. Zhang, L., Y.-C. Jiao, Z.-B. Weng, and F.-S. Zhang, \Designof planar thinned arrays using a Boolean differential evolutionalgorithm," IET Microwaves, Antennas & Propagation, Vol. 4,2172{2178, 2010.
9. Rocca, P., G. Oliveri, and A. Massa, \Diferential evolution asapplied to electromagnetics," IEEE Antennas and PropagationMagazine, Vol. 53, 38{49, 2011.20.

AUTHORS PROFILE

D.Rajitha M.Tech(Ph.D.)
Assistant Professor
Department of ECE
Chaitanya Engineering College,VSP.

Dr.G.Karunakar
Associate Professor
Department of ECE
GITAM Deemed to be University, VSP.

Dr.Rudra Pratap Das
Director R&D
NSRIT, VSP.

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