Muş Alparslan Üniversitesi Mühendislik Mimarlık Fakültesi Dergisi
3(2), 50-56, 2022
Araştırma Makalesi/Research Article

Sidelobe Suppression of Dipole Antenna Array Using Genetic Algorithm

Gökhan SATILMIŞ[1*]

[1] Muş Alparslan Üniversitesi, Uygulamalı Bilimler Fakültesi, Muş, Türkiye, ORCID: 0000-0002-8188-7242
Sorumlu yazar: g.satilmis@alparslan.edu.tr

Geliş tarihi:01.08.2022 Kabul tarihi:12.09.2022

Abstract

In this paper, two different linear dipole antenna arrays are created for suppressing side lobe levels. The magnitude of each antenna and the distance between each antenna are optimization parameters. The genetic Algorithm (GA) is used for optimizing magnitude and distance parameters for the required side lobe level where phi angle ranges between 40 to 60 degrees and 60 to 80 degrees. Furthermore, equally, and unequally spaced dipole antenna array is designed in MATLAB environment, and radiation pattern of these configuration is plotted with using obtained results from GA. The same results from GA are also used to design linear dipole antenna arrays in CST environment. In addition, a radiation pattern of both analytical and numerical results is compared on the same graph. As a result, GA can be used to suppress sidelobe levels of dipole antenna arrays, and the accuracy of the obtained results is not only valid in analytical solutions, but also the numerical solution.

Keywords: Sidelobe Suppression, Genetic Algorithm, Linear Antenna Arrays, Dipole Antenna

1. INTRODUCTION

The radiation of antennas presents some unwanted effects such as sidelobe level (SLL). In most antenna array applications, the first SLL is an undesired effect since it causes electromagnetic interference. SLL suppression is a hot topic in the literature [1,2] for microwave antenna arrays [3]. Particle swarm optimization [4], cuckoo search–chicken swarm optimization [5], hybrid optimization such as mixing antlion and grasshopper optimization [6], wind-driven optimization [7], and Improved Chicken Swarm [8] are used to suppress sidelobe levels of antenna arrays in the literature. Neural network and point spread function (PSF) based algorithms are also used as a suppression technique [9]. Furthermore, GA is widely used on antenna application such as synthesizing geometry [10], changing distance parameter [11], synthesizing radaiation patern [12], and designing non-uniform type of antenna arrays [13].

In this study, the Genetic Algorithm (GA) is chosen for optimizing the distance and magnitude parameters of linearly spaced antenna arrays. These parameters have an effect on the radiation of the equally and un-equally spaced antennas. The first parameter is the distance parameter, which means how far two pairs of dipole antennas should be placed considering all antennas are equally fed. The second parameter is the magnitude parameter, which means what magnitude level should be fed to each antenna considering all antennas are placed equally. Furthermore, the MATLAB environment is used first to determine the optimum values of distance and magnitude. In this case, the dipole antenna array factor is optimized using GA both for distance and magnitude parameters. Later, the CST environment is used to construct linear dipole antenna arrays and optimum parameters are used in this antenna configuration. The radiation pattern of both analytical and numerical results is compared for the validity of the study.

The novelty and the technical contribution of this work include: (i) optimizing distance and magnitude parameters with GA for sidelobe suppression of linear dipole antenna arrays at varying phi angle, (ii) comparing GA results with designing the same linear dipole antenna arrays in an electromagnetic simulation environment (iii) proposing the GA for suppression of SLL for any given phi angle.

2. GENETIC ALGORITHM

GA is widely used for many disciplines that require optimization and search techniques. It is a naturally inspired algorithm that is based on natural selection procedures such as mutation, crossover, and selection [14]. The working principle of GA is using a population that is composed of different individuals to evolve for maximizing the fitness function or minimizing the cost function. This method was known and developed by John Holland [15], and later David Goldberg [16] made this method popular for solving control of gas-pipeline transmission problems. There are many advantages of using GA such as continuous or discrete variables can be used, derivative information is not needed, capable of dealing with numerous variables, parallelization is easily realized, providing a list of optimum solutions, and working with a variety of data such as experimental, analytical, or numerically generated data. However, there are some limitations to using GA compared to alternative optimization algorithms. For instance, in many problems, GA is likely to converge towards local optimum value rather than the global optimum value of the problem. Other optimization algorithms may work better than GA in terms of speed and converge depending on specified optimization problems. These optimization algorithms are based on algorithms such as evolution strategies, evolutionary programming, or swarm intelligence. GA is incapable of solving problems, which the only fitness measure is binary wrong/right answer. In this problem type, a random search can be as efficient as GA.

In Figure 1, the flowchart of GA is depicted. It starts with randomly generating possible solutions at the initial population stage and using the fitness function to test each possible solution at the evaluation stage. At this stage, there is a stopping criteria, and if the criteria is met, then the best solution is found, and the algorithm stops. If stopping criteria is not met, then the selection, crossover, mutation, evaluation, and replacement loop starts until stopping criteria are met.

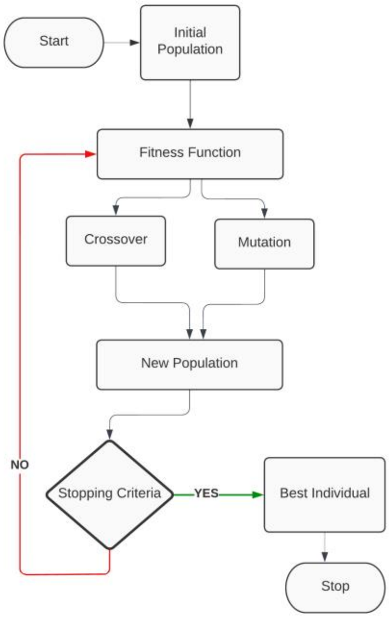

Figure 1: GA Flowchart [17]

The first step of designing an antenna array is a unit element. In this case, the unit element is a single dipole antenna. This dipole antenna can be easily designed using macro in the CST environment. This antenna is simple, and the radiation pattern can be calculated with trigonometric functions. A simple dipole antenna can be seen in Figure 2. In this dipole antenna, a discrete port is selected to feed the antenna. The port is placed between the upper and lower part of the antenna. A perfect electric conductor is chosen as the material type of the antenna.

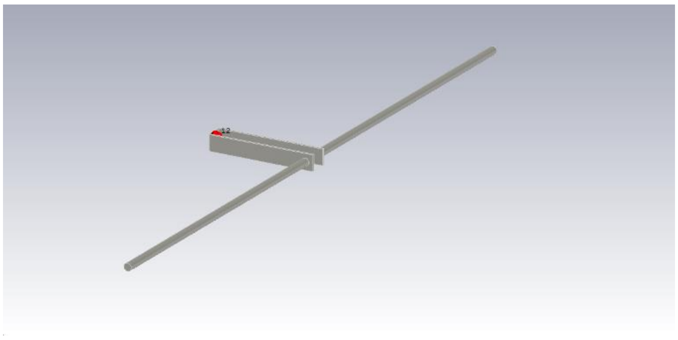

Figure 2: A Single Dipole Antenna

Dipole antenna arrays which have 20 elements are created linearly using the antenna in Figure 2. The dipole antenna array is symmetrical, so the number of an element is chosen as half of the total antenna. In this linear dipole antenna array, distance and magnitude parameters are used for suppression of sidelobe levels where phi angles are between 40 to 60 degrees and 60 to 80 degrees.

a. Distance parameter

In distance optimization, the suppression of SLL angle is chosen between 40 to 60 degrees, changing phi values. For instance, the resonance frequency is chosen at 2.4 GHz. The fitness function that is used for minimizing can be found in the following Equation 1.

$$AF(\varphi) = AF((\varphi)) + 2 * A(n) * cos(\frac{\pi}{2} * (d(n) + p(n)) * cos(\varphi * \frac{\pi}{180}) - cos(\varphi_{max} * \frac{\pi}{180}) \quad (1)$$

The above Equation is considered a fitness function and the GA algorithm is used to find out the p(n) values for the required SLL. In Table 1, the p(n) values are given in terms of lambda (λ). The total distance between each antenna is the sum of d and p values in Table 1. The obtained distances are used in the CST environment for creating the dipole antenna array which has 20 elements. The dipole antenna array which has 20 elements is the sum of two 10-element dipole antenna arrays that are symmetrical on the origin. The radiation pattern of the unequally spaced antennas is also obtained in the MATLAB environment using Equation 1.

Table 1. Optimum Distance Parameters

Parameters	Values
N	10
A	1, 1, 1, 1, 1, 1, 1, 1, 1, 1
d	0.25, 0.75, 1.25, 1.75, 2.25, 2.75, 3.25, 3.75, 4.25, 4.75
p	-0.17, -0.17, -0.43, -0.14, -0.26, -0.15, -0.23, 0.09, 0.15, 0.31
φ	40, 41, 42 …,58, 59, 60 degrees

2.1 Magnitude Parameter

In magnitude optimization, the suppression of SLL angle is chosen between 60 to 80 degrees, changing phi values. For instance, the resonance frequency is chosen at 0.8 GHz. The fitness function that is used for minimizing can be found in the following Equation 2.

$$AF(\varphi) = AF((\varphi)) + 2 * (A(n) + p(n)) * cos(\frac{\pi}{2} * d(n) * cos(\varphi * \frac{\pi}{180}) - cos(\varphi_{max} * \frac{\pi}{180}) \quad (2)$$

Where AF: Antenna Factor, n is the number of antennas, φ_{max} is 90 degrees, d is the distance 0.5 *λ and p is the result of the genetic algorithm in both Equations.

The above Equation is considered a fitness function and the GA algorithm is used to find out the p(n) values for the required SLL. The obtained magnitude values are used in the CST environment for creating the equally spaced antennas. The radiation pattern of the dipole antenna array is also obtained in the MATLAB environment using Equation 2.

Table 2. Optimum Magnitude Parameters

Parameters	Values
N	10
A	1, 1, 1, 1, 1, 1, 1, 1, 1, 1
d	0.25, 0.75, 1.25, 1.75, 2.25, 2.75, 3.25, 3.75, 4.25, 4.75
p	6.07, 2.67, 1.35, 9.94, 0.76, -0.82, 9.03, -0.58, -0.82, 5.01
φ	60, 61, 62 …,78,79, 80 degrees

3. RESULTS

The radiation pattern of dipole antenna arrays can be plotted with 2D graph, which axis are Θ (theta), and φ (phi) or 3D graph in cartesian coordinate system. In 2D graph, the vertical line corresponds to Θ (theta), and the horizontal line corresponds to φ (phi). Spherical coordinate system is used to plot radiation pattern of equally and un-equally spaced and antenna arrays in 2D graph.

The radiation of unequally spaced antennas is plotted using all parameters in Table 1 in Figure 3. In this figure, φ (phi) is the x-axis, and Θ (theta) is the y-axis. Analytical results and numerical results are compared, and it shows a good agreement about SLL where phi ranges between 40 to 60. Moreover, SLL is lower than -20 dB in the figure, which means the GA goal is realized. The radiation of unequally antennas is given in Figure 4. In this figure, it can be seen clearly that the first SLL is decreased after the main lobe. The radiation of the equally and unequally spaced antennas is symmetrical to phi angle, which is equal to 90 degrees.

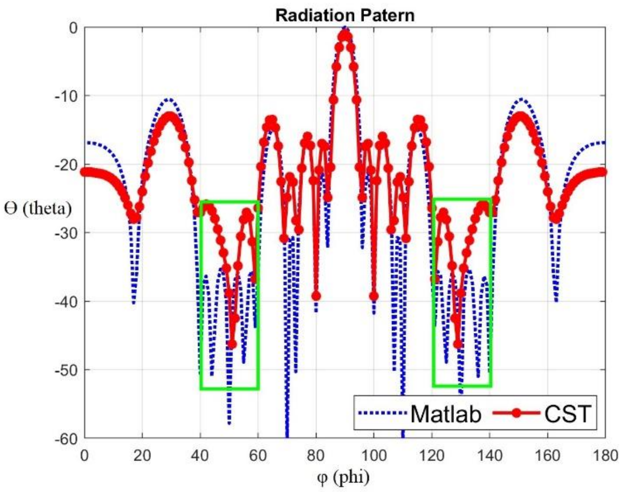

Figure 3: 2D Radiation Pattern of Optimum Distance Parameter

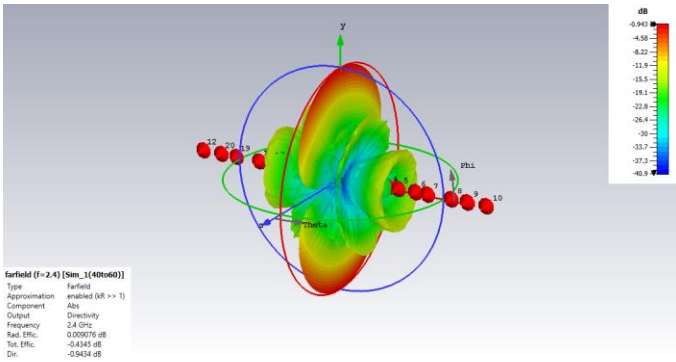

Figure 4: 3D Radiation Pattern of Optimum Distance Parameter

The radiation of equally spaced antennas is plotted using all parameters in Table 2 in Figure 5. In this figure, φ (phi) is the x-axis, and Ө (theta) is the y-axis. Analytical results and numerical results are compared, and it shows a good agreement about SLL where phi ranges between 60 to 80. Moreover, SLL is lower than -20 dB in the figure, which means the GA goal is realized. The radiation of the equally spaced antennas is given in Figure 6. In this figure, it is visible that after the main lobe, the first SLL is suppressed. The radiation of the equally spaced antennas is symmetrical to phi angle, which is equal to 90 degrees.

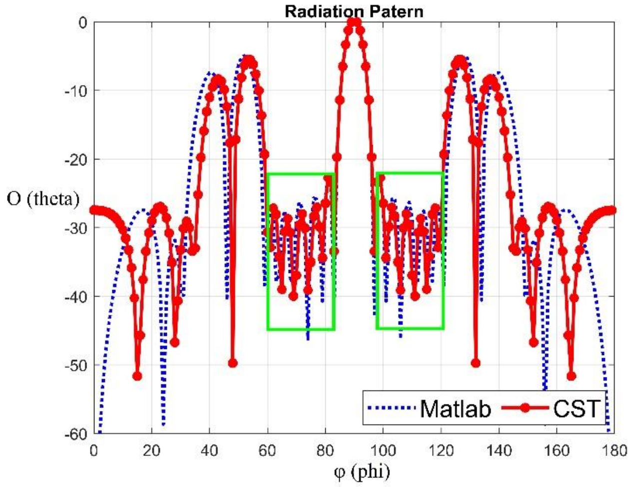

Figure 5: 2D Radiation Pattern of Optimum Magnitude Parameter

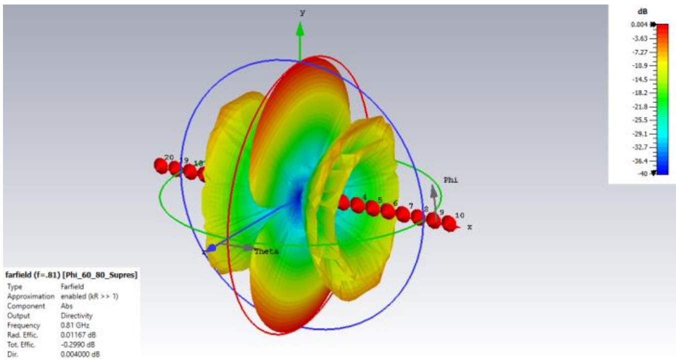

Figure 6: 3D Radiation Pattern of Optimum Magnitude Parameter

4. CONCLUSION

In this study, the GA algorithm is used for suppressing SLL for linear dipole antenna arrays. A single dipole antenna is designed using the built-in macro in the CST environment. A linear dipole antenna array is created using the single dipole antenna. There are two variables that are used for suppressing SLL for different angles in this linear antenna array. The first variable is the distance between each antenna, and the second parameter is the magnitude of each antenna. In Equations 1 and 2, the fitness function can be found. Equation 1 is optimized using the distance parameter for suppressing sidelobe levels of linear antenna arrays when phi angles vary between 40 to 60 degrees. The result of the p values is given in Table 1. Furthermore, Equation 2 is optimized using the magnitude parameter for suppressing sidelobe levels of linear antenna arrays when phi angles vary between 60 to 80 degrees. The result of the p values is given in Table 2. In addition, linear dipole antenna arrays are designed in a CST environment by using parameter values in Table 1 and Table 2. The radiation pattern of Equation 1 with obtained p values in MATLAB environment and CST result is compared in Figure 3. The radiation pattern of Equation 2 with obtained p values in MATLAB environment and CST result is compared in Figure 5. As a result, analytical and numerical results of linear dipole antenna arrays are plotted on the same graph to show both validities of the optimization results and the accuracy of the analytical and numerical approaches. There are minor mismatches in these graphs since the analytical approach does not consider interference between antennas. GA is a powerful optimization technique for many disciplines, and it can be used for suppressing SLL at any given phi angle.

REFERENCES

1. Boskovic, N., Jokanovic, B., & Nesic, A. Frequency scanning antenna array with enhanced side lobe suppression. In 2014 8th International Congress on Advanced Electromagnetic Materials in Microwaves and Optics, pp. 67-69, August,2014.
2. Nesic, A., Micic, Z., Jovanovic, S., & Radnovic, I.. Millimeter wave printed antenna array with high side lobe suppression. In 2006 IEEE Antennas and Propagation Society International Symposium, pp. 3051-3054, July, 2006.
3. Satılmış, G. & Güneş, F.. Mikro Şerit Dizi Anten Tasarımı için Besleme Ağı Tasarımı ve Uygulanması . Bitlis Eren Üniversitesi Fen Bilimleri Dergisi , 7 (1) , 32-38, 2018.
4. Khodier, M. M., & Christodoulou, C. G.. Linear array geometry synthesis with minimum sidelobe level and null control using particle swarm optimization. IEEE transactions on antennas and propagation, 53(8), 2674-2679, 2005.
5. Liang, S., Feng, T., & Sun, G. , Sidelobe-level suppression for linear and circular antenna arrays via the cuckoo search–chicken swarm optimisation algorithm. IET Microwaves, Antennas & Propagation, 11(2), 209-218, 2017.
6. Amaireh, A. A., Al-Zoubi, A. S., & Dib, N. I. ,Sidelobe-level suppression for circular antenna array via new hybrid optimization algorithm based on antlion and grasshopper optimization algorithms. Progress In Electromagnetics Research C, 93, 49-63, 2019.
7. Mahto, S. K., Choubey, A., & Suman, S.. Linear array synthesis with minimum side lobe level and null control using wind driven optimization, In 2015 International Conference on Signal Processing and Communication Engineering Systems (pp. 191-195), January, 2015.
8. S. Liang, Z. Fang, G. Sun, Y. Liu, G. Qu and Y. Zhang, Sidelobe Reductions of Antenna Arrays via an Improved Chicken Swarm Optimization Approach, IEEE Access, vol. 8, pp. 37664-37683, 2020.
9. Yang, Lijie, et al.,A sidelobe suppression algorithm for 77 GHz MIMO radars, Measurement:110691, 2022.
10. Khodıer, Majid M.; Chrıstodoulou, Christos G. Linear array geometry synthesis with minimum sidelobe level and null control using particle swarm optimization. *IEEE Transactions on Antennas and propagation*, 53.8: 2674-2679, 2005.
11. Goudos, Sotirios K., et al. Application of a comprehensive learning particle swarm optimizer to unequally spaced linear array synthesis with sidelobe level suppression and null control. *IEEE antennas and wireless propagation letters*, 9: 125-129, 2010.
12. Jın, J., et al. Array patterns synthesizing using genetic algorithm. *PIERS Online*, 2.1: 64-68, 2006.
13. Panduro, Marco A., et al. Design of non-uniform circular antenna arrays for side lobe reduction using the method of genetic algorithms. *AEU-International Journal of Electronics and Communications*, 60.10: 713-717,2006.
14. Katoch, Sourabh, Sumit Singh Chauhan, and Vijay Kumar,A review on genetic algorithm: past, present, and future, Multimedia Tools and Applications 80.5: 8091-8126.,2021.
15. Holland, John H, Genetic algorithms and the optimal allocation of trials,SIAM journal on computing 2.2: 88-105,1973.
16. Goldberg, David E., and Chie Hsiung Kuo, Genetic algorithms in pipeline optimization,PSIG Annual Meeting, OnePetro ,1985.
17. Kaya, Turgay; Ince, Melih Cevdet. The design of analog active filter with different component value using genetic algorithm. Int J Comput Appl, 45.8: 43-47,2012.