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A FRAMEWORK FOR OPTIMIZING ANTENNA THROUGH GENETIC ALGORITHM-BASED NEURAL NETWORK

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Abstract

In this research paper, the application of Artificial Neural Networks (ANN) for designing antennas is introduced. The primary objective of this optimization technique is to focus on the antenna's parameters to achieve a desirable S_{11} value, which is a key metric of an antenna's performance. To demonstrate the effectiveness of this approach, the optimization method to design three different antennas using the Numerical Analyzer (MATLAB) tool is employed. Through this study, it is tried to provide new insights into the optimization of antenna design using ANN and demonstrate its potential applications in the field of antenna engineering. The results of this research could potentially lead to the development of more efficient and effective antenna systems with improved performance in various applications.

Key words: Artificial Neural Network (ANN), genetic algorithm (GA), Optimization method, S-parameters

1 Introduction

The significance of having efficient and effective antennas has become increasingly apparent with the development of wireless technology. As the number of users continues to grow, it is essential to use antennas with adequate bandwidth to support more users [1, 2]. In other words, a high-performing antenna system is critical to meeting the demand for wireless connectivity in today's world. The ability to support a larger number of users is not only essential for ensuring the smooth functioning of wireless applications but also for meeting the growing demand for high-speed data transfer. Therefore, the need for optimized and efficient antenna systems is more significant than ever. This highlights the importance of ongoing research and development in antenna engineering to meet the ever-growing demands of the wireless industry [3].

Designing antennas can be challenging due to various factors, such as the complexity of their structure and the time-consuming nature of the process. To address these issues, several optimization methods have been developed, including surrogate-based optimization [4], particle swarm optimization [5], and spider monkey optimization [6]. These methods aim to simplify the design process and reduce the time and effort required to achieve optimal antenna performance. Surrogate-based optimization uses models to represent the antenna's behavior, allowing for a more efficient optimization process. Particle swarm optimization and spider monkey optimization use algorithms inspired by the behavior of swarms and primates to identify the optimal antenna design. By utilizing these optimization techniques, designers can overcome the challenges associated with antenna design and create high-performance antenna systems more efficiently. This highlights the importance of continually exploring new and innovative approaches to optimize the design of antennas in the rapidly evolving field of wireless technology.

The methods of optimization mentioned earlier have a limitation in that they do not allow for a fully automated environment and require human intervention at some level. This can lead to errors and inefficiencies in the optimization process, ultimately affecting the antenna's performance. To address this issue, more advanced optimization methods such as artificial neural networks (ANN) have become increasingly important [7, 8]. These methods utilize machine learning algorithms to optimize antenna design, reducing the risk of errors and improving overall performance. ANN-based optimization techniques can effectively automate the design process, allowing for more efficient and accurate optimization of antenna systems. The use of ANN-based methods highlights the importance of incorporating advanced technology and techniques into the field of antenna engineering to address ongoing challenges and improve overall performance.

The primary objective of this paper is to use Artificial Neural Networks (ANN) to design antennas that offer suitable bandwidth and evaluate the effectiveness of the optimization method. To achieve this, the input data for the ANN is designed parameters, and the optimization process is carried out automatically without the need for human intervention. The study aims to demonstrate that the ANN-based approach can successfully optimize the antenna design process and produce antennas with improved performance. By eliminating the need for manual intervention, the fully automated environment created by the ANN-based optimization method can reduce errors and enhance the efficiency of the antenna design process. The results of this research could potentially contribute to the development of more efficient and effective antenna systems, paving the way for new applications of wireless technology in various fields.

This paper is divided into three sections as follows. In the first section, the use of ANN in the antenna design process is discussed. The second section presents the simulation and results obtained using MATLAB. Finally, in the third section, the conclusion of the study is reported.

2 Design Process with ANN

This section devotes to presenting the optimization method that is based on the ANN and Genetic Algorithm (GA). The GA algorithm is the process of natural selection that is based on the evolutionary algorithms [9]. Figure 1 presents the structure of the proposed optimization process where the input layer devotes to the various design parameters in the antenna design, e.g., width and length, and the output layer presents the results of S_{11} that is optimized through GA algorithm.

This ANN can be trained through the achieved dataset where this dataset is obtained using random optimization for the various variables. The number of neurons in the hidden layer is achieved through the rule of thumb and the accuracy of the ANN is achieved by calculating the differences between the predicted output and actual output results.

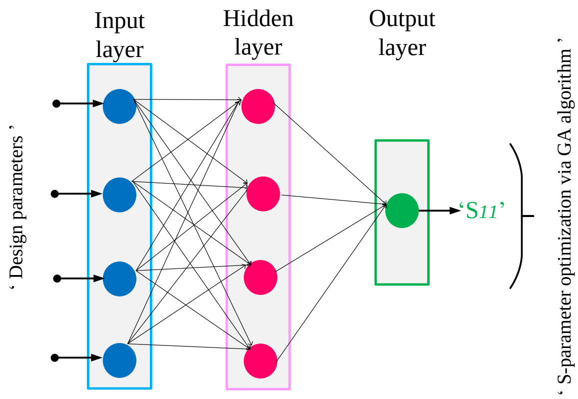

Figure 1: General view of the proposed ANN.

3 Simulation and Results

This section of the paper illustrates the design and simulation results of three variety antennas by using MATLAB tool. The ANN is trained with an accuracy of 80% for optimizing the output responses in terms of S-parameters.

Figure. 2 and Fig. 3 illustrate the geometry of antenna 1. The parameters of the toothed antenna which is built on FR-4 substrate with $\epsilon_r = 4.8$ and $\tan\delta = 0.026$ are reported in Table.1:

Table 1: Proposed antenna 1 with design parameters (mm) in Fig.2 and Fig.3

name	value (mm)	name	value (mm)
W_a	15.2	L_a	35.2
W_g	15.2	L_g	31
L_p	9.48	L_1	7.88
L_2	5	L_3	12
L_4	2	L_5	2.7
L_6	3.94	W_1	0.9
W_2	0.5	W_3	1.4
W_4	1.7		

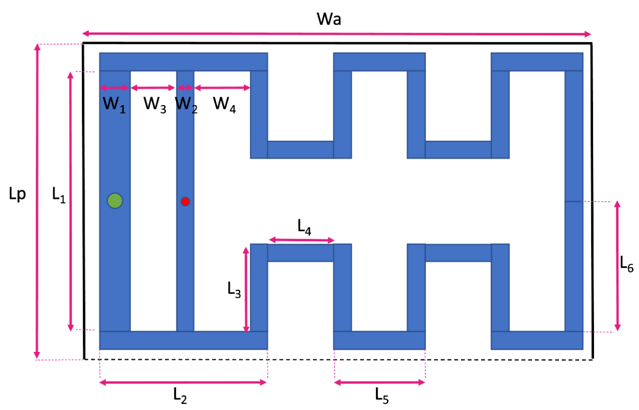

Figure 2: Geometry of the proposed antenna 1

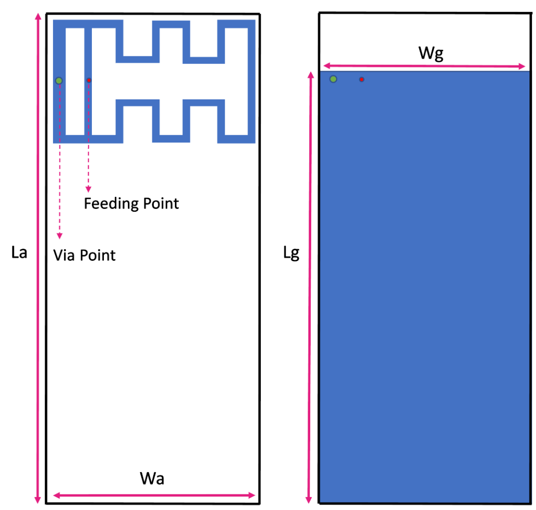

Figure 3: Geometry of the proposed antenna 1: **(a)** top-view of the antenna **(b)**ground view of the antenna.

The S_{11} performance parameter of the antenna 1 simulation is illustrated in Fig. 4. The operation frequency covers from $8.68GHz$ to $9.7GHz$ with a return loss of $-14db$ at $9.4GHz$. Moreover, the 3D radiation pattern and current distribution of antenna 1 are shown in Fig. 5 and Fig. 6, respectively. The current distribution is presented at $9.4GHz$ which the return loss occurs.

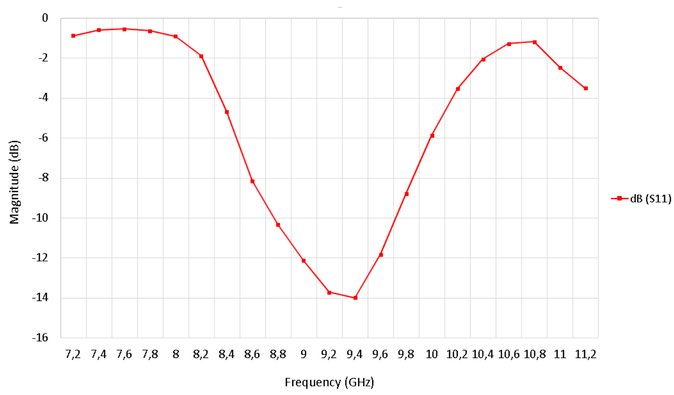

Figure 4: S11 specifications of optimized antenna 1.

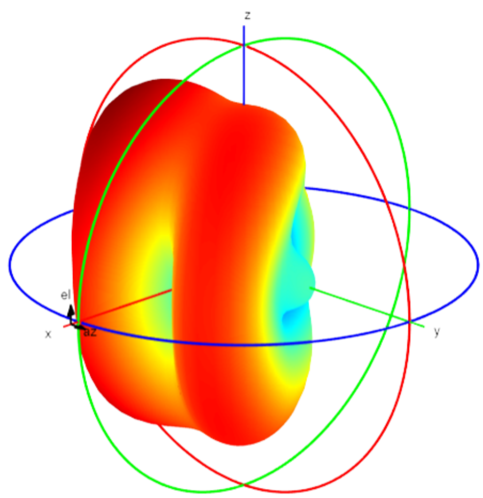

Figure 5: Antenna 3D radiation model.

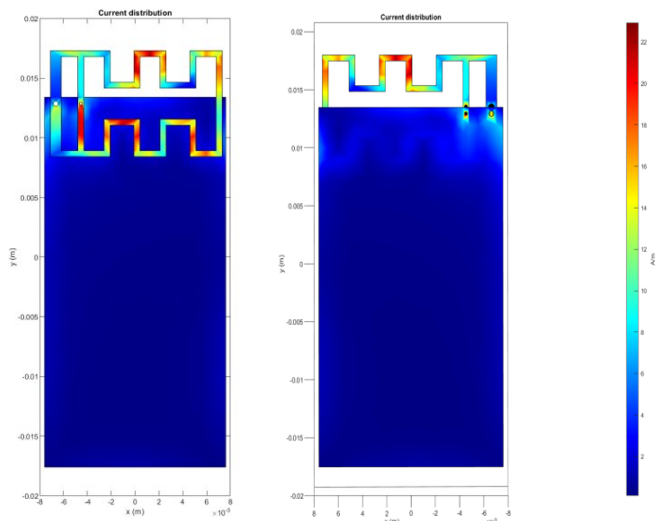

Figure 6: Surface current contributions of antenna 1 at 9.4 GHz.

The second design of the antenna with the use of ANN method is presented in Fig. 7. This type of antenna is simulated on the F4BM350 substrate ($\epsilon_r = 3.5$ and $\tan\delta = 0.001$). The dimensions of the

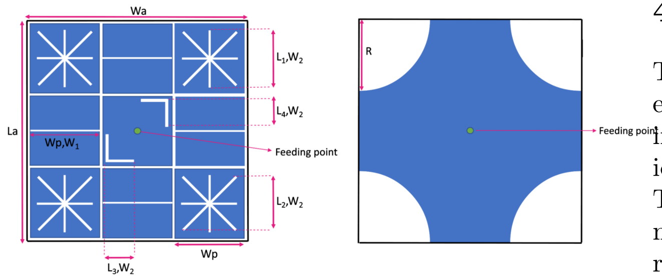

Figure 7: Geometry of the proposed patch antenna 2: **(a)** top-view of the metasurface structure with 3×3 elements; **(b)** ground view of the antenna 2.

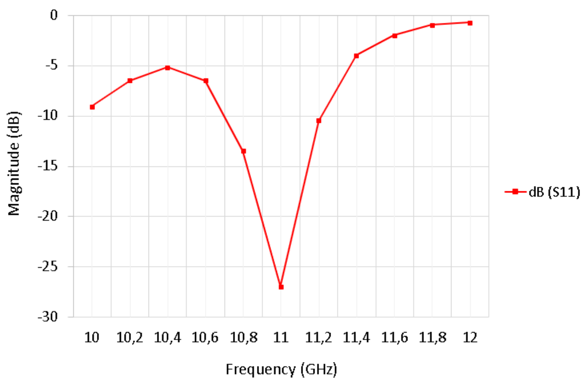

Figure 8: S11 specifications of antenna2.

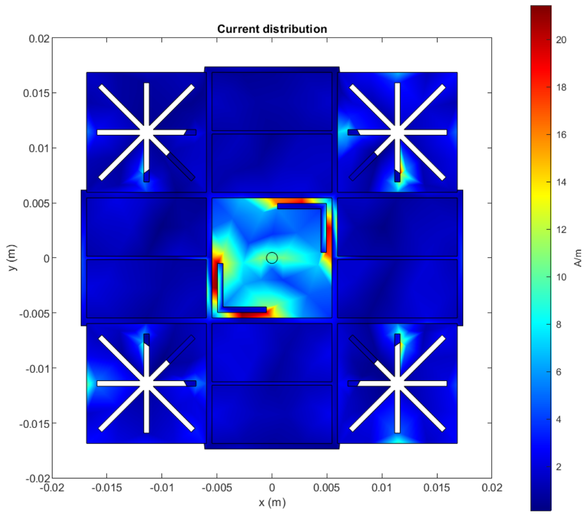

Figure 9: Surface current contributions at 11 GHz.

second antenna are proposed as follows: $W_a = 34.7$, $W_p = 10.9$, $W_1 = 0.3$, $W_2 = 0.5$, $R = 11.25$, $L_a = 34.7$, $L_1 = 9$, $L_2 = 12$,$L_3 = 3.95$, and $L_4 = 4.45$ all parameters are reported in mm.

Figure. 8 shows the S_{11} parameters which its bandwidth is $500MHz$ ($10.7GHz$ - $11.2GHz$) with attenuation level $-27dB$ at $11GHz$.

Moreover, the 3D current distribution is presented in Fig. 9 at the $11GHz$ where the return loss happens.

4 Conclusion

The main objective of this research is to explore the effectiveness of Artificial Neural Networks (ANN) in designing three distinct types of antennas and identifying optimal antenna parameters such as S_{11}. The study aims to create a fully automated environment for antenna design to minimize the risk of errors and improve overall efficiency. The models for the three antennas are developed using the MATLAB software tool, which is widely used in antenna design and simulation. By employing ANN-based optimization techniques, the study aims to demonstrate the potential benefits of machine learning in the field of antenna engineering. The results of this research could help to advance the development of more efficient and effective antenna systems, contributing to the continued growth of wireless technology in various industries.

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