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Design and Comparative Analysis of E-Shape and H-Shape Microstrip Patch Antenna for IoT Application

Nesnelerin İnterneti Uygulaması için E-Tip ve H-Tip Mikroşerit Yama Anten Tasarımı ve Karşılaştırmalı Analizi

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ABSTRACT

In this study, H-Shape and E-Shape microstrip antenna arrays with high efficiency and management are designed using Surrogate Model Assisted Differential Evolution Algorithm (SADEA) for antenna synthesis. In order to meet the increasing wireless communication requirements of the internet of things (IoT) technology it has become very important to design new antenna designs with artificial intelligence techniques to transmit electromagnetic waves between antenna elements in the most efficient way. With a view to operate in the 2.5 GHz band, which is widely used in wireless communication technologies. H-Shape and E-Shape microstrip antennas with a 2x2 structure are analyzed and finally compared. By using the SADEA method, the amplitude and the distance between the array elements are optimized. The total amplitude of the 4-element E-Shape and H-Shape microstrip antenna array is minimized to 2.45885 V and 2.14929 V, respectively, after optimization, while it is 4V for both before optimization.

MAKALE BİLGİSİ

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ÖZET

Bu çalışmada, anten sentezi için vekil model destekli diferansiyel evrim metodu (SADEA) kullanılarak yüksek verimliliğe ve yönelticiliğe sahip H-tipi ve E-tipi mikroşerit anten dizileri tasarlanmıştır. Nesnelerin interneti (IoT) teknolojisinin artan kablosuz haberleşme gereksinimlerini karşılamak amacıyla, elektromanyetik dalgaların anten elemanları arasında en verimli şekilde iletilmesi için yapay zeka teknikleri ile yeni anten tasarımlarının yapılması oldukça önemli hale gelmiştir. Kablosuz haberleşme teknolojilerinde yaygın olarak kullanılan 2.5 GHz bandında çalışmak üzere 2 farklı durum ele alınmıştır. 2x2 yapıya sahip H-tipi ve E-tipi mikroşerit anten dizisi analiz edilmiş ve karşılaştırılmıştır. SADEA yöntemi kullanılarak, genlik ve elemanlar arasındaki mesafe optimize edilmiştir. Dört elemanlı E-tipi ve H-tipi mikroşerit anten dizisinin toplam genliği, optimizasyondan önce her ikisi için de 4V iken, optimizasyondan sonra sırasıyla 2.45885 V ve 2.14929 V'a indirgenmiştir.

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1. INTRODUCTION

Today, Internet of Things (IoT) systems are predicted to support a wider user base, offer higher data rates, faster latency, and higher energy efficiency [1-2]. For these reasons, there is a need for an antenna with higher gain and a more directional radiation pattern. Since the antenna used for this purpose alone could not achieve high efficiency and the desired directivity, antenna arrays are formed by combining multiple antennas with different geometries [3]. Thus, the communication speed of IoT systems can be increased with optimum antenna array design. In the design of antenna arrays, parameters such as amplitude, position, and phase are optimized [4]. Since this optimization process is a complex nonlinear problem, it is very difficult to solve it with classical methods. Antenna design has become very important with artificial intelligence methods used in many different fields in recent years instead of classical methods [5]. Searching in the search space with a single search agent using classical methods is insufficient to find suitable solutions for difficult problems such as antenna array design. Artificial intelligence methods that can distinguish global and local minimum points, which have more search agents, overcome difficult problems such as antenna array design [6].

The production of distinct radiation patterns for a consistent antenna configuration necessitates iterative rerunning of algorithms for every distinct model, culminating in a notable extension of computational duration. In recent times, widely used artificial intelligence methodologies have been employed across diverse realms of scholarly investigation and practical implementation, encompassing domains such as electromagnetic (EM) computation problems. Artificial intelligence optimization techniques have also been used to design and synthesize various antenna types. When designing the antenna structure, artificial intelligence techniques can be used to reduce simulation time and obtain the optimum radiation pattern. Increasing the antenna array gain by using new artificial intelligence techniques, such as machine learning methods, is quite common in the literature [3-12].

Antenna arrays are used to increase signal strength, have good directivity and reduce electromagnetic noise. In this study, two different type microstrip antenna arrays with 4 elements are designed using MATLAB Antenna Array Designer tool and their performances are presented comparatively. The antenna types compared in this study are H-Shape and E-Shape antennas. The 4-element antenna array is chosen because it is generally easier to design and is more frequently used in medium-scale applications. This antenna array is capable of transmitting and receiving signals at different frequencies and in different directions. They also cost less and consume less power than larger antenna arrays. Therefore, they are highly efficient, cost-effective, and energy-efficient options that provide adequate performance for many applications.

Surrogate model assisted differential evolution for antenna synthesis (SADEA) methods are machine learning based SAEAs that use metaheuristic algorithms to support antenna synthesis. To help optimize the process, SADEA generates a surrogate model using statistical learning methods. SADEA's advantages of good convergence, efficiency, fast solving, and accurate computation make it an appropriate choice for this study. The literature contains several studies on the design of E-Shape and H-Shape antennas.

A 1x3 microstrip antenna array for automotive radar applications is designed by Sumit S. at 24 GHz [7]. A new microstrip antenna element operating operating in a millimeter wave band is designed by Jia-Fu [8]. The H-Shaped coupling slot feeding is used to extend the bandwidth and reduce the back radiation, and the parasitic patching methods are added [8]. The H-Shaped compact microstrip antennas designed by Ahmet using the Weed algorithm made it possible to determine the resonance frequencies depending on the size of the antenna in the 1-3 GHz frequency band [9]. A study by Amit A. using H-, C- and W-shaped ground plane profiles increased the bandwidth and gain of a compact broadband proximity-fed rectangular and circular microstrip antenna [10]. Arijindinav E. obtained the design of the microstrip antenna with an H-Shaped patch in the 2.4 GHz frequency band for WLAN applications, using Advanced Design Software (ADS); With this design simulation results, advanced antenna parameters such as gain, directivity, bandwidth, return loss, VSWR and impedance matching are presented [11]. In a study by Alireza Jafarieh et al. using the Kriging technique model generator, the optimal array for high gain and wide BW in the designed Yagi-Uda array is designed [12]. Ahmed M. Montaser used a hybrid MGSA-PSO approach and a DNN trained with the backpropagation technique to design a compact and low-cost 20-element SIW-guided microstrip patch antenna array for 120 GHz ISM band applications [13]. Dumbbell shaped 4 and 8 element microstrip patch antenna arrays suitable for 5G are fabricated in five different frequency bands (4.4 GHz, 5.9 GHz, 5.9 GHz, 6.05 GHz and 7.3 GHz) with a maximum gain of 6.74 dB and a bandwidth of 1383 MHz in the study by Rovin Tiwari et al. [14]. The 30 GHz band antenna designed by Mohammad B.A. et al. using the CST application has a compact structure of $10\times10\times0.245$ mm^3 and a reflection coefficient below -14 dB [15]. The microstrip patch antenna operating at 2.4 GHz is designed by Sohel Rana et al. using the CST program to have a lower return loss, a higher gain, and lower VSWR values. The values obtained from the simulation are -13.89 dB, 6.66 dB and 1.50 of return loss, gain, and VSWR respectively [16]. The 1×8 antenna array proposed by Al-Gburi et al. is designed using the CST application to be fed by the microstrip enterprise feed line and provides directional radiation useful for the base station to provide high quality and high-capacity network connectivity, and 6.938 at 5 GHz [17]. Hasan Biddut et al. designed an ultra-wide, multi-slot microstrip patch antenna that operates in the V-band. The slots are placed at random intervals on the microstrip patches to increase the bandwidth and a microstrip patch antenna array is operated at a frequency of 54.504 GHz [18]. Jae H.K. and Sang W.C. designed a 4×1 patch antenna using DNN trained with 6.859 pattern samples by determining the amplitude and phase of antenna elements according to radiation patterns. The E-Shaped microstrip patch antenna array (MSPAA) designed in this study by K.P Nadar et al. is compared with other antennas in the literature, and a more efficient MSPAA is designed [19]. A tiny, inexpensive E-Shape antenna array is created for WLAN applications in research by R.M. Gonzalez et al. [20]. In the study by S. Gupta et al., Shape of E-H, and U antennas are designed and analyzed comparatively [21]. This study, which shows how the DOE method will increase the effect of the optimization efficiency by using antenna simulation software, is carried out by J. H. Chen et al. by designing an E-Shape antenna [22].

In this study, E-Shape and H-Shape microstrip antenna arrays, which are known to have high gain, are selected for comparison. Antenna gains can vary depending on antenna parameters like orientation and inter-element distance. They also offer high bandwidth and can be used for a wide range of applications. These microstrip array antennas have a simple structure and are thus easy to manufacture, making them ideal for large-scale production. As a result, they are less expensive than other antenna types, making them ideal for low-cost communication systems. They advantageous and useful compared to other antennas in terms of compact design, high directivity, high gain, wide bandwidth, easy manufacturing, and cost effectiveness. E-Shape and H-Shape microstrip antennas are widely used in applications due to these features. In this paper, we consider the design of E-Shape and H-Shape 4-elements microstrip antenna arrays.

Additionally, a comparative presentation of the simulation results and the evaluation criteria for the antenna array design performance is provided.

The 5G NR (New Radio) technology of 5G networks uses a frequency range of 2.5 GHz, between the 2.4 GHz and 5 GHz bands. The advantages of 5G networks, including increased bandwidth, faster data rates, and reduced latency, are enhanced by this frequency. Furthermore, it enables higher data rates and bandwidths due to its higher frequency than lower frequencies like 2.4 GHz. For applications that need high-speed data transmission, the 2.5 GHz frequency is therefore recommended.

In this study, an optimization method called SADEA is used in E-Shape and H-Shape microstrip 4 element antenna array design. SADEA is an evolutionary algorithm that optimizes the amplitude and phase values of the elements specially developed by MATLAB to direct the radiation patterns of the antenna arrays in the desired direction, zero the side beams and increase the gain. How the SADEA method is applied in antenna array design, which parameters are used and how they are adjusted are explained in detail in this article. Additionally, a comparative presentation of the simulation results and the evaluation criteria for the antenna array design performance is provided.

The 5G NR (New Radio) technology of 5G networks uses frequencies in the 2.4 GHz and 5 GHz bands. The advantages of 5G networks, such as increased bandwidth, higher data rates and lower latency in networks with previous technology, are enhanced with this frequency. Furthermore, it enables higher data rates and bandwidths due to its higher frequency in comparison to lower frequencies like 2.4 GHz. For applications that need high-speed data transmission, the 2.5 GHz frequency is therefore recommended.

Section 2 describes the optimization method. Section 3 explains the problem formulation of the H-Shape and E-Shape microstrip antenna array. Section 4 descriptions the numerical results. Section 5 discusses the conclusions.

2. SADEA OPTIMIZER

Antenna design is a discipline that plays an important role in modern communication systems. Traditional methods for antenna design are based on mathematical models and the design process is quite time consuming. Machine learning methods allow rapid and intelligent optimization in the antenna design process and automate the design process to a large extent. Machine learning is a method that enables computer systems to improve through data-based experience. This method integrates statistical and mathematical techniques to analyze data, identify pattern and make predictions to solve complex problems. Machine learning techniques can be inspired by optimizing algorithms and using surrogate modeling to tackle challenging problems. In this way, it can search more effectively. It can also effectively process large datasets and develop automated decision-making systems. All of this offers the potential for innovation and progress in a wide range of areas, from industrial applications to medical research and beyond. Surrogate Model Aided Evolutionary Algorithms (SAEAs) have recently received much interest due to the increasing demand for optimizing many computationally real-world problems [23]. Surrogate model assisted differential evolution for antenna synthesis (SADEA) is an artificial intelligence-driven antenna design technique that stands for surrogate model assisted differential evolution for antenna design. SADEA method, which is an SAE, is supported by the Differential Evolution Algorithm (DEA) and Gaussian Process (GP) for the design of the antenna [24]. SADEA uses machine learning and evolutionary computing techniques with the advantages of good convergence, efficiency, fast solving, and accurate computation [25, 26]. Due to the aforementioned characteristics of SADEA, E-Shape and H-Shape antenna array designs using SADEA are considered appropriate for this study. The way SADEA works is explained in the following equations:

$$x = (x_1, x_2, x_3, \dots x_n) \tag{1}$$

$$y = (y_1, y_2, y_3, \dots y_n) \tag{2}$$

Using the GP model for the function value of y(x^*) at a new point x^* is determined as Eq. 3.

$$y(x*) = \mu + r^T R^{-1}(y - I\mu) \tag{3}$$

$$Corf(x_i, x_j) = R_{i,j} \text{ and } i, j = 1,2, \dots n. \quad (4)$$

$$r = [Corf(x_i, x_j), Corf(x^*, x_2, \dots, Corf(x^*, x_2)] \quad (5)$$

$$\mu = (I^T R^{-1} I)^{-1} I^T R^{-1} y \quad (6)$$

Eq. 3 below provides an illustration of this correlation function:

$$Corf(x_i, x_j) = \exp\left(\sum_{l=1}^{d} \theta_1 \left|x_i^l - x_j^l\right|^{pl}\right);\ \theta_1 > 0{,}1 \leq 2 \quad (7)$$

where θ_l is the correlation parameter, and d is the dimension of $x. pl$ is the function's smoothness with relation to x^l. The GP will maximize the likelihood function in order to calculate the correlation parameter and the smoothness function:

$$h = \frac{1}{(2\pi)^{\frac{n}{2}}\ (\sigma^2)^{\frac{n}{2}}\ |R|^{\frac{1}{2}}} \quad (8)$$

$$\exp\left(-\frac{(y-l\mu)^T R^{-1} (y-l\mu)}{2\sigma^2}\right) \quad (9)$$

where l is nx1 vector of ones. Assuming that θ_l and pl are known, the value of σ^2 will be and the value of μ will be obtained by setting the derivatives of the probability function to 0.

$$\sigma^2 = (y - l\mu)^T R^{-1} (y - l\mu)^{n-1} \quad (10)$$

The prediction uncertainty s^2, which is obtained by substituting μ and σ^2 into Eq. 9, is used to evaluate the accuracy model as

$$s^2(x^*) = \sigma^2 [I - r^T R^{-1} r + (I - r^T R^{-1} r)^2 (r^T R^{-1} I)^{-1}] \quad (11)$$

$$y_{lcb}(x) = y - \omega s, \omega \in [0,3] \quad (12)$$

Figure 1 shows the flow chart of the antenna array design with SADEA mentioned in the above formulas.
The range of values for which optimization is to be performed is selected.

- The first step is to generate the population by selecting "λ-best" solutions. λ is one of the solutions in the population. λ-best is the best solution. At each iteration, the population is formed by updating the values.
- If a predefined condition for the termination criterion is met, the best answer is removed from the database. Otherwise, it continues.
- The number of stopping iterations is set to 10 due to the fast processing time and since no significant increase is observed after the tenth iteration.
- The population standard deviation (PSD) is calculated and must be below threshold (T).
- It performs the EM simulation for the best sub-solution at each iteration and records the results.
- When the finishing requirement is reached, the iteration is completed and the best results are determined.
- The results obtained are given in Section 4 through tables and figures.

3. PROBLEM FORMULATION

Antenna design is an important issue that directly affects the performance of modern communication systems. The aim of antenna design is to obtain high-gain, low sidelobe, and wideband antennas with the desired radiation characteristics. Antenna arrays are often used for this purpose. Antenna arrays are antenna systems created by placing and feeding more than one antenna element according to a certain geometry. The radiation characteristics of antenna arrays depend on parameters such as the number, shape, position, orientation, and amplitude of the elements. Various methods have been developed to optimize these parameters. In this article, SADEA method, which is specially developed by MATLAB for antenna optimization, is used to optimize the distance and amplitude values between elements in antenna arrays. The SADEA method is an artificial intelligence supported method for antenna design. Based on machine learning and evolutionary computing techniques, this method has advantages such as optimization generality, efficiency, quality, and robustness. The SADEA method performs global optimization and uses a compensatory model created with statistical learning techniques. In the adaptive model-assisted optimization methods, it is critical that the performer modelling and optimization work in harmony. The SADEA method borrows some ideas from the fulfilling pattern-aware evolutionary search framework. The SADEA methodology employs differential evolution (DE) as its underlying search mechanism, coupled with Gaussian process (GP) machine learning serving as an adjunctive compensatory modelling approach. For the application of the microstrip antenna array, FR4 substrate, which is easily available in the market, is preferred, loss tangent of the FR4 material (δ = 0.020), relative dielectric constant (ε_r= 4.40), insulator plate height (h = 1.5750 mm) and conductor thickness (t = 0.0350) are planned to be produced in mm. While calculating the physical parameters of the classical microstrip patch antenna modelled to be used for LoRa WAN at operating frequencies of 433 MHz and 868 MHz, the transmission line model is taken as a reference and an element of the E-Shape and H-Shape antennas geometry shown as Figure 2.

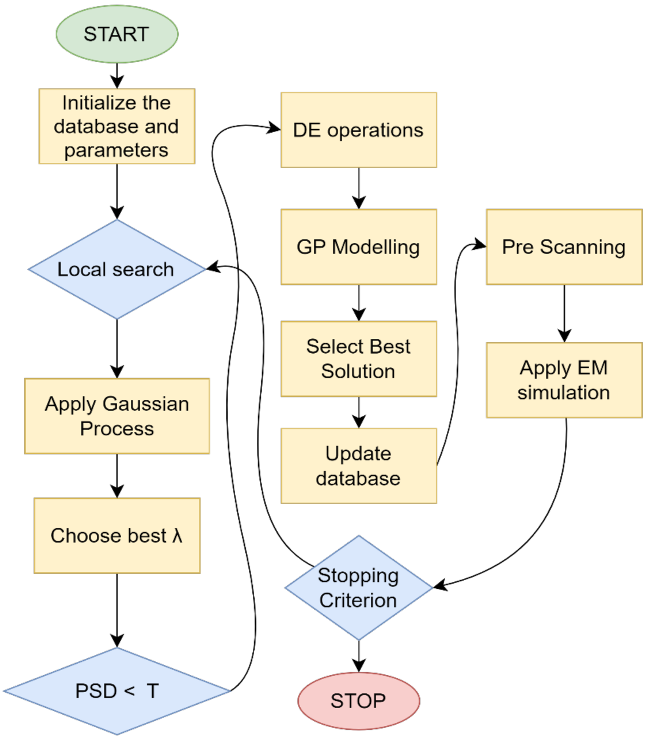

Figure 1. Flowchart of optimization process.

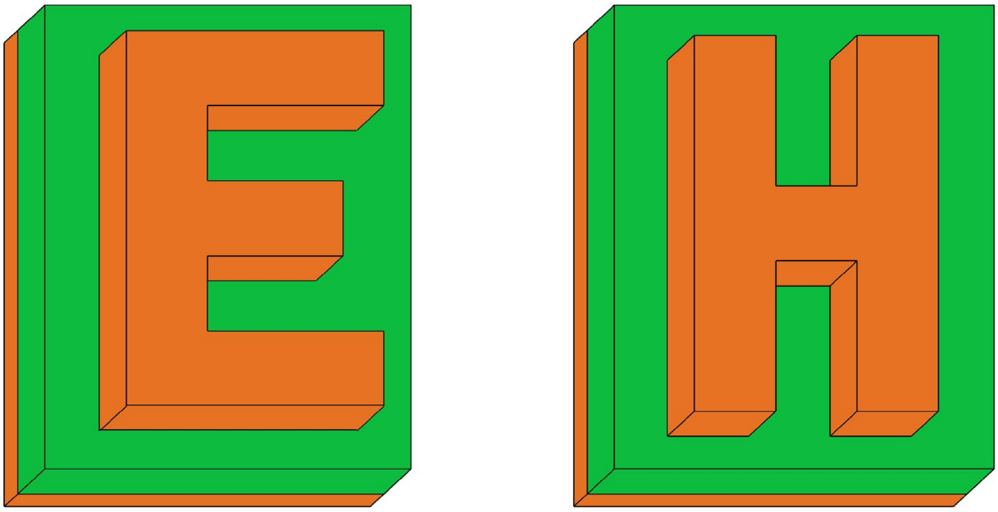

Figure 2. Structure of E-Shape and H-Shape microstrip antenna.

The part shown in green in Figure 2 represents the substrate consisting of FR4 material. The part shown in orange represents the conductive PEC material. As it is widely known, the frequency of resonance is provided in the Eq. 13:

$$f_r = \frac{2}{2L\sqrt{\varepsilon_r r}} \quad (13)$$

The radiation properties are determined by the shape and size of the patch, as described in the Eq.14 and Eq. 15.

$$W = \frac{2}{f_r}\, \varepsilon_r + \frac{1^{\frac{-1}{2}}}{2} \quad (14)$$

$$L_{eff} = \frac{c}{2f_r\sqrt{\varepsilon_r} - 2\Delta l} \quad (15)$$

where c, f_r, ε_r, Δl and L are the free space velocity of the light, resonant frequency of the antenna, the effective dielectric constant of the substrate, the length of equivalent radiation gap and the actual length of the current, respectively. The structure of the E-Shape and H-Shape slot antenna are illustrated in Figure 2. A substrate characterized by a low dielectric constant has been designated to achieve a compact radiating structure conforming to stringent bandwidth requirements. Increasing antenna efficiency is one of the most important factors in improving wireless communication quality and saving energy. As a result, designing an antenna array with more efficient antennas that meet next-generation wireless applications is a difficult task, particularly when it comes to maintaining stable radiation patterns across the operating frequency band.

4. NUMERICAL RESULTS

The radiation properties are determined by the size and shape of the patch. The performance of the antenna arrays is analyzed by simulations. In this study, the important parameters of antenna arrays such as gain, radiation pattern and inter-element distance are analyzed. While designing these antenna arrays, first the model design is carried out and then the optimization process is carried out on this model. In our literature review, the most common iteration numbers vary between 20 and 50. Therefore, we did preliminary studies with iterations between 20 and 50. In our studies, when we exceeded 20, no significant performance increase and no significant change in the data in the comparisons are detected. In the light of this information, we set the number of iterations as 20, which is our completion criterion. CPU time are taken for E and H shape microstrip antennas. 120 s and 150 s are the times taken for the optimization of E-Shape and H-Shape microstrip antennas, respectively. For the simulation of the microstrip antenna array, ideal materials where the losses are assumed to be 0 are used. The default value for the material is a PEC. For the design problem, FR4 substrate, which is easily available in the market, is preferred, the loss tangent of FR4 material (δ = 0.020), relative dielectric constant (ε_r= 4.40), insulator plate height (h = 1.5750 mm) and conductor thickness (t = 0.0350 mm) have been planned. The operating frequency is set at 2.5 GHz. E-Shape and H-Shape 4-element microstrip antenna arrays are analyzed in separate cases.

4.1. Case 1: 4-Element Microstrip H-Shape Antenna Array

The results show that microstrip antenna arrays are a high performance and efficient technology. The 3D radiation pattern of the 4-element H-Shape microstrip antenna array is illustrated in Figure 3. Before the optimization process, each element has an amplitude value of 1 V. The distance between the elements in both rows and columns is 0.059958 mm. After optimization, these values are 0.069192 mm for row spacing and 0.095527 mm for column spacing.

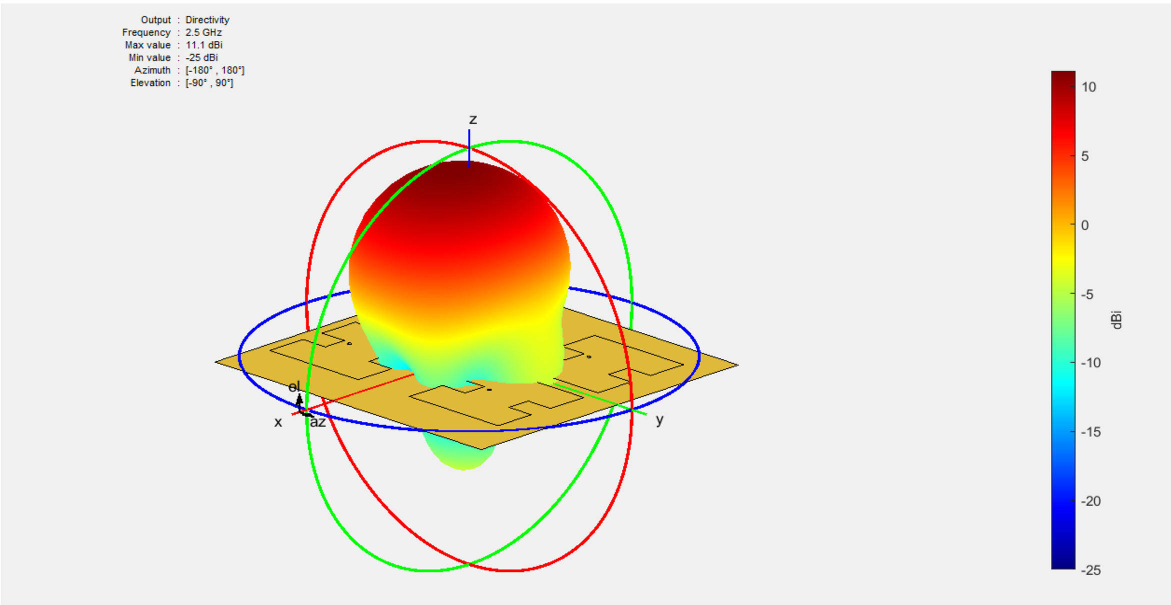

Figure 3. 3D Radiation pattern of a 4-element H-Shape microstrip antenna array.

A total of 20 iterations are run. The total amplitude of the elements before optimization is 4 V. The amplitude values obtained for the elements after optimization are given in Table 1.

Table 1. Amplitude values in a 4-element microstrip antenna array after optimization.

Antenna Element	Amplitude(V)
1	0.49020 V
2	0.46000 V
3	0.83866 V
4	0.36043 V

While it had a total amplitude value of 4V before the optimization, it had an amplitude value of 2.14929 V after the optimization, and a gain of about 42% is obtained. S11 parameter shows the reflectance value of the antenna. As the reflection decreases, the losses in the antenna will decrease and it will be more efficient. The value of the

S11 parameter is considered good when it is below 10 dB in the literature. Because 10 dB represents a 10% power loss. Antennas with power loss up to 10% are the antennas with the desired reflection coefficient in the literature. Values of S-Parameter for 4 element H-Shape antenna are given in the Table 2.

Table 2. 4-Element H-Shape microstrip antenna array S-Parameter values.

	Magnitude (dB)
S11	-2.99899
S21	-28.4212

The S21 parameter, on the other hand, is known as the transmission parameter, and it means that the transmission decreases the more you minimize, the better transmission is maximized. The transmission coefficient of the 4-element H-Shape microstrip antenna array designed by SADEA is -28.421 dB, showing high transmission performance. Correlation coefficient in microstrip antenna is a parameter that measures the communication performance of the antenna and expresses the compatibility and signal transmission between antennas. A high correlation coefficient is considered value because it means that the transmitted signal is correctly detected by the receiving antenna. However, a desired value depends on specific application requirements and standards and must therefore be above a certain threshold. In a study by Cohen J., this threshold value is accepted as good values above 0.5 [1]. The Figure 4 shows the correlation coefficient between each element.

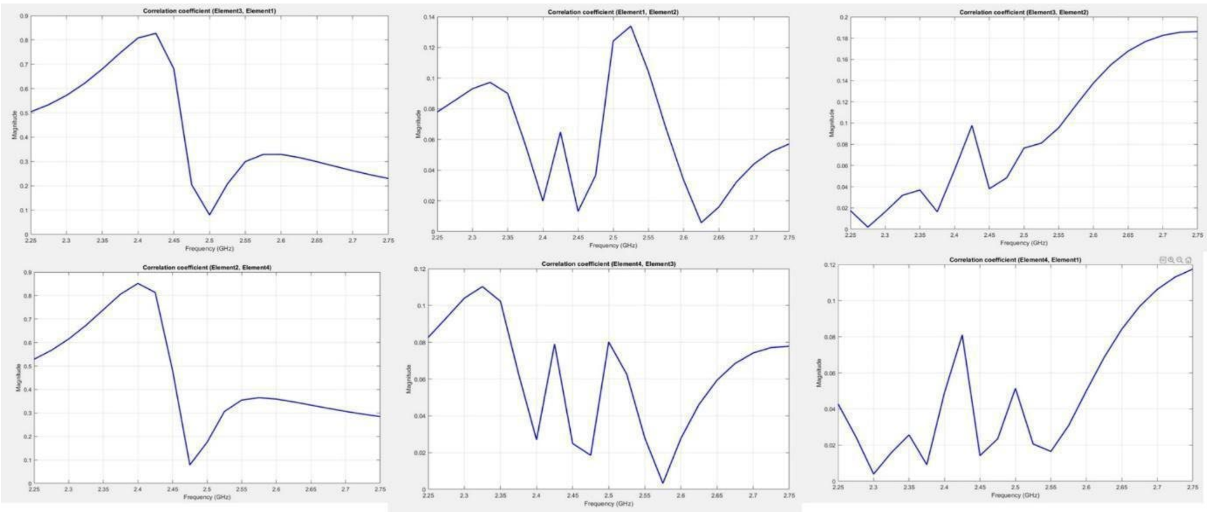

Figure 4. Correlation coefficient between antenna elements for 4 elements H-Shape microstript antenna.

The reflectance values of each element against each other are different. However, when examined in general, it is seen that they have better reflectance values in the 2.3-2.55 GHz range. Since it is desired to operate the microstrip antenna array with 4 elements, which are calculated to be operated in Wi-Fi applications, at 2.5 GHz, it has been analyzed that it will be a suitable antenna for the application.

4.2. Case 2: 4-Element Microstrip E-Shape Antenna Array

Microstrip antennas are known for their high performance, low cost and easy installation. E-Shape microstrip antennas have shown better performance than normal microstrip antenna arrays in different studies. In this section, a 4 element E-Shape microstrip antenna array is designed and its performance parameters are analyzed. The inter-element distance values before optimization are 0.059958 mm for both rows and columns. After optimization, these values are 0.069192 mm for row spacing and 0.095527 mm for column spacing. The Figure 5 shows the 3D radiation pattern of this array.

A total of twenty iterations are performed. In addition, the amplitude value given to each element is optimized by giving it in V. Before optimization, each element is built with a total amplitude of 1 V. The amplitude values for the elements after optimization are shown Table 3.

While it had a total amplitude value of 4 V before the optimization, it had an amplitude value of 2.45885 V after the optimization, and a gain of about 38.5% is obtained. The values of the S-Parameter are given in the Table 4.

Table 3. Amplitude values in a 4-element E-Shape microstrip antenna array after optimization

Antenna Element	**Amplitude(V)**
1	0.45884 V
2	0.62346 V
3	0.43362 V
4	0.94293 V

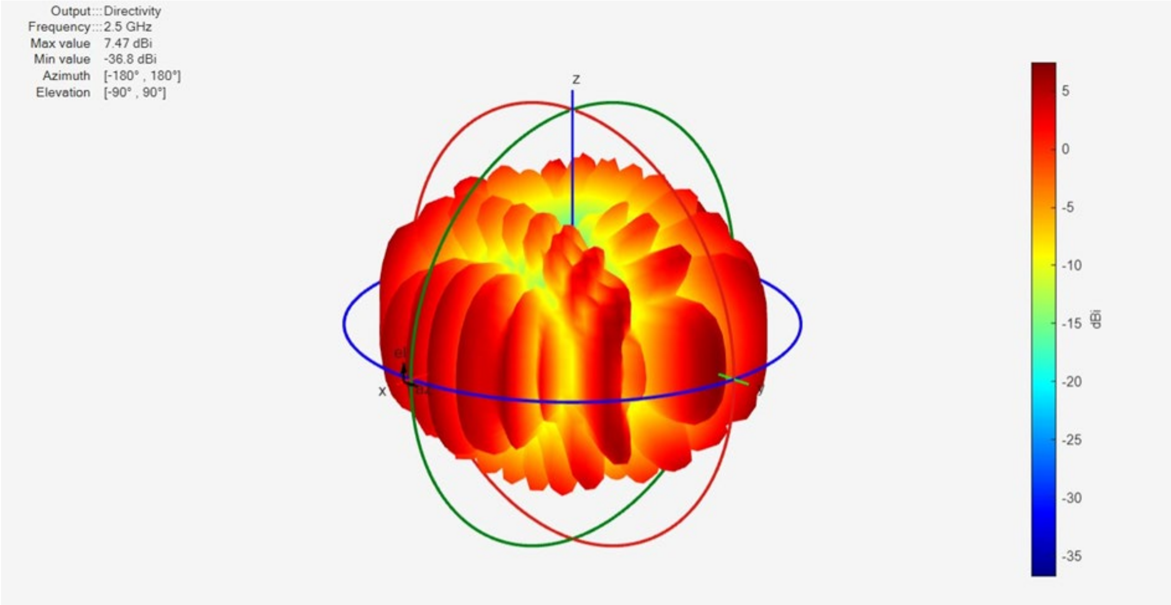

Figure 5. 3D Radiation pattern of a 4-element E-Shape microstrip antenna array.

Table 4. 4-element E-Shape microstrip antenna array S-Parameter values

	Magnitude (dB)
S11	-14.9429
S21	-31.9391

SADEA's 4-element E-Shape microstrip antenna array has a transmission coefficient of -31.9391 dB, indicating transmission performance. The correlation coefficient in a microstrip antenna is a parameter that measures the communication performance of the antenna and expresses the compatibility and signal transmission between antennas. However, the desirable value depends on specific application requirements and standards and therefore must be above a certain threshold. Figure 6 indicates the correlation coefficient between each element.

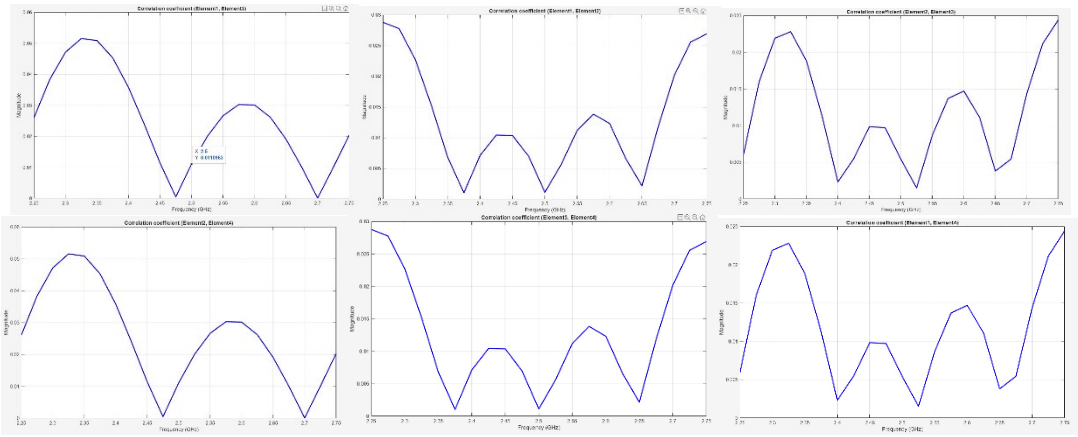

Figure 6. Correlation coefficient between antenna elements for 4 elements E-Shape microstript antenna.

The reflectance values of each element against each other are different. However, when examined in general, it is seen that they have better reflectance values in the 2.4-2.55 GHz range. Since it is desired to operate the microstrip antenna array with 4 elements, which are calculated to be operated in Wi-Fi applications, at 2.5 GHz, it has been analyzed that it will be a suitable antenna for the application.

5. CONLUSION

In this study, 4-element E-Shape and H-Shape microstrip antenna arrays are optimized using artificial intelligence techniques. The antenna array designed in the MATLAB antenna array designer tool is constructed using SADEA. The default value for the material is PEC. For the design problem, the FR4 substrate, which is readily available on the market, is preferred. The loss tangent (δ=0.020), relative dielectric constant (ε_r=4.40), insulator plate height (h=1.5750 mm) and conductor thickness (t=0.0350 mm) of FR4 material are planned. The total amplitude of the 4-element E-Shape and H-Shape microstrip antenna array is reduced from 4V before optimization to 2.45885 V and 2.14929 V after optimization, respectively. The distance values between the elements before optimization are

0.059958 mm for both rows and columns. After optimization, these values are 0.069192 mm for row spacing and 0.095527 mm for column spacing. After optimization, these values are 0.60001 mm and 0.069192 mm for E-Shape and H-Shape respectively, 0.24911 mm and 0.095527 mm for row spacing values and 0.24911 mm and 0.095527 mm for column spacing. There is a 68% minimization for the former and a 92% growth for the H-Shape. The gain for the four-element E-Shape and H-Shape antenna arrays is -20.9 dB and -36.9 dB. The results show that the size of the E-shape antenna is minimized compared to the H-Shape antenna and higher gain is achieved with smaller dimensions. In addition, the E-Shape antenna occupies about one fourth of the area compared to the H-shape, consumes 15% more V and provides more than 50% more gain. Considering these data, the E-Shape antenna is generally more efficient than the H-shape antenna and can be produced at cheaper costs in the production phase since it will occupy less area in the production phase. Therefore, it is concluded that E-Shape antenna is more efficient than H-Shape antenna. The results of the E-Shape antenna array design study will ensure that microstrip antenna arrays will continue to be an important design element for communication systems and will shed light on future work.

Author's Contribution

Ali Durmuş and Zafer Yıldırım contributed to the implementation of the research, coding, analysis of the result, and writing.

Statement of Conflict of Interest

The authors have declared no conflict of interest

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