ENHANCING MICROSTRIP PATCH ANTENNA PERFORMANCE THROUGH GENETIC ALGORITHM AND ANFIS OPTIMIZATION

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Abstract. Microstrip patch antennas play an important role in modern wireless communication systems due to their small size, compactness, lightweight, and easy integration into electronic circuits. These types of antennas are widely used in various applications, such as mobile phones, Wi-Fi routers, satellite communications internal systems and radar systems. This paper provides a detailed research study on the improvement and optimization of the measurement of the Aperture Coupled Microstrip Patch Antenna (ACMPA) utilizing a Genetic Algorithm (GA) as well as an Adaptive Neuro-Fuzzy Inference System (ANFIS). The goal is to enhance the total efficiency of the antenna by achieving far better return loss and high directivity coupled with a reduced Voltage Standing Wave Ratio (VSWR). The recommended method includes the usage of GA within the CST software application together with ANFIS within the MATLAB software application to enhance the ACMPA measurements for the procedure at 7.5 GHz. The outcomes show the performance of the recommended antenna measurements in contrast with substitute information in the CST program, verifying the precision as well as the effectiveness of the optimization procedure. This research study offers beneficial insights into the application of innovative optimization methods for the style coupled with the improvement of microstrip patch antennas in contemporary cordless interaction systems.
Keywords: *microstrip patch antenna, optimization, GA, ANFIS, performance, return loss*

Introduction

Microstrip patch antennas are becoming crucial components of current cordless interplay structures due to their small size, the simplicity of their building and creation, and the large array of programmed in extraordinary frequency stages. These antennas are regularly utilized in radar structures, satellite TV for PC interaction, cordless devices, and commercial, in addition to military, interplay structures (Balanis, 2016). However, notwithstanding their advantages, microstrip patch antennas often face demanding situations in attaining preferred performance parameters, which include bandwidth, benefit, performance, and radiation pattern traits, and those demanding situations arise due to factors that include substrate cloth residences, antenna geometry, feeding techniques, and environmental situations. Therefore, there's a notable want to adopt optimization strategies to improve the general overall performance of microstrip patch antennas. Optimization strategies, together with GA, particle swarm optimization (PSO), and neural networks (NN), had been appreciably used to enhance the overall performance of these antennas. Using optimization techniques, designers can analyze the layout, optimize antenna parameters, and benefit the favored universal overall performance. These consequences in the development of microstrip patch antennas with

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excessive performance, extensive bandwidth, price-effectiveness, and accurate radiation traits, as a result of assembly the requirements of modern Wi-Fi communication structures (Balanis, 2016). In precis, the significance of microstrip patch antennas in modern-day Wi-Fi communication systems highlights the importance of the use of optimization techniques to improve their average overall performance Emphasis Optimization strategies permit designers to triumph over format stressful situations and gather an greatest antenna layout that meets the stringent necessities of contemporary communique structures. A ground plane is placed at the back of a sending-out vicinity released on one aspect of a dielectric substratum in a everyday microstrip patch antenna. The antenna's functioning regularity is hooked up by using the complete measurements of the spot and substratum, which might be commonly related thru a feed line. Vibration is the premise for simply how microstrip patches antennas feature; to accumulate vibration at a particular regularity, accurate measurements of the spot in addition to the substratum are decided on. Microstrip patch antennas have several blessings, consisting of being low priced, light-weight, and smooth to contain into complicated systems (Akdagli et al., 2014). Nonetheless, they additionally have existing problems, consisting of tightening power management abilities and transmission capacity. Scholars constantly strive to surmount these restrictions by using imaginative layout approaches as well as optimization approaches. In the period of cordless interaction, the demand for tiny, efficient antennas is expanding, which makes the research study of microstrip patch antenna layout along with optimization more vital (Wong, 2004). To boost cordless interaction, modern technology scientists are working to boost data transfer, gain, and the radiation pattern of microstrip patch antennas. Microstrip patch antennas are fit for unification right into planar frameworks as a result of their reduced account and easy layout, which provides release adaptability.

As a result of their appealing top qualities of being light-weight, reduced account, easy to manufacture, affordable, and ideal for circuit card instalment, traditional microstrip patch antennas with rectangle-shaped round, as well as triangular geometries have actually been presented as well as used in several applications (Kumar and Ray, 2003). Various other functional disadvantages of microstrip patch antennas consist of limited transmission capacity, reduced performance, and reduced gain. To increase data transfer as well as effectiveness, a thicker substratum product can be used with a reduced dielectric consistency, broadening the antenna's physical measurements. Nonetheless, contemporary mobile interaction tools making use of the UHF band need few antennas. The transmission capacity and effectiveness qualities of the smaller-sized antennas can be given up to make use of substratum products with a high dielectric constant. Consequently, using the conventional microstrip patch antenna to satisfy the requirements of mobile interaction tools is challenging (Vincenti Gatti et al., 2020). The key goal of this research study is to boost the efficiency of microstrip patch antennas by using hereditary formulas together with the ANFIS. This job intends to advance the bigger purpose of boosting interaction systems for numerous usages. The antenna geometry criteria utilizing ANFIS are selected to provide a bigger data transfer along with the most affordable feasible return loss (S11 specification) at the resonant regularity. With VSWR=1.04 return loss (S11) of -34 dB as well as directivity of 8.32 at a resonant regularity of 7.5 GHz, the antenna style shows a very wide functioning data transfer of 7.5 GHz, covering the regularity variety of 5 GHz to 10 GHz. Additionally, the recommended antenna has a straight directional discharge pattern, which certifies it for wide-band usage (Mishra et al., 2018). It also discusses a deeper examination of the

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antenna characteristics and how they affect performance. This work's simulations were all performed with the ANSYS CST (High Frequency Structural Simulator) program (Errifi et al., 2014). To design aperture coupled patch antennas, an ANN model has been created and tested. It converts the data with the resonant frequency (fr), substrate thickness (h), and dielectric constant (εr) into the patch dimensions, or the patch's length (L1) and breadth (W1) (Ozkaya and Seyfi, 2015).

The paper does cope with an important issue in wireless conversation generation via focusing on improving the overall performance of microstrip patch antennas the usage of advanced optimization strategies together with the GA ANFIS and VSWR are stepped forward. This studies contributes to medical rigour, innovation, and sensible packages inside the subject by exploring the adoption of recent efficiency methods to fabricate microstrip patch antennas and beautify them in present day wireless conversation systems The mixture of GA and ANFIS introduces an effective new technique for optimizing antenna overall performance, demonstrating the potential to satisfy the developing needs of wireless communication systems within the area. The contribution of the paper to enhancing microstrip patch antenna overall performance thru genetic design and ANFIS optimization includes: (1) New methodology: The paper introduces a unique approach that combines GA and ANFIS to generate microstrip patch antennas work nicely, demonstrating the capacity to combine superior optimization strategies. (2) Improvement in antenna parameters: The study identifies key antenna parameters such as return loss, directness, and voltage-standing-wave ratio (VSWR) improved by using GA and ANFIS together, which builds on a proposed method. (3) Addressing evolving communication desires: By leveraging the harmonies of GA and ANFIS, the research objectives are to deal with the evolving requirements of current wireless verbal exchange systems, imparting a complete and modern-day optimization method that can be applied across numerous communication scenarios. (4) Valuable insights for antenna optimization: The paper provides treasured insights into the application of advanced optimization techniques for designing and improving microstrip patch antennas, contributing to the sphere of Wi-Fi conversation technology. Overall, the contributions of the paper lie in its progressive approach, development of antenna parameters, their relevance to modern data needs, and valuable insights for antenna optimization in Wi-Fi communication architectures.

Literature review

In the context of enhancing microstrip patch antenna performance, in particular, for ACMPA, the selection of optimization strategies plays a pivotal role in achieving preferred antenna characteristics. This review seeks to cope with this by providing an in-depth evaluation and justification for selecting GA and ANFIS over other optimization strategies. GA offers numerous strengths that make it properly desirable for antenna optimization tasks. Inspired by the aid of herbal selection and genetics, GA successfully explores large solution spaces, making it especially suitable for coping with the high-dimensional search areas often encountered in ACMPA optimization. Furthermore, GA's potential to keep a diverse population allows effective exploration of trade-offs between conflicting design goals, which include bandwidth, benefit, and performance. In assessment with conventional optimization techniques like gradient-primarily based techniques, GA's populace-based seek are tons less at risk of being trapped in nearby optima, making it higher equipped to cope with the non-linearity and discontinuity inherent in ACMPA optimization. Similarly, the ANFIS offers specific

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blessings for ACMPA optimization. By combining fuzzy commonplace experience and neural networks, ANFIS can model complex, non-linear relationships amongst enter and output variables, that is crucial for capturing complicated interactions among numerous antenna parameters. This capability is especially relevant for ACMPA optimization, wherein elements including substrate residences, patch geometry, and coupling mechanisms showcase complicated and non-linear outcomes on antenna traits. Moreover, ANFIS's potential to integrate empirical statistics and expert understanding into the optimization technique complements decision-making and probably ends in higher overall performance outcomes. Unlike simpler optimization methods, ANFIS's specific incorporation of fuzzy good judgment policies permits it to provide interpretable and obvious models, contributing to deeper information and validation of the optimization consequences in antenna layout. These research goals provide a strong rationale for the chosen technique, strengthening the study's scientific rigour and credibility by clarifying the specific benefits of GA and ANFIS in handling the challenging situations of ACMPA optimization and comparing them with alternative strategies.

The research on microstrip patch antennas has seen significant advancements, with various studies exploring optimization techniques to enhance their performance. A comprehensive literature review reveals the progress made in this field while also highlighting gaps that pave the way for the current study. In Sharma et al. (2020), the authors investigated the fundamental aspects of designing and optimizing microstrip patch antennas for wireless communication systems. The application of genetic algorithms and particle swarm optimization showcases the capacity to improve antenna performance. The utilization of genetic algorithms and particle swarm optimization demonstrates the potential for enhancing antenna performance. The authors (Singh et al., 2019) focused specifically on WLAN applications. This study uses a combination of genetic algorithms and artificial neural networks to optimize microstrip patch antennas. The outcomes give an understanding right into antenna layout for certain interaction criteria. As 5G modern technology arises (Swain and Sharma, 2019), this research study explores the layout as well as optimization of microstrip patch antennas for 5G applications. Using hereditary formulas coupled with bit-move optimization addresses the distinct obstacles posed by this innovative interaction criterion. Discovering the world of RFID applications, this research study (El Alami and Bennani, 2015) uses a hereditary formula coupled with a fabricated neural network for the layout and optimization of microstrip patch antennas. The outcomes illuminated the possibility of customizing antennas for effective RFID interaction. The optimization of microstrip patch antennas specifically for satellite interactions is the topic of this job. Also, if a different application is the primary focus, the optimization methods used and the results acquired provide useful historical information for relevant optimization efforts (Singh et al., 2020). The research (Mishra et al., 2022) study discovers the efficiency optimization of microstrip patch antennas made for IoT applications provided the expanding universality of Web of Points gadgets. The techniques of optimization used offer understanding right into the adaptability of microstrip patch antennas in numerous interaction contexts. The paper (Verma and Srivastava, 2019) contrasts and also analyses different optimization techniques for microstrip patch antennas such as substitute annealing bit move optimization, coupled with hereditary formulas. Relative analyses of this kind are important for understanding the benefits coupled with negative aspects of various optimization methods. For microstrip patch antennas (Saraereh et al.,

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2016) this job utilizes a multi-objective optimization approach to take on the trouble of straight interaction.

The outcomes highlight the value of considering a range of objectives as well as offer an understanding of antenna optimization for interaction demands. While these studies give beneficial insights into the optimization of microstrip patch antennas, a research study void ends up being apparent. The existing literary works does not have an extensive exploration of the mixed application of the GA and the ANFIS for enhancing microstrip patch antennas (Bashir et al., 2017) the recommended research intends to connect this space by leveraging the harmonies of these two optimization strategies, offering a unique technique to boost antenna efficiency. The value of this research hinges on its potential to add an extensive and cutting-edge optimization method that can be used throughout numerous interaction situations dealing with the advancing requirements of contemporary cordless interaction systems (Sharma, 2020).

Materials and Methods

The Genetic Algorithm and ANFIS methodologies were selected for optimizing ACMPA because of their respective strengths and their ability to address the specific challenges encountered in ACMPA optimization. Genetic Algorithm (GA): GA is a metaheuristic optimization method stimulated through natural choice and genetics. It operates on a population of capability answers, mimicking the technique of herbal evolution to locate most efficient answers to complex issues. ACMPA optimization affords demanding situations together with excessive-dimensional seek spaces and non-linear, multi-modal objective functions. GA is specifically well-acceptable for such problems because of its potential to successfully discover big solution spaces and handle non-linearity. The preference of GA over different optimization techniques is justified by using its robustness and potential to avoid getting trapped in neighbourhood optima. Traditional optimization techniques like gradient-primarily based techniques might also struggle with ACMPA optimization because of the non-linearity and discontinuity of the objective characteristic, making GA a top-rated preference. Additionally, ACMPA optimization regularly involves exploring trade-offs between conflicting layout objectives, consisting of bandwidth, gain, and performance. GA's potential to preserve a various populace allows it to address multi-objective optimization tasks efficiently, making it appropriate for optimizing ACMPA configurations efficaciously.

Adaptive Neuro-Fuzzy Inference System (ANFIS): ANFIS combines the capabilities of fuzzy common sense and neural networks to model complex, non-linear relationships among enter and output variables. It adapts and learns from facts, making it suitable for issues wherein the underlying device dynamics aren't properly understood or tough to model analytically. ACMPA overall performance is prompted through various factors, inclusive of substrate houses, patch geometry, and coupling mechanisms, which may additionally have complicated and non-linear outcomes on antenna traits. ANFIS's ability to model such complicated relationships make it nicely-desirable for optimizing ACMPA performance. ANFIS can integrate empirical facts and expert information into the optimization method, bearing in thoughts greater knowledgeable selection-making and doubtlessly higher ordinary overall performance results. Its specific incorporation of fuzzy logic rules lets in it to offer an interpretable and obvious fashion, that’s brilliant for expertise and validating the optimization effects in antenna layout. Compared to one-of-a-kind tool reading tactics like artificial neural networks (ANNs) or assist vector

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machines (SVMs), ANFIS's ability to approximate complex capabilities and offer interpretable models makes it a appropriate preference for addressing the stressful conditions of ACMPA optimization. In summary, GA and ANFIS have been selected for ACMPA optimization because of their complementary strengths in exploring complex solution regions, coping with non-linear relationships, and providing interpretable fashions. These strategies offer robust tactics to cope with the precise challenges of ACMPA optimization and acquire improved antenna performance.

Design aperture of integrated microstrip patch antenna system

A ground plane separates two dielectric substrates in an aperture-connected patch antenna, which eliminates the direct electrical connection between the feed and transmission wires. The microstrip transmission line feed as well as transmitting spot can currently be separately maximized. The feed line as well as patch is electromagnetically attached through a ground-level aperture. A layout can be utilized to show such an idea in fantastic information. An exceptionally slim metal strip is positioned over dielectric product in a microstrip spot antenna with the ground as the most affordable layer. The measurements as well as product attributes of the microstrip spot antenna identify its specifications (Thakare and Singhal, 2010). A crucial considers establishing a microstrip antenna's effectiveness is its patch measurements. The measurements as well as product qualities of the microstrip patch antenna establish its specifications. A vital considers establishing a microstrip antenna's efficiency is its spot measurements. The spot sizes (W1) as well as sizes (L1) of the microstrip antennas are set up over a ground airplane with substratum density (h) as well as dielectric constants (εr) (Vincenti Gatti et al., 2020) (*Figure 1*).

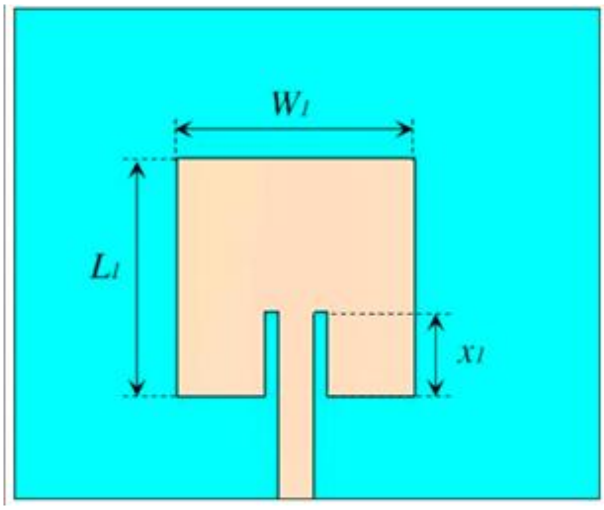

Figure 1. *Microstrip antenna patch.*
Source: Vincenti Gatti et al. (2020)

Structure the patch

The values of the dielectric constant (εr), the resonant frequency (fr), and the height of the substrate (h) beneath the patch are the main factors that can be used to compute the patch's length (L1) and width (W1) as mentioned in Eq. (1) to Eq. (4) (Akdagli et al., 2014; Wong, 2004; Kumar and Ray, 2003).

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$$W1 = \frac{c}{2fr\sqrt{\frac{2}{\varepsilon r+1}}} \qquad \text{Eq. (1)}$$

$$L1 = L_{eff} - 2\Delta L \qquad \text{Eq. (2)}$$

$$\frac{\Delta L}{h} = 0.412\,\frac{(\varepsilon_{eff}+0.3)(\frac{w}{h}+0.264)}{(\varepsilon_{eff}+0.258)(\frac{w}{h}+0.8)} \qquad \text{Eq. (3)}$$

$$\boldsymbol{\varepsilon_{eff}} = \frac{\boldsymbol{\varepsilon r+1}}{\mathbf{2}} + \frac{\boldsymbol{\varepsilon r-1}}{\mathbf{2}}\,(\mathbf{1} + \frac{\mathbf{12h}}{\mathbf{w}})^{-\frac{1}{2}} \qquad \text{Eq. (4)}$$

Where; c is the speed of light in free-space (fr) and the resonant frequency of the antenna.

Implement the design on the microstrip feed line

Typically, the transmitting location is supplied via a 50-microstrip line. To determine the necessary resistance, the feed line's specific resistance is determined by the feed line size. Additionally, the feed line needs to be positioned perpendicular to the slot's center to achieve maximum coupling (Akdagli et al., 2014; Wong, 2004; Kumar and Ray, 2003). The slot is centered below the patch.

Determine the specifications for the aperture

The level of coupling between the patch and feed line is determined by the aperture, making it a critical element of the microstrip antenna with aperture linked feeding. The key elements taken into account for the behaviour of the antenna are the aperture length (La) and the length of the stub. The aperture width (Wa) is relatively small and has a negligible effect on the antenna's performance (Akdagli et al., 2014; Wong, 2004; Kumar and Ray, 2003).

Design of the stub

The part of the feed line that comes after the slot is known as the stub length. It is used to regulate the excessive reactance of the aperture (Akdagli et al., 2014; Wong, 2004; Kumar and Ray, 2003). The dimension of the ACMPA determined using MATLAB is displayed in *Table 1*. The formulas from Section 3 are utilized by this calculator. The time saved by using this calculator instead of manually calculating the patch dimensions for various sets of inputs is one of its advantages.

Table 1. *Patch antenna dimensions with aperture feed that is not optimized.*

Category	Frequency
Resonance Frequency (fr)	7.5GHZ
Dielectric (€r) (both of the substrate have same values)	2.2
Thickness of the substrate (h)	0.787mm
Length of the patch (L)	15.05mm
Width of the patch (w)	13.05mm
Width of the aperture (Wa)	4.46mm
Length of the aperture (La)	0.37mm
Width of the feed line (Wf)	2.42mm
Length of the feed line (Lf)	14.61mm

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Implementation details

To gain a detailed insight into the implementation of the optimization process, including the specific parameter settings for the GA, the design of the ANFIS model, and the release criteria optimization, they successfully relate to careful parameter tuning and structured model development. The following are descriptions of procedures and parameters commonly used in the optimization process: (1) GA Parameters: Population Size: A population of 50 individuals was selected in order to balance the research and resource use of the search area. Crossover Rate: A crossover rate of 0.8 was used to promote genetic variation and convergence to the optimal solution. Mutation Rate: Mutation rate was set to 0.1 to promote stochasticity and prevent premature convergence. Selection method: Competitive selection with a competition size of 3 was used to select individuals for breeding. Termination criteria: The optimization process terminated after 100 generations to ensure convergence while avoiding over fitting. (2) ANFIS Structure: ANFIS Type: The ANFIS model used a Sugeno-type fuzzy inference system for its transformation and interpretation. Fuzzy Rules: The ANFIS model incorporated unlikely if-then rules based on expert knowledge and empirical data. Membership Functions: A Gaussian membership function was used to better capture input-output relationships Training Algorithm: A hybrid learning algorithm combining least squares and surface propagation was used to train the ANFIS model. Epochs: The training process involved 500 sessions to ensure consistency and sampling accuracy of the input-output mapping. (3) Optimization Stopping Criteria: Convergence Threshold: The optimization process stopped when the change in fitness function values between successive generations fell below a predetermined threshold of 0.001. Fitness Evaluation: Each eligible individual in the GA population was assessed based on a composite objective function considering return loss, directness, and VSWR. The use of this specific framework for GA, in which the ANFIS model is properly formulated, defines explicit assumptions to sustain the optimization process and facilitates reproducibility and peer review of results thus this usage information ensures transparency and rigor in the optimization process.

ANFIS optimization

The utilization of ANFIS enables an advanced and flexible method to optimizing microstrip patch antennas, resulting in improved efficiency and reliability. ANFIS is a cross-breed computational design that successfully versions intricate systems by integrating the benefits of neural networks with unclear reasoning. Concerning the style of microstrip patch antennas, ANFIS is necessary for maximizing as well as customizing the process. ANFIS's ability for flexible knowing enables it to customize its specifications based on adjustments in input-output connections, enabling the system to continually find out as well as execute much better. To make it possible for the ANFIS design to identify intricate patterns as well as connections inside the antenna-style room, the design has to be educated with relevant information. ANFIS is preferably fit for dealing with the complicated and vibrant homes of microstrip patch antennas as a result of its convenience in dealing with non-linearity as well as questions in the optimization procedure. Subsequently, the ANFIS release assists in enhancing antennas by adaptably personalizing antennas for specific interaction situations. The flow chart used to create ACMPA is depicted in Figure 2. We compute the antenna's parameters first, and then assess its performance. If the outcomes are not satisfactory, we employ ANFIS optimization. Once the requirements are satisfied, optimization is over.

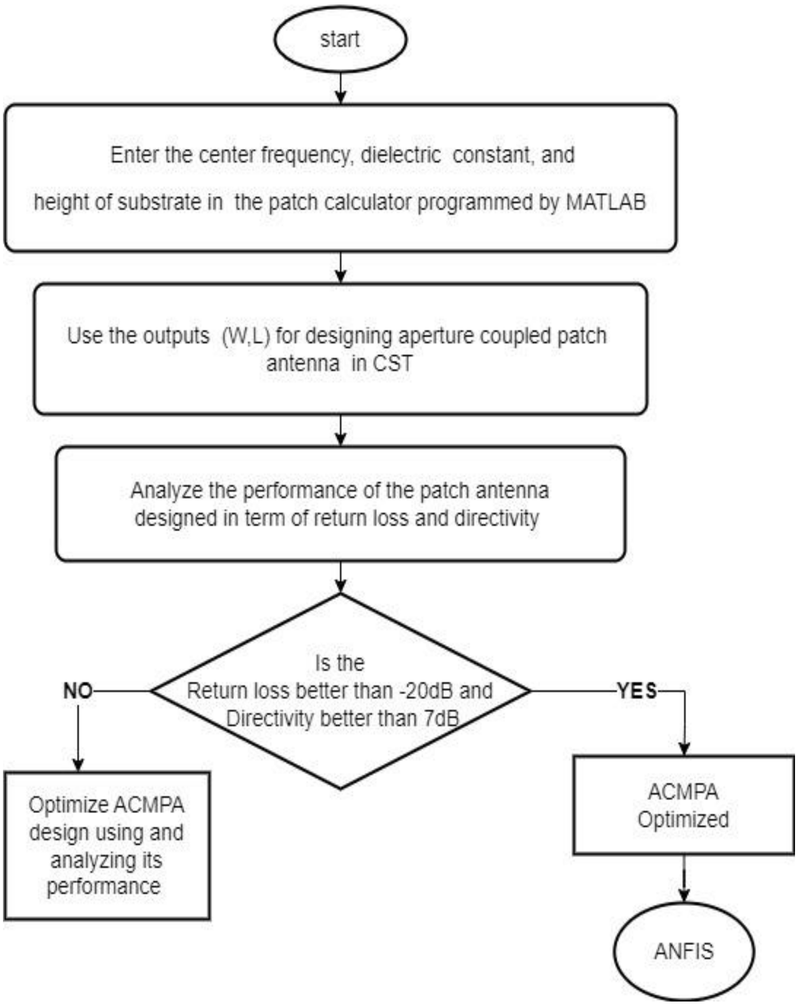

Figure 2. *ACMPA Design flowchart illustrating the utilization of ANFIS.*

ANFIS implementation

Artificial intelligence systems comprise neural networks, fuzzy systems, and neuro-fuzzy systems. For example, Jang's suggested ANFIS incorporates a fuzzy system into its adaptive network design, making it a neuro-fuzzy system. By fusing the best features of the least-squares and back propagation gradient descent algorithms, ANFIS generates input-output data pairs and an input-output mapping based on human knowledge expressed as fuzzy if-then rules. To build the ANFIS reference model, MATLAB's ANFIS editor is utilized. With enough epochs in its training, ANFIS can generate the input-output mapping for training datasets. *Figure 3* illustrate ANFIS training proposed model then *Figure 4* show ANFIS testing proposed model. To generate the proper output for varying input values, ANFIS creates a set of fuzzy rules. The parameters of the membership function are adjusted or fine-tuned until the error is minimized, as illustrated in *Figure 5* (Mlakić and Nikolovski, 2016). Finally the structure proposed model after ANFIS optimization show in *Figure 6*.

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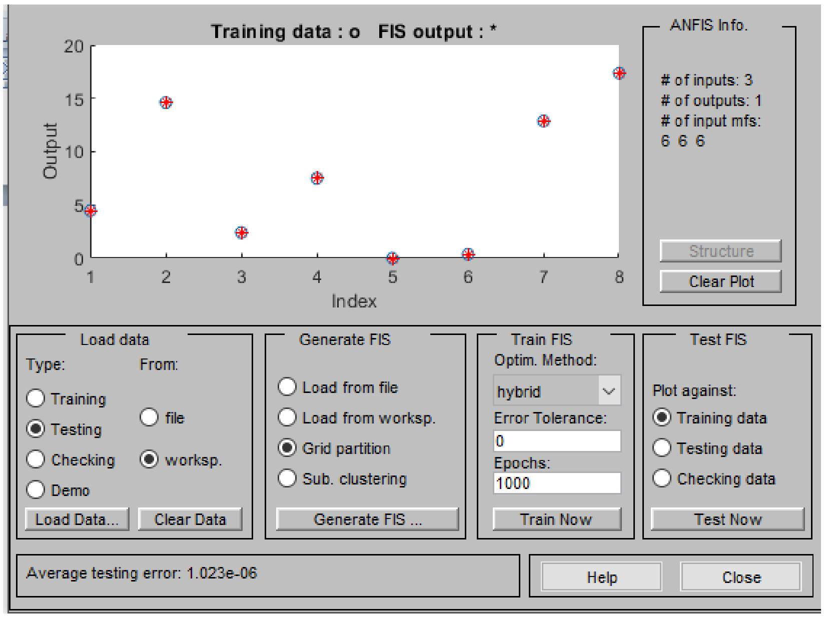

Figure 3. *The data after training for the proposed antenna.*

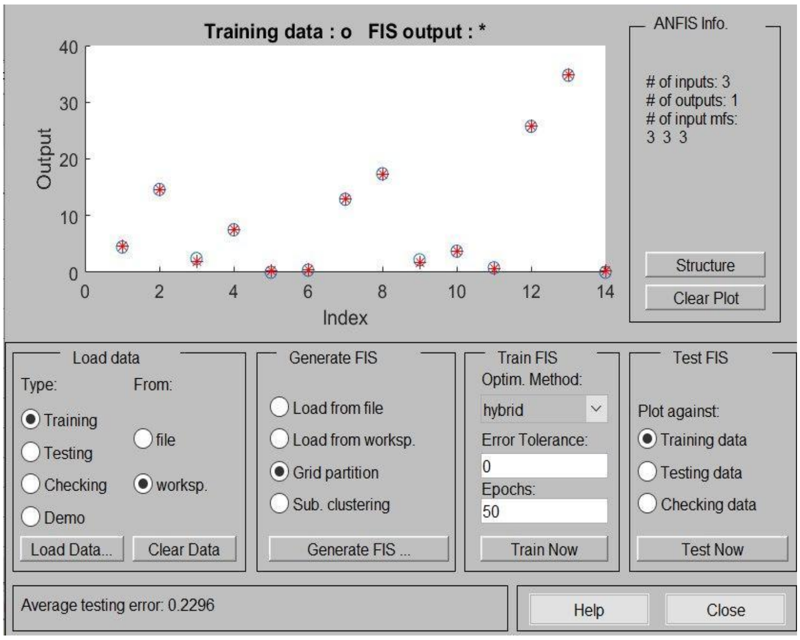

Figure 4. *The data after testing for the proposed antenna.*

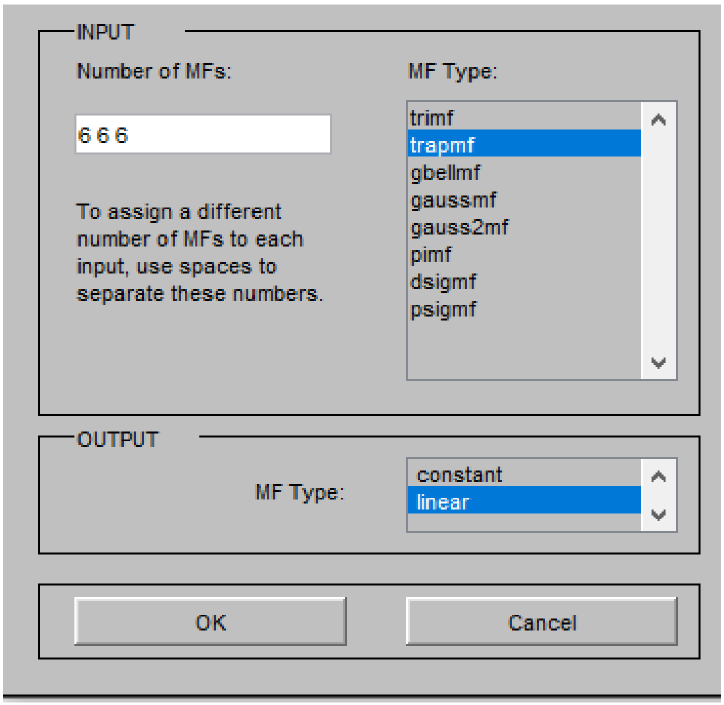

Figure 5. *Add member ship functions to the proposed antenna.*

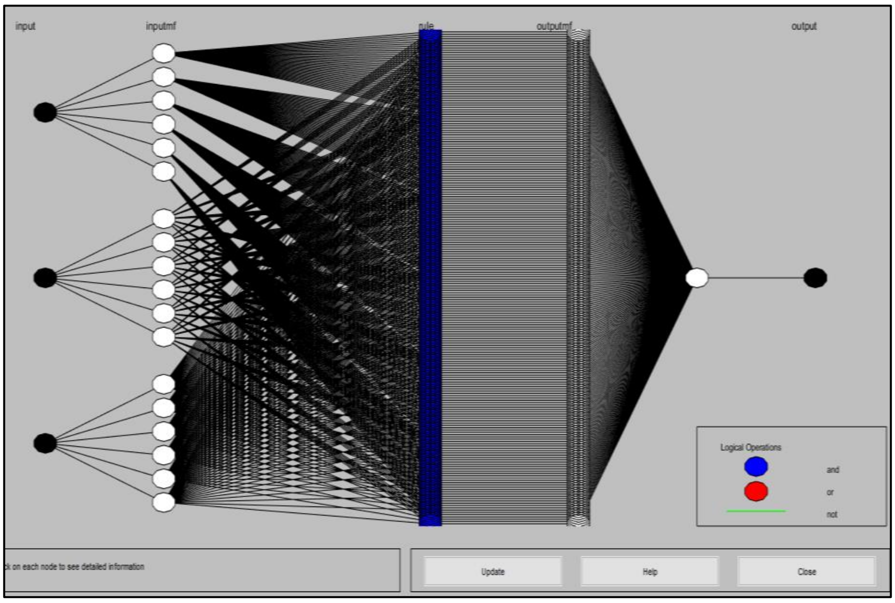

Figure 6. *The structure ANFIS for the proposed antenna.*

Results and Discussion

Simulation without ANFIS optimized

In order to assess the effectiveness of the designed ACMPA, a patch antenna has been created in CST software *Figure 7*. A number of significant performance indicators are assessed. With CST software, the aperture coupled microstrip patch antenna design model is depicted in the above image. The dimensions determined in Section 3 were employed. The return loss, expressed in decibels (dB), is the ratio of the incident power to the reflected power. For optimal performance, the return loss at resonance frequency

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should be as small as possible; *Figure 8* displays the return loss plot for the specified antenna. The resonance frequency is not precisely at 7.5 GHz, thus the value is poor. Through the use of evolutionary algorithms to optimize the patch in the CST environment, this precision with respect to the center frequency is improved. The term "VSWR" is used to characterize an antenna's performance when connected to a transmission line. It gauges how well the characteristic impedance of the transmission line and the antenna terminal impedance match. The ideal SWR value is unity, which denotes the absence of a standing wave on the line. At 7.4831 GHz, the un-optimized ACMPA has a VSWR of 1.33457727. *Figure 9* illustrates the un-optimized patch antenna's VSWR change with frequency. The un-optimized patch has an SWR of 1.33457727 at 7.4831GHz, as can be seen from this plot. Impedance of input: An essential prerequisite for a well-crafted patch design is that its input impedance must be entirely genuine at the frequency at which the patch resonates. We observe the input impedance of the patch design is 49.609248 Ω at 7.4831GHZ. One of the most crucial characteristics of a patch antenna is its directivity, which indicates how well the antenna can concentrate its radiation. The greatest directivity of the un-optimized ACMPA, as depicted in *Figure 10*, is 8.16 dB at 7.4831 GHz. For the un-optimized, in *Figure 11*, the author observe a 2-D radiation pattern plot at 7.4831GHZ for Φ=0°.

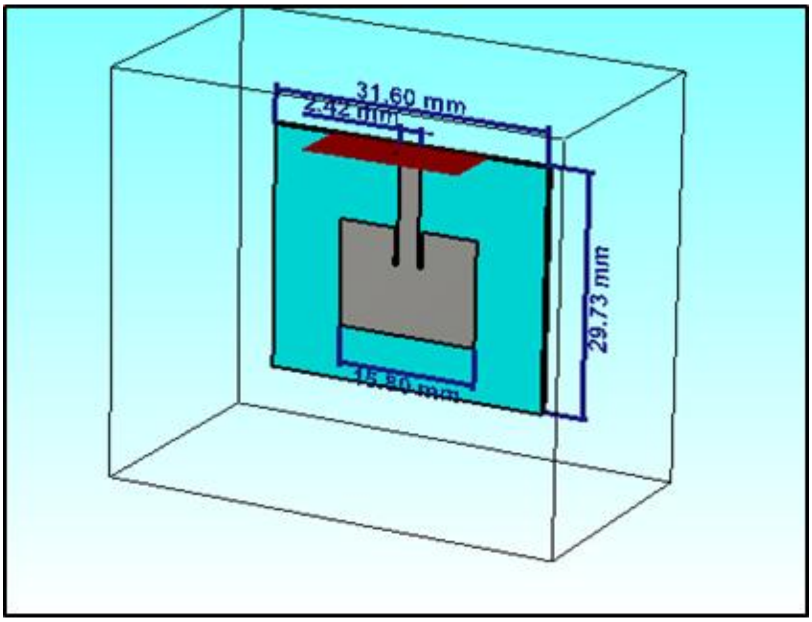

Figure 7. *ACMPA Design.*

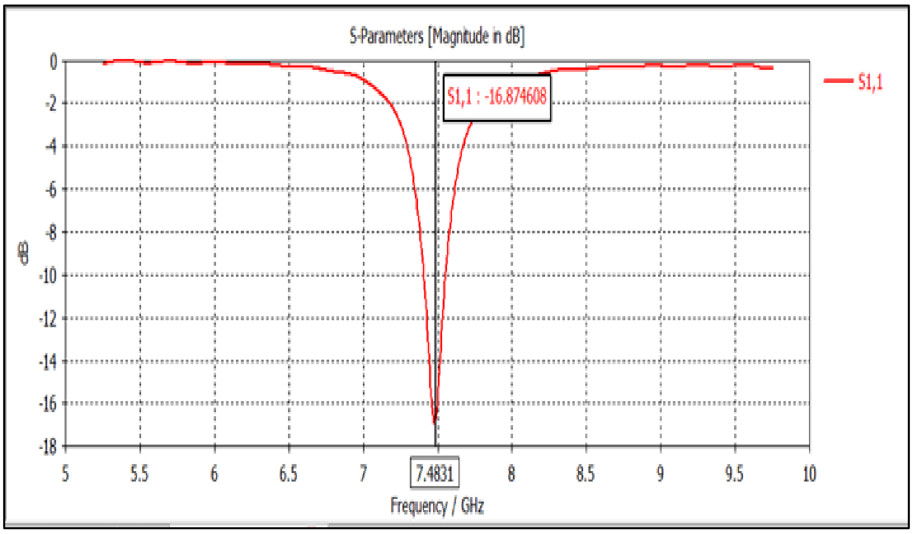

Figure 8. *Return loss plot of un-optimized ACMPA.*

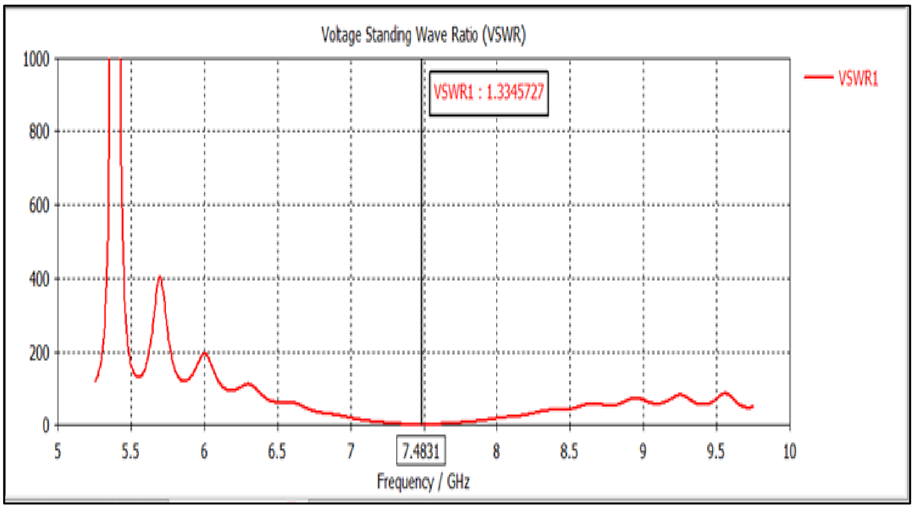

Figure 9. *VSWR vs. frequency plot un-optimized ACMPA.*

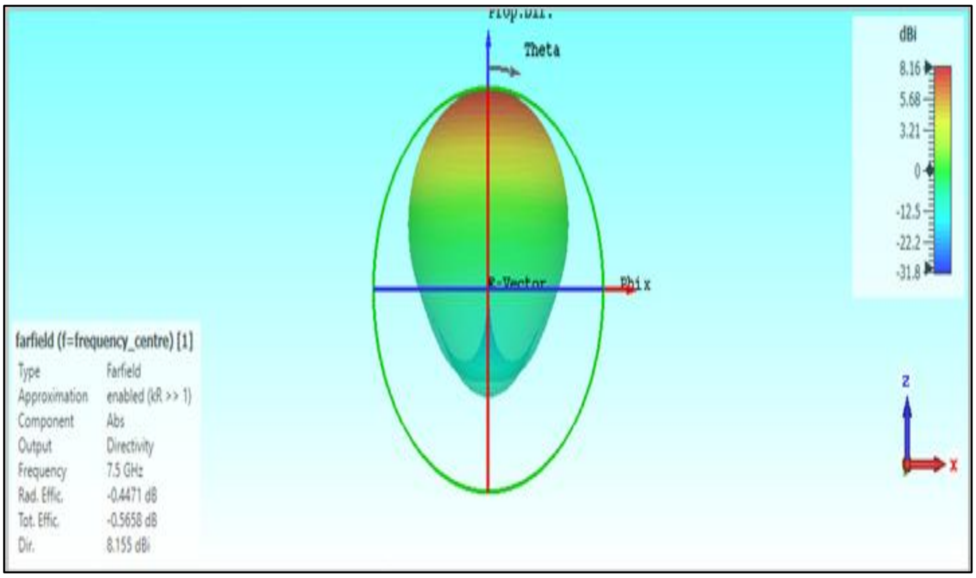

Figure 10. *3D polar plot of un-optimized.*

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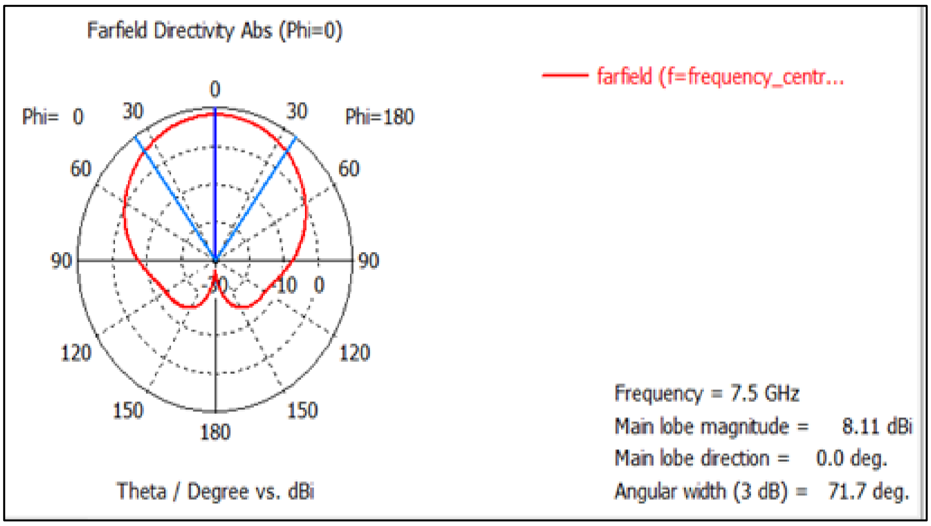

Figure 11. *Radiation pattern of un-optimized ACMPA.*

Simulation with ANFIS optimized

The result of the enhanced ACMPA simulation in the CST was based on the data testing and training phases performed by ANFIS in MATLAB. *Figure 12* shows that in the optimized ACMPA example, the return loss is -34 dB at 7.5101 GHZ, compared to -16 dB at 7.4831 GHZ in the un-optimized ACMPA case. This is a better case scenario regarding return loss. In *Figure 13* the optimized ACMPA instance, the VSWR is 1.0400271 at 7.5101 GHZ, whereas in the un-optimized ACMPA scenario, it is 1.33457727 at 7.4831 GHz. This indicates that the VSWR is closer to ideal. This is thought to be an antenna with improved performance. *Figure 14* displays the 3D polar directivity plot of the optimized ACMPA. At 7.5101 GHZ, the highest directivity attained is 8.32 dB, which is higher than the un-optimized ACMPA's 8.16 dB at 7.4831 GHZ. Figure 15 shows the radiation pattern of optimized ACMPA. *Table 2* displays a comparison of the optimized and un-optimized ACMPA.

Table 2. *Patch antenna dimensions with aperture feed that is not optimized.*

Parameter	Without optimized results	Optimized results using GA	Optimized results using ANFIS
Substrate width	31.60mm	2×patch width	2×patch width
Substrate length	29.73mm	2×patch–length	2×patch–length
Substrate height	0.01mm	0.787mm	0.787 mm
Patch length	15.80mm	15.80004498770061 mm	12.872126284643 mm
Patch width	13.05mm	13.0497501232267 mm	17.38 mm
Patch-feed spacing	0.37mm	0.367603235800817 mm	0.367603235800817 mm
Material thickness	0.01mm	0	0
Feed line width	2.42mm	2.4288350379959 mm	2.4288350379959 mm
Feed line length	14.61mm	14.610638295838 mm	14.610638295838 mm
Feed inset	4.46mm	4.45708354918438 mm	4.45708354918438 mm
Return loss	-10 dB	-16 dB	-34 dB
VSWR	1.8036598	1.3345727	1.0400271
Directivity	8.29 dBi	8.16dBi	8.32 dBi

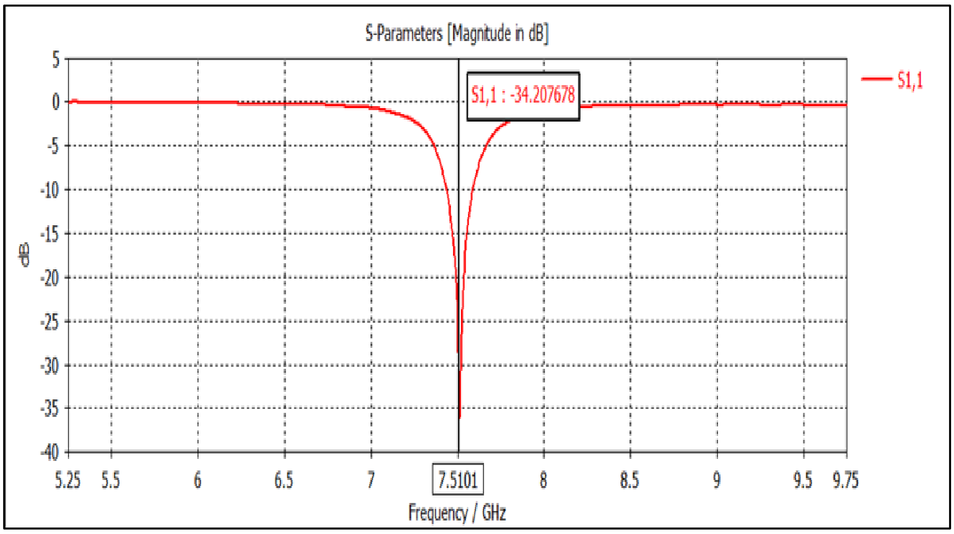

Figure 12. *Return loss plot of optimized ACMPA.*

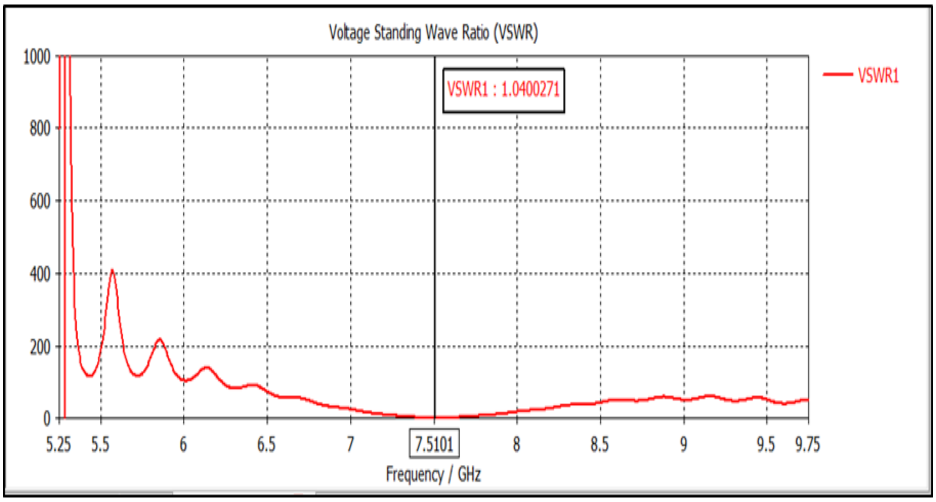

Figure 13. *VSWR vs. Frequency plot of optimized ACMPA.*

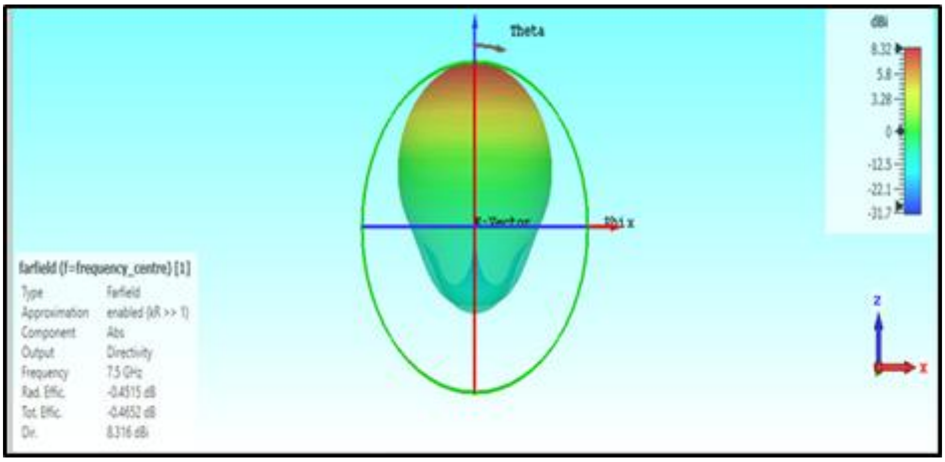

Figure 14. *3D polar plot of optimized.*

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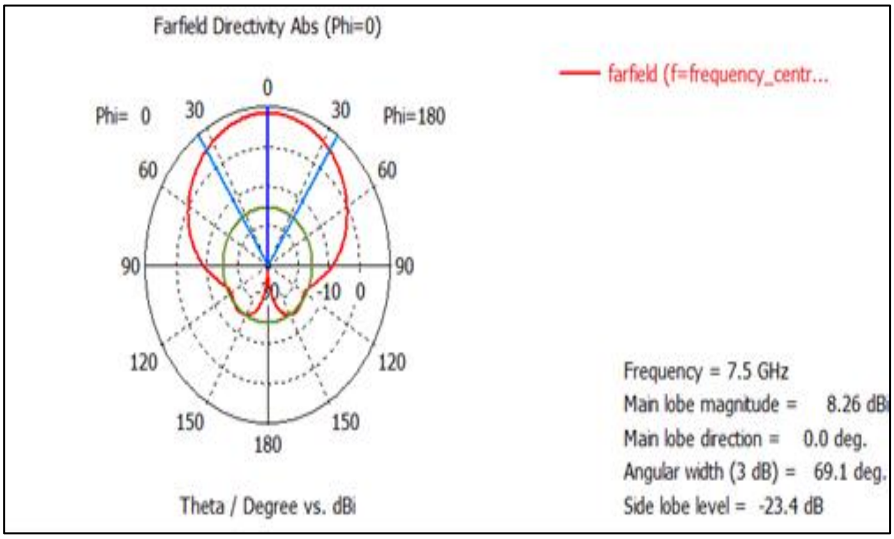

Figure 15. *Radiation pattern of optimized ACMPA.*

Conclusion

In conclusion, the integration of the GA and ANFIS presents a novel and effective approach for optimizing the performance of microstrip patch antennas. By leveraging the synergies of these two advanced optimization techniques, this study has successfully demonstrated the enhancement of key antenna parameters such as return loss, directivity, and VSWR. The results not only validate the effectiveness of the proposed methodology but also highlight its potential to address the evolving needs of modern wireless communication systems. This comprehensive exploration of GA and ANFIS in antenna optimization contributes a valuable and innovative methodology that can be applied across various communication scenarios, paving the way for improved performance and efficiency in wireless communication technologies.

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Conflict of interest

The authors confirm that there is no conflict of interest involve with any parties in this research study.

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