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Study Of 5g Patch Antenna Using Artificial Neural Network

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Abstract: With the rapid advancement of wireless communication technologies, 5G mm Wave patch antennas have become increasingly important due to their capability to operate at high frequencies, their small size, and their support for high-speed data transmission. However, the development and analysis of these antennas often involve time-consuming full-wave electromagnetic simulations, which can slow down the design cycle. To overcome this limitation, Artificial Neural Networks (ANNs) offer a promising alternative by enabling quick prediction of essential antenna characteristics. In this work, a compact patch antenna operating in two bands 38.93-39.63GHz and 41.79 GHz to 42.92 GHz band is introduced, making it well-suited for 5G applications. The trained ANN model provides fast and accurate S11 predictions, effectively minimizing the need for lengthy simulation processes.

***Index Terms*- Artificial neural network, 5G antenna, Machine Learning**

I. INTRODUCTION

The deployment of 5G millimeter-wave (mm-Wave) technology requires highly efficient and compact antennas to support high-speed data transmission, low latency, and improved network capacity. Microstrip antennas are widely used due to their advantages, such as lightweight structure, low cost, and ease of fabrication. Designing 5G microstrip antennas operating at millimeter-wave (mmWave) frequencies (24 GHz and above) poses several challenges, including increased propagation losses, limited bandwidth, and complex impedance matching. Traditional full-wave simulation methods are often time-consuming and require repeated iterations when design parameters change. To overcome these inefficiencies, this study adopts Artificial Neural Networks (ANNs) for the design and optimization of 5G mmWave patch antennas. ANNs offer rapid and accurate predictions of key performance metrics such as gain, bandwidth, return loss, and radiation efficiency, thus minimizing the need for repeated simulations and reducing development time.Prior studies support this shift. Kumar et al. [1] reviewed key design enhancements like MIMO, beamforming, and metamaterials for improved 5G antenna performance. Ismail [2] highlighted the advantages and limitations of mmWave antennas in terms of bandwidth and signal loss. Ahmed et al. [3] discussed MIMO configurations for capacity enhancement, while Huang et al. [4] demonstrated a compact, dual-polarized patch antenna with high gain suitable for MIMO applications. Zainud-Deen et al. [5] focused on mmWave antennas integrated on-chip, emphasizing compactness and efficient system integration.In this work, we evaluate a 5G mmWave patch antenna by analyzing its gain and reflection coefficient over a range of frequencies. ANNs are used to model the relationship between antenna geometry and performance, enabling faster and more adaptive design solutions for next-generation communication systems.

II. DESIGN SPECIFICATIONS

The efficiency of a patch antenna is largely determined by its structural dimensions and the dielectric characteristics of the substrate used. Depending on the required dielectric constant, various substrate materials can be chosen for microstrip antenna fabrication. In the present design, FR4 is selected as the substrate material, offering a thickness of 0.8 mm. The radiating element is shaped like a dumbbell, measuring 9 mm by 4.6 mm. The antenna is energized using a lumped port feeding technique.

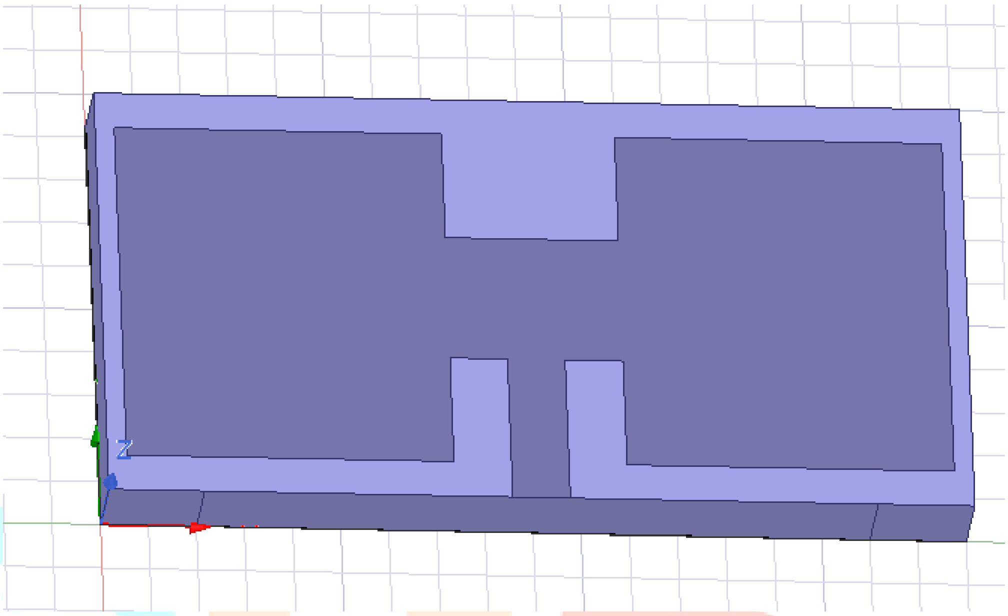

Fig.1 (a) Proposed antenna

III. ARTIFICIAL NEURAL NETWORK

IV. Artificial Neural Networks (ANNs) have gained significant traction since the early 1990s for solving a wide range of complex problems. Unlike conventional rule-based methods, ANNs rely on a data-driven approach. A typical ANN is composed of an input layer, one or more hidden layers, and an output layer. These layers are interconnected, allowing data to flow through weighted connections that influence how information is processed. Each weight determines the impact of one neuron's output on another's input. The feedforward backpropagation algorithm forms the backbone of most ANN models, enabling them to learn from data by adjusting these weights during training. This allows ANNs to capture intricate patterns and relationships between inputs and outputs without the need for manual rule definitions or complex programming [7–8]

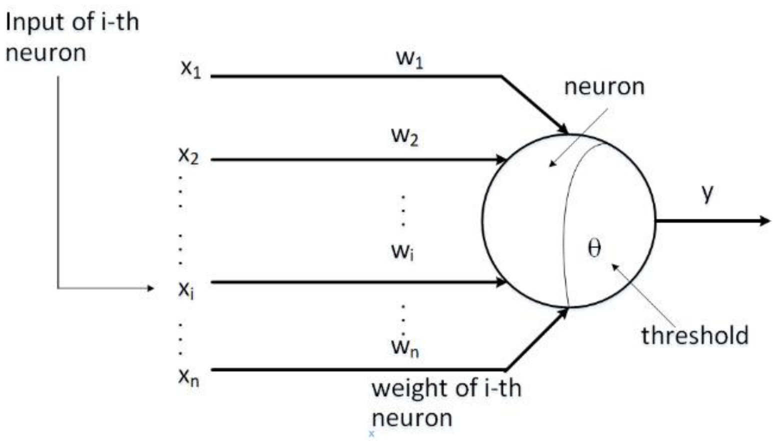

Fig.2 ANN model

The dataset generated for this study is split into three segments: 70% is assigned for training, 15% for validation, and the remaining 15% for testing the model's performance [9–10]. The data is produced by designing and simulating a rectangular patch antenna using the HFSS electromagnetic simulation software. To build a diverse dataset, essential antenna parameters—such as patch length, patch width, ground plane dimensions, substrate height, and frequency—are varied step-by-step within predefined ranges. Each combination yields a corresponding S11 value, forming the input-output pairs used to train the ANN model. The goal of the ANN is to accurately predict the S11 behavior of the antenna.

IV. RESULTS

Figure 3 depicts the S11 variation with frequency graph obtained from the simulation result of HFSS. Using the data samples of 1500 from the simulated result of HFSS, the ANN model is trained with one input, hidden layer and output layer. The ANN model has 62 neurons with six inputs and one output as S11.It is observed that the operating impedance bandwidth is 4.87GHz to 9.36GHz making antenna work for wideband application This result is matched with the ANN model and the S11 result using ANN covers a bandwidth of 5.01GHz to 9.20GHz, which has a close matching with the HFSS result.

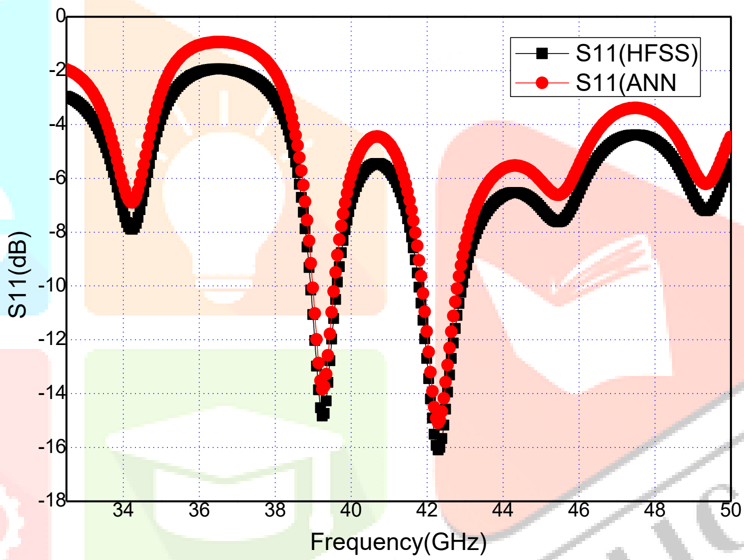

Fig.3 S11 versus frequency (with ANN and HFSS)

Figure 5 presents the 3D radiation pattern, indicating favorable radiation characteristics

Fig.4 Gain variation with frequency F

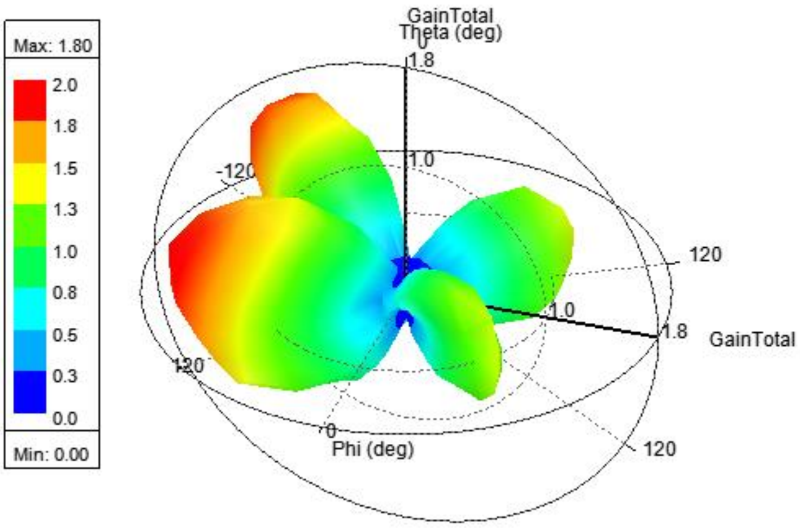

Fig.5 3D plot of antenna

V. CONCLUSION

With the growing demands of 5G and next-generation networks, designing efficient antennas has become essential. Patch antennas, valued for their compactness and high-frequency capabilities, are now being optimized using Artificial Neural Networks (ANNs). This method offers a faster and more efficient alternative to traditional simulations, improving both design speed and accuracy for advanced wireless applications.

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