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Study Of Wideband Rectangular Patch Antenna Using Artificial Neural Network

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Abstract: Microstrip antennas in modern era wireless communication has become widely prevalent because of their efficiency and versatility as radiators. However, the design, optimization, and sensitivity analysis processes of microstrip antennas can be hindered by the time-consuming nature of full-wave electromagnetic simulation. In overcoming these issues, Artificial Neural Networks (ANNs) have emerged as a valuable tool for estimating the performance metrics of microstrip antennas. This paper proposes a compact rectangular microstrip antenna operating within the frequency range of 4.87 GHz to 9.36GHz, suitable for wireless applications. The trained ANN model can swiftly predict S11 of the microstrip antenna without the need for time-consuming simulations.

Index Terms- Gain, bandwidth, Artificial neural network, patch antenna

I. Introduction

The demand for communication methods that offer both very high-speed and exceptional reliability has become increasingly prominent in recent years. The best solutions in achieving the desired speed and reliability can be thought of wideband antennas. Researchers backed in 1995 [1] had started their best efforts to uncover the possibility of designing microstrip antenna as a solution of wideband application such as WIFI, WLAN GPS many more. In [1] U-slot microstrip patch antenna was suggested in circular shape and authors of [2,3] examined various other shapes such as rectangular, hexagonal, square etc for its ability to perform best in desired frequency band. Due to many advantages such as easy fabrication process, operating at multi frequency, cheap and weight designs, low profile in nature and compatibility with monolithic microwave integrated circuits, we can state that microstrip antenna gained researchers and industries attentions in recent decade. Despite many advantageous, microstrip antenna is still examined for great bandwidth and super gain for enabling it to be used for most commercial purposes. Efforts have been made for increasing bandwidth by analyzing feed lines of various types. In [4] tunnel-based ANNs were used to match the resonant frequency of patch antenna. In [5], the antenna structure is customized to optimize broadband performance through the utilization of a Genetic Algorithm (GA). This GA capitalizes on input impedance forecasts generated by the ANN across diverse antenna geometries and a wide frequency spectrum. The efficiency and accuracy of the ANN's performance are assessed to ensure optimal results. In [6], metamaterials employing Complementary Split-Ring Resonators were developed with a focus on miniaturization. This involved leveraging Particle Swarm Optimization, a proven computational method, to ascertain the dimensions of the planar CSRR structure, enabling the miniaturization of a C-band antenna. Furthermore, the incorporation of two machine learning (ML)-trained neural networks (NNs) notably expedited the design process. In our current research, we will be examining performance of rectangular patch antenna and will be analysing the gain and reflection coefficient against frequency. This analysis will be done using Artificial Neural Networks. ANNs offer a powerful approach to optimizing antenna designs by leveraging their ability to learn and adapt to complex relationships between antenna geometry.

II. DESIGN SPECIFICATIONS

Parameters of the antenna is effected by the dimensions of the patch antenna and properties of the substrate. There are various types of substrates which can be used in designing microstrip antenna based on their dielectric constants. In our proposed antenna the substrate is built of FR4 material of height 1.6mm. The rectangular patch is on a substrate of dimension 18x18mm^2 each and is excited using lumped port.

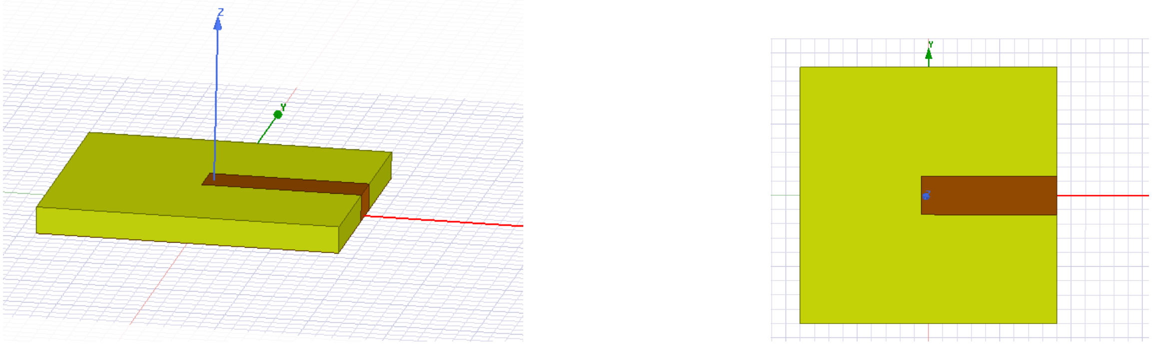

Fig.1 (a) Proposed antenna (b) Top view

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III. ARTIFICIAL NEURAL NETWORK

Artificial neural network(ANN) , a concept which is being used to explore many applications finds its traces since 1990's. This artificial neural network provides an alternative approach towards problem analysing and solving as compared to earlier conventional methods. ANN works on the principle of feed forward back propagation. This principle has 3 layers as input layer, hidden layer and output layer. ANN has well organised form of layers in which all elements are well connected to each other. A point at which two neurons communicate each other is referred as connections; Weights define the bond of a connection being communicated. While a mapping process in involved to map input and output[7-8] but it has no requirement of complex codes to do so. A simple extract relationship by learning process can be enabled between input data and output data

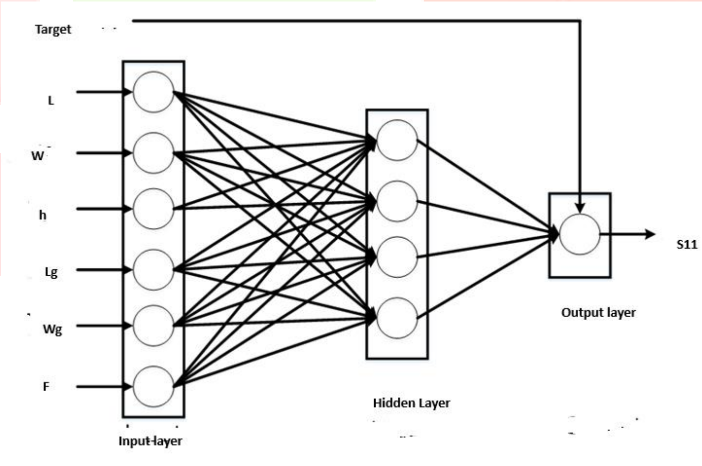

Fig.2 Suggested ANN model

Though no complex codes for mapping input and output data's, but collected data is required to train the ANN. The collected data may be treated as steps in creating and training network. One side this increases the efficiency and accuracy of the network but it also increases the complexity of the network. This large quantity of data can be obtained by varying the initial dimensions of the antenna and recording the response obtained. Out of total data samples collected, 15% is utilised for testing, other 15% is utilised for validation and remaining 70% is utilised in training [9-10]. For generation of the data set the rectangular antenna is design using the HFSS EM simulator. A dataset is generated from the simulated model. The independent parameters of proposed antenna i.e. Patch Length, Patch Width, groundplane Length, ground plane Width, Substrate Height and frequency are varied in defined step size to determine S_{11}.This dataset is used for training ANN Model to predict the S11 graph. The optimal model is determined based on accuracy and lowest Mean Squared Error (MSE) value.

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.

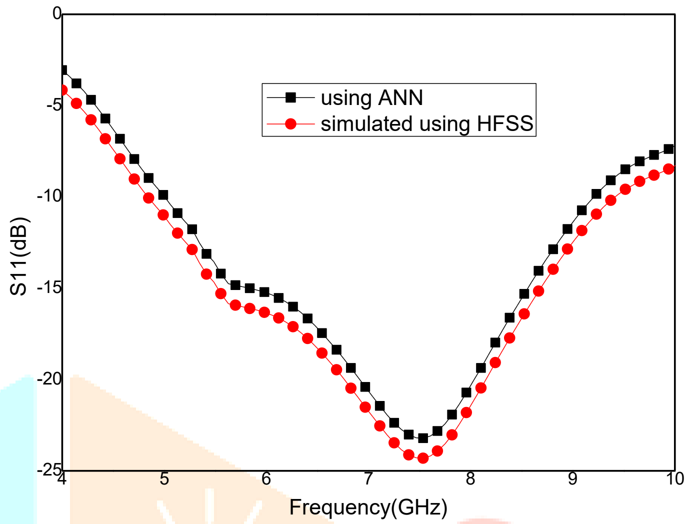

Fig.3 S11 versus frequency (with ANN and HFSS)

Figure 4 illustrate that the gain attains a highest value of 6.8dBi in the operating bandwidth. Figure 5 depicts the 3D plot of antenna with good radiation characteristics.

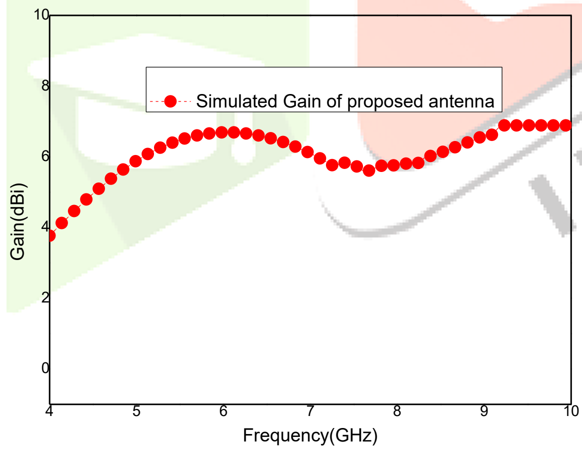

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Fig.4 Gain variation with frequency F

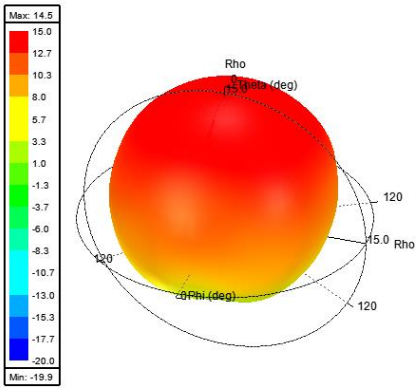

Fig.5 3D plot of antenna

V. CONCLUSION

As wireless communication technologies continue to advance, there is great want for antennas that can meet the stringent requirements of emerging standards such as 5G and beyond. Antennas optimized with ANNs are well-suited to address these demands and ensure reliable and efficient performance for advanced communication systems. The utilization of ANNs presents a promising avenue for enhancing the efficiency of the design process, especially when compared to traditional electromagnetic simulators.

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