Analysis of Square Patch Antenna using Machine Learning

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Abstract–This paper deals with designing patch antenna which is square in shape and is excited using coaxial feed. The dimensions of proposed structure dimension 30x30x1.6mm^3 with resonant frequency of 6GHz. The S11 which is obtained from simulation is verified using Artificial Neural Networks (ANN) and Support Vector Machines (SVM). These algorithms predict that a bandwidth ranging from 5.86GHz to 6.1 GHz is achieved which closely relates to the simulated results. It is also concluded that the ANN algorithm results in better results in comparison to SVM. The proposed structure presents peak gain of 4dBi and is applicable for wireless communication.

Index Terms– Machine Learning, bandwidth, Gain, algorithms.

I. INTRODUCTION

Antennas are vital device that enable wireless communication, forming the foundation of modern telecommunications systems. Incorporating machine learning (ML) methods into the design and analysis of antennas has introduced exciting opportunities for progress and innovation. With ML algorithms, engineers can pursue creative strategies to elevate the performance, efficiency, and adaptability of antenna systems. The use of ML into antenna design brings several advantages, such as enhanced signal reception, finely tuned radiation patterns, and optimized bandwidth usage. These enhancements lead to the development of more dependable and effective communication networks, adept at meeting the increasing demands of today's interconnected society1-2].

Many researchers have worked on various types of microstrip antenna using various ML techniques. In a study published in [3], researchers utilized Support Vector Regression to optimize the resonant frequency, internal input impedance, and bandwidth of a rectangular patch antenna. The effectiveness of this method was evaluated by comparing it with Artificial Neural Network (ANN). Results indicated that ANN outperformed Support Vector Regression in terms of generalization ability, convergence rate, and computational efficiency. The accuracy rates achieved with Support Vector Regression and ANN were 98.79% and 98.33%, respectively, with a negligible error margin of only 2MHz. In [4], researchers utilized Gaussian Process Regression to optimize multiple parameters for a multiband microstrip antenna. They successfully integrated slot loading to effectively reduce the size of the antenna. In [5], a model for antenna classification using Fuzzy Inference Systems (FIS) was introduced. It achieved an impressive accuracy rate of 99% by employing Decision Trees (DT). Additionally, a geometric parameter estimation model using FIS yielded a Mean Absolute Percentage Error (MAPE) of less than 5.8%. Thus various methods adopted related to ML demonstrated that designing patch antenna using ML methods are more efficient. This paper gives an exploration ML techniques comprising ANN and SVM. The proposed antenna operates in band 5.86GHz to 6.1 GHz which makes it applicable for wireless communication. Section II briefs about ML techniques, In Section IV, the proposed structure is presented and in section using SVM and ANN, with results in section of V.

II. MACHINE LEARNING

Integrating Artificial Neural Networks (ANN) and Support Vector Machines (SVM) in optimization of patch antenna plays a crucial role. In this section a brief introduction is given on the above two methods of machine learning. Artificial Neural Networks (ANNs) and Support Vector Machines (SVMs) represent two distinct yet influential machine learning methodologies, each tailored to specific tasks and domains. ANNs, inspired by the intricate architecture of the human brain, comprise interconnected nodes organized in layers. Renowned for their prowess in deciphering complex patterns [6-7], ANNs find extensive utility in domains such as image recognition, speech analysis etc. They refine their predictive capabilities through backpropagation, adjusting connection weights to minimize errors. Despite their adaptability and scalability, ANNs necessitate substantial labeled data for training.

In contrast, SVMs serve as formidable tools in supervised learning tasks, predominantly focusing on classification and regression challenges. By seeking the optimal hyperplane to segregate data points across distinct classes with maximal margin, SVMs demonstrate efficacy in high-dimensional spaces. Their versatility extends to both linearly and non-linearly separable datasets, facilitated by the kernel trick, which projects data into higher-dimensional realms [8-10]. While SVMs offer resilience against the curse of dimensionality and excel in scenarios with limited to moderate datasets, they incur computational costs, particularly in large-scale applications, and may struggle with noisy or overlapping data. Nonetheless, SVMs maintain popularity across diverse domains, spanning bioinformatics, text analysis, and financial prognostication.

III. PROPOSED ANTENNA

Figure 1(a) and (b), depicts the proposed model with the top-view respectively of the suggested antenna. The dimensions of the patch antenna and the ground plane of dimension $30 \times 30 mm^2$ with the substrate made of FR4 having dielectric constant of 4.4mm. The proposed model has a square patch of dimension $11 \times 11 mm^2$ which is excited using coaxial probe. The coaxial probe is varied in both x and y direction for better impedance matching.

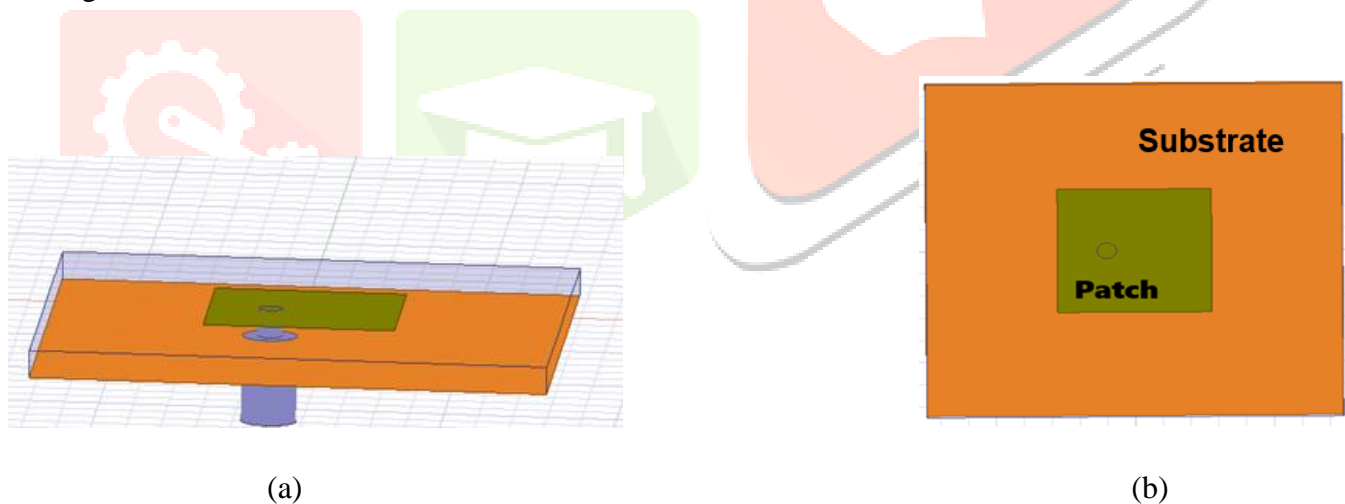(a)   (b)

Fig.1. (a) Proposed Antenna geometry, (b) bottom-view

With the help of High frequency structural simulator (HFSS vs.19) data collection was carried on with 2000 samples by varying the length(L), width (W)of patch, length(Lg) and width (Wg) of ground plane, frequency(f) and position of feed(y). Among the 2000 samples 80% is for training and 20% for testing. The two models of ANN and SVM used for training is depicts in figure 2 (a) and (b) respectively.
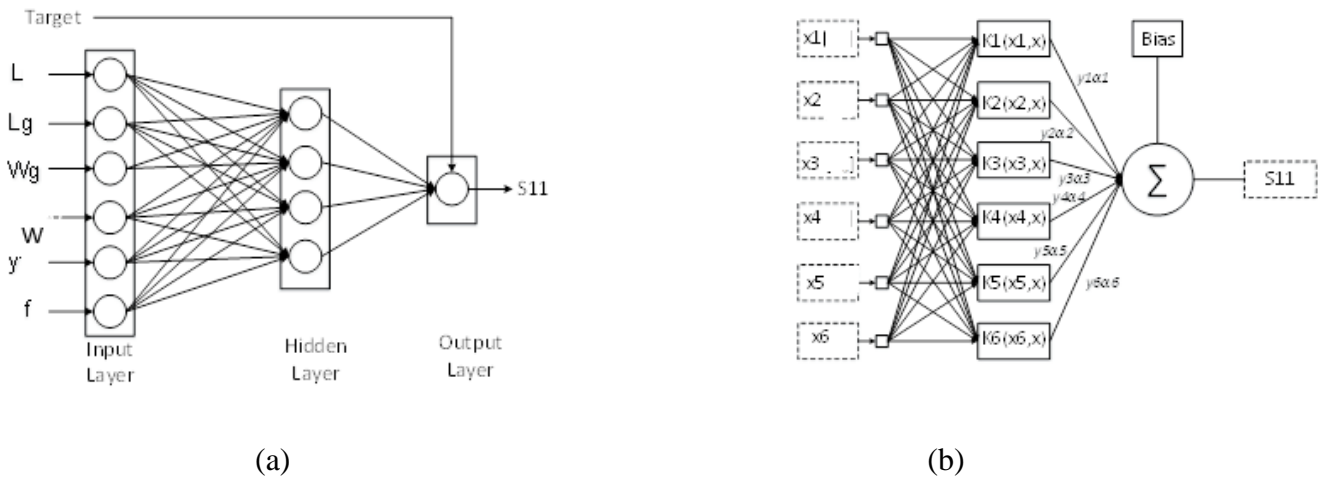
(a)   (b)

Fig.2 (a) ANN model (b) SVM model

IV. RESULTS AND DISCUSSION

Three robust predicting machine learning techniques ANN, SVM] and GPR are used to train and prepare models for optimization and predicting the S11 of the proposed antenna. Here Mean squared error (MSE) is the average squared difference between predictions and actual observations. Table 1 shows the MSE value of both the model and hence the performance of the model is predicted.

Table 1. Different models R-square score and mean squared error

S.No	Model	MSE
1	Artificial Neural Networks (ANN),	0.04
2	Support Vector Machines (SVM),	0.004

Figure 3(a) depicts the predicted S11 using both ANN and SVM and the simulated result which is the actual graph is verified by the S11 graph obtained using the two ML models. From the graph it is clear that ANN is giving well matched output with the actual S11.
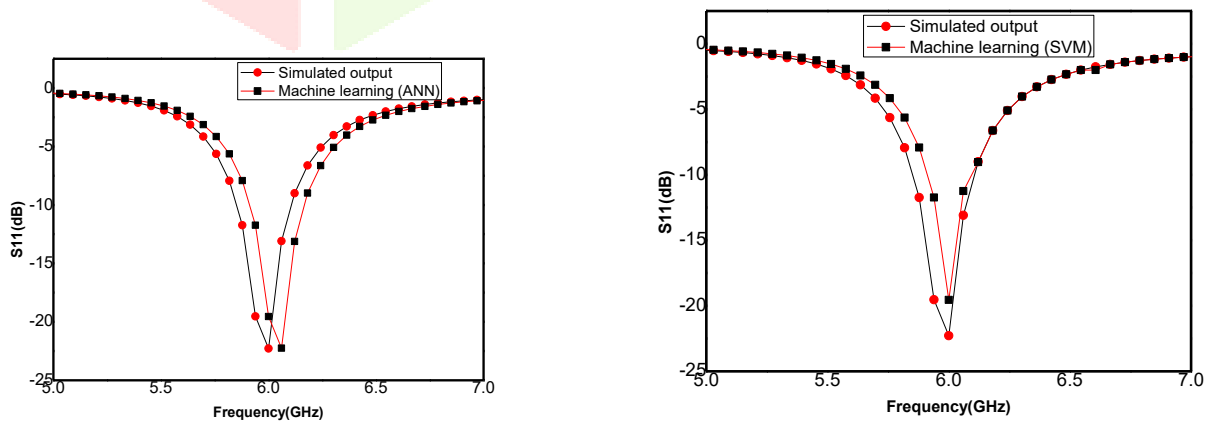

Fig.3 *S*11 values predicted for various frequency values: (a)ANN (b) SVM

Figure 4(a) illustrate that a peak gain of 4.0dBi is obtained with the3D plot of the antenna at frequency 6.0GHz being depicted in figure4(b) which reveals that antenna has stable radiation.
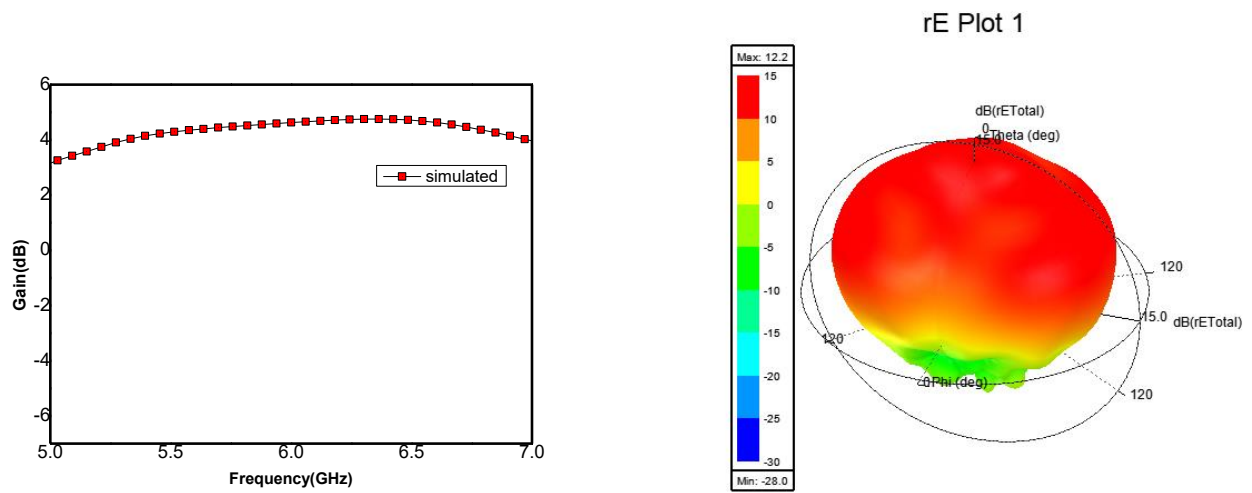
Fig.4 (a) Gain versus frequency of Proposed Antenna (b) 3D plot of antenna

V. CONCLUSION

This paper throws insights to the ML algorithms in designing antenna in comparison to simulated results which is obtained through HFSS. The proposed antenna has frequency range 5.9 to 6.0 GHz making it suitable for applicable for wireless communication. It is well noted that Artificial neural network gives good result in comparison to Support vector machine for predicting the S11 of the proposed model.

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