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Employment of Artificial Neural Network in Manipulating Design Constraints of Rectangular Microstrip Patch Antenna

Vilas Mapare, Suraj Shinde, Maheshkumar Latpate, Tejas Khairnar Pallavi Kadam

Abstract*: The parameter optimization by means of the neural networks is the major attraction, which highlights the ease, precision and reduction in computational time for the designers of interest. The paper deals with the design of a probe fed rectangular Microstrip patch antenna for 2.4 GHz frequency. The analytical results for various conceivable dimensions and different dielectric values were intended without any structural complexities. To achieve an optimum value for the design parameters of the Microstrip antenna, Multilayer Perceptron Neural Network (MLP) and Back Propagation algorithm were implemented to train the network. The analytical results were tested by simulating with basic design software HFSS. The bid of artificial neural network ensures an optimal design methodology which is revealed when relating the results with analytical methods, results of the simulation software.

***Index Terms*: ANN, HFSS, Microstrip, nntool.**

I. INTRODUCTION

A microstrip patch antenna, also referred to as patch antenna is a narrowband, widebeam antenna fabricated by etching the antenna element patch in metal trace bonded to an insulating dielectric substance with a continuous metal layer bonded to opposite side of substrate which forms a ground plane [1]. Microstrip lines widely used for good reason, are broadband in frequency and provide circuits that are compact and light in weight. In this work, rectangular Microstrip antenna is the under consideration. The patch dimensions of rectangular Microstrip antennas are usually designed so its pattern maximum is normal to the patch. Because of their narrow bandwidths and effectively operation in the vicinity of resonant frequency, the choice of the patch dimensions giving the specified resonant frequency is very important. In the literature, **Artificial Neural Network** (ANN) models have been built usually for the synthesis of Microstrip antenna. Although, the existing **EM** simulation models used for the synthesis and analysis of Microstrip lines are accurate, they are computationally intensive. Neural networks recently gained attention as flexible vehicles to microwave modeling, simulation and optimization.

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* Correspondence Author
Prof. Vilas Mapare*, Department Of Electronics & Telecommunication, Sinhgad Institute of Technology, Lonavala
Suraj Shinde, Department Of Electronics & Telecommunication, Sinhgad Institute of Technology, Lonavala
Mahesh Latpate, Department Of Electronics & Telecommunication, Sinhgad Institute of Technology, Lonavala
Tejas Khairnar, Department Of Electronics & Telecommunication, Sinhgad Institute of Technology, Lonavala
Pallavi Kadam, Department Of Electronics & Telecommunication, Sinhgad Institute of Technology, Lonavala

II. RECTANGULAR MICROSTRIP ANTENNAS

Microstrip patch antennae radiate primarily because of the fringing fields between the patch edge and the ground plane [1][2]. For a rectangular patch, the length L of the patch is usually $0.3333\lambda 0 < L < 0.5\ \lambda 0$, where λ0 is the free space wavelength. The patch is selected to be very thin such that thickness $t << \lambda 0$. The height h of the dielectric substrate is usually $0.003\ \lambda 0 \le h \le 0.05\ \lambda 0$ [2]. Dielectric constants are usually used in the range **2.2** $\le \varepsilon_r \le$ **12** however, the most desirable ones are the dielectric constants at the lower end of this range together with the thick substrates, because they provide better efficiency and larger bandwidth, but at the expense of larger element size [5].

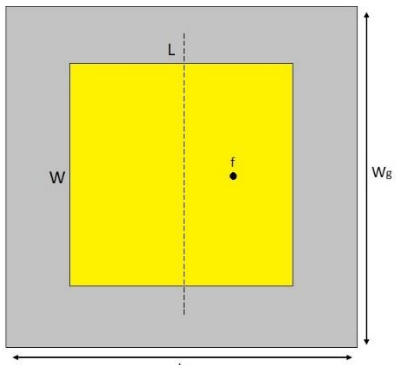

Fig1. Rectangular Microstrip antenna.

The effective dielectric constant of the dielectric material is given by,

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(1 + 12\frac{h}{w}\right)^{\frac{-1}{2}} \qquad \ldots (1)$$

For an efficient radiator, a practical width that is given by,

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$$w = \frac{c}{2 * f_r}\sqrt{\frac{2}{\varepsilon_r + 1}} \quad \ldots (2)$$

Where C is free space velocity of light.
The actual length of the patch given by,

$$w = \frac{c}{2 * f_r}\sqrt{\frac{2}{\varepsilon_r + 1}} \quad \ldots (3)$$

Where ΔL is the extension of the length due to the fringing effects and given by,

$$L = \frac{c}{2 * f_r * \sqrt{\varepsilon_r}} - \Delta L \quad \ldots (4)$$

Ground plane dimensions (L_g and W_g) is given by

$$L_g = 6h + L \quad \ldots (5)$$

$$W_g = 6h + W \quad \ldots (6)$$

Theoretical calculations are done using above formulae.

III. ARTIFICIAL NEURAL NETWORK

An ANN is normally composed of three layers of many computing elements called nodes. Each node receives an input signal from other nodes or external inputs and after processing the signals locally through a transfer function, it outputs a transformed signal to other nodes or final result [6][7]. In fig2 first layer is called as input layer where external information is received. The last layer is called as output layer where the network produces the model solution. In between, there are one or more hidden layers which are critical to ANN to identify the complex patterns in the data [6].

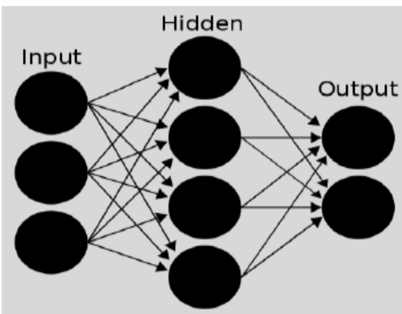

Fig2. Multilayer Perceptron Model

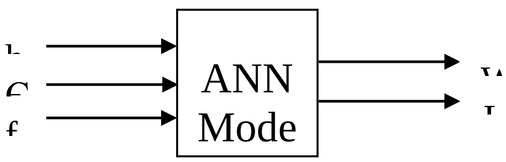

Fig 3. Synthesis using ANN model

Once the ANN model is fully developed, the computation time is usually negligible and much faster than any EM simulator [8]. The 3 inputs and 2 output were used for the synthesis ANN. The neural network is trained with data set of various values of height h, dielectric constant ε_r and resonant frequency f_r. Once you have trained the network, choose the frequency to simulate, for which design parameter is to be find. It can calculate the design constraints close to experimental value of width W and length L.

For designing neural network we use nntool in matlab software. Simple Rectangular microstrip antenna analysis has been made in Fig.3. For this configuration, performance goal was set as 0.01. The number of input layer is 1, hidden layer is 2 and output layer is set as 1. The MLP network, which has a configuration of 3 input neurons, 10 and 5 neurons in 2 hidden layers, and 2 output neurons. Train Function is set to TRAINLM, Adaption Learning Function is set to LEARNGDM and Performance Function is set to MSE. The W, L was calculated by inputting the resonant frequency, height of the substrate and their dielectric constants using synthesis ANN model. 1000 epochs were set to achieve the desired performance goal.

IV. RESULTS

An ANN model for finding the width and length has been designed. After training of neural network some value were simulated in neural network to check performance of the network. Simulated results are shown below.

Table 1. Results of the synthesis ANN and comparison with the targets

f_r in GHz	ϵ_r	h in mm	W (ther.) In cm	W (ANN) In cm	deviation In W	L (ther.) In cm	L (ANN) In cm	deviation In L
2.4	4.4	1.6	3.803	3.784	-0.019	2.944	2.929	-0.015
2.81	4.4	1.6	3.248	3.217	-0.031	2.505	2.499	-0.006
3.5	4.4	1.6	2.60	2.491	-0.109	1.998	1.911	-0.087
4.8	4.4	1.6	1.901	1.921	0.020	1.437	1.451	0.014
5.2	4.4	1.6	1.776	1.755	-0.021	1.34	1.32	-0.02
6.8	4.4	1.6	1.342	1.314	-0.028	0.98	0.818	-0.162
7.6	4.4	1.6	1.201	1.141	-0.061	0.875	0.892	0.017

In Table 1, the accuracy values of synthesis ANN networks giving the best results are given. Table 1 compares the dimension of simple microstrip antenna calculated by ANN and theoretical. The dimension of microstrip antenna calculated by ANN is very close to the target value. Thus neural network gives approximately same design parameters as theoretical method. Thus values for rectangular patch resonating at 2.4 GHz frequency is calculated using ANN.

V. HFSS IMPLEMENTATION

HFSS (High frequency structural simulator) is commercial finite element solver for Electromagnetic structures like antenna, RF electronic circuit including filters, transmission lines etc.

Design constraints calculated in ANN network for rectangular patch resonating at 2.4 GHz frequency needs to be verified thus for this Ansoft HFSS software is used to simulate the patch structure.

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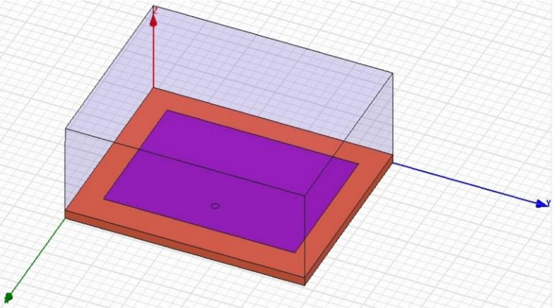

Fig 4. Ansoft-HFSS Generated probe Fed Patch Antenna

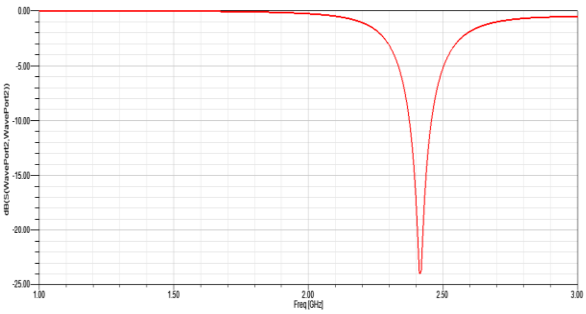

Fig 5. Return Loss v/s Frequency Curve

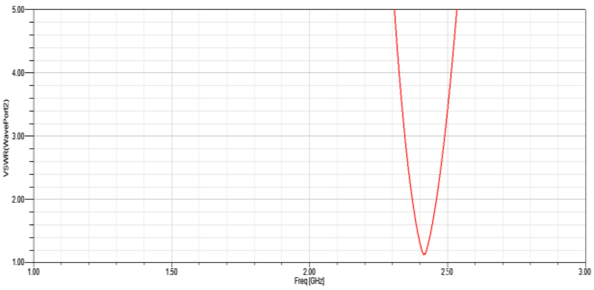

Fig 6. VSWR of given rectangular patch geometry

The Fig 5. shows that rectangular patch antenna whose dimension were calculated by neural network is resonating at 2.412 GHz frequency means near to the specified value i.e. 2.4 GHz frequency. It gives return loss of -24 dB which is good. Fig 6. shows the VSWR of given antenna is near about 1.2. Thus patch geometry for 2.4 GHz is simulated in HFSS.

VI. CONCLUSION

An efficient design procedure for rectangular Microstrip patch has been demonstrated using ANN. In the analysis network, one can obtain geometrical parameters of antenna by inputting resonant frequency, height and dielectric constant of the substrate.

In this work, the neural network is employed as a tool in design of the Microstrip antennas. In this design procedure, synthesis is defined as the forward side. Therefore, one can obtain the geometric dimensions with high accuracy, i.e. length and width of the patch in our geometry, at the output of the synthesis network by inputting resonant frequency, height and dielectric constants of the chosen substrate. In this work, parameters of the ANN network are verified by using HFSS software. Finally, in this work, a general design procedure for the Microstrip antennas is suggested using artificial neural networks and this is demonstrated using the rectangular patch geometry.

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AUTHOR PROFILE

Prof. Vilas Mapare is currently worked as Assoc. Prof. at Department of Electronics & Tele communication, Sinhgad Institute of Technology, Lonavala. He has done his M.E. degree at Mubai University. His research interests are in the areas of microstrip antennas, neural network, microwave communication and radar. His research papers are published in IEEE journal, International Journal of Computer Applications.

Suraj Shinde is currently pursuing B.E. degree at Department of Electronics & Tele communication, Sinhgad Institute of Technology, Lonavala affiliated to University of Pune.

Maheshkumar Latpate is currently pursuing B.E. degree at Department of Electronics & Tele communication, Sinhgad Institute of Technology, Lonavala affiliated to University of Pune.

Tejas Khairnar is currently pursuing B.E. degree at Department of Electronics & Tele communication, Sinhgad Institute of Technology, Lonavala affiliated to University of Pune.

Pallavi Kadam is currently pursuing B.E. degree at Department of Electronics & Tele communication, Sinhgad Institute of Technology, Lonavala affiliated to University of Pune.

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