Investigations for the Prediction of Resonant Frequency of Microstrip Patch Antenna Using RBF Neural Network

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Abstract**—**In this paper, an application of radial basis function (RBF) neural network is presented for the prediction of resonant frequency of microstrip patch antenna. The training and testing data for artificial neural network (ANN) model are generated with the help of method of moment based IE3D simulation software. ANN model predicted accurate results for resonant frequency of microstrip patch antenna. Simulated and ANN model results are compared with the experimental results which are available in the literature and found in good agreement.

Keywords*-Artificial neural network; Radial basis funjction; Microstrip antenna; Resonant frequency*

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I. INTRODUCTION

Microstrip patch antennas gained attention of researchers due to their fruitful advantages in several fields such as, mobile communications, GPS applications, satellite applications, missiles applications etc. these antennas having low profile, light weight, low fabrication cost, and easily mountable on MMICs [1]. Microstrip antennas suffer with few limitations, such as low gain and narrow bandwidth [1]. So due to narrow bandwidth resonant frequencies of these antennas should be accurately determined. In this work artificial neural network is suggested for the prediction of resonant frequency of microstrip patch antenna.

Artificial neural networks are computational models based on the human brain model. The artificial neural networks are widely used because of its universal approximation capability and greater generalization capability [2]. In last few years, ANN adopted attention of researchers for the field of microstrip patch antenna. ANN was firstly employed by Vegni et al. [3] for the analysis of microstrip patch antenna. Furthermore several approaches have been made for calculating resonant frequency [4], input impedance [5], radiation resistance [6], and bandwidth [7]. In few other papers an investigations has been made using artificial neural network for MSA [8-11].

In this paper, a RBF neural network model is proposed for the prediction of resonant frequency of microstrip patch antenna. Data sets are generated using IE3D simulation software [12] for training of ANN model and model is tested with the experimental data sets given in [13-14].

II. ANTENNA DESIGN AND DATA GENERATION

The basic geometry of the microstrip patch antenna is shown in Figure 1. Here a simple rectangular patch of dimension $L \times W \times h$ is considered as the base of the work. In this work, input variables length (L), width (W), substrate thickness (h), dielectric constant (ε_r), and feed position (x_f) of microstrip patch antenna geometry are initially calculated equations 1-5 [1]. From here 30 data sets are generated and used in IE3D simulation software. The respective resonant frequency of these data sets are recorded and used in training of ANN model. Training data sets are given in Table I for the training of ANN model.

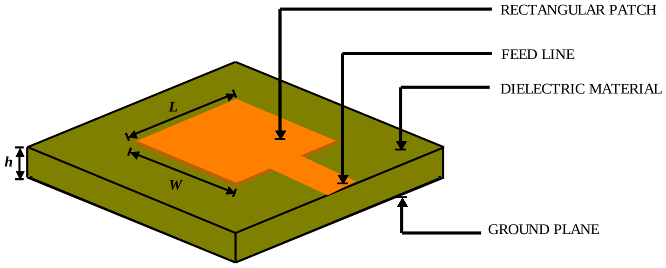

Figure 1. Geometry of microstrip patch antenna.

$$L_{eff} = \frac{c}{2 f_r \sqrt{\varepsilon_{eff}}} \tag{1}$$

$$W = \frac{c}{2 f_r \sqrt{\frac{(\varepsilon_r + 1)}{2}}} \tag{2}$$

$$\varepsilon_{eff} = \frac{(\varepsilon_r + 1)}{2} + \frac{(\varepsilon_r - 1)}{2}\left[1 + 12\frac{h}{W}\right]^{-\frac{1}{2}} \tag{3}$$

$$\Delta L = 0.412h \frac{(\varepsilon_{eff} + 0.3)(\frac{W}{h} + 0.264)}{(\varepsilon_{eff} + 0.258)(\frac{W}{h} + 0.8)} \tag{4}$$

$$L = (\varepsilon_{eff} - 2\Delta L) \tag{5}$$

TABLE I. DATA SET FOR TRAINING OF ANN MODEL

L (mm)	**W** (mm)	**h** (mm)	ε_r	x_f	f_r (GHz)
22.87	29.42	1.58	4.7	7	3.02
23.68	30.60	1.58	4.7	7	2.91
25.05	32.74	1.58	4.7	7	2.78
26.50	33.84	1.58	4.7	7	2.64
27.64	35.54	1.58	4.7	7	2.5
30.78	39.85	1.58	4.7	7	2.35
32.98	42.58	1.58	4.7	7	2.18
34.56	44.42	1.58	4.7	7	2
39.85	49.97	1.58	4.7	7	1.84
43.98	53.69	1.58	4.7	7	1.60
46.09	59.23	1.58	4.7	7	1.5
50.45	67.82	1.58	4.7	7	1.35
62.51	79.59	1.58	4.7	7	1.22
69.15	88.85	1.58	4.7	7	1
49.20	58.21	1.52	2.32	7	2
48.25	55.36	1.52	2.32	7	2.18
45.35	52.38	1.52	2.32	7	2.23
42.49	50.75	1.52	2.32	7	2.31
41.06	48.65	1.52	2.32	7	2.43
39.35	46.56	1.52	2.32	7	2.5
37.56	44.58	1.52	2.32	7	2.58
35.79	42.35	1.52	2.32	7	2.79
33.46	40.98	1.52	2.32	7	2.95
32.75	38.80	1.52	2.32	7	3
27.48	34.09	1.57	3.3	7	3
30.56	39.54	1.57	3.3	7	2.88
34.36	42.25	1.57	3.3	7	2.63
36.84	46.52	1.57	3.3	7	2.45
39.54	49.58	1.57	3.3	7	2.15
41.25	51.14	1.57	3.3	7	2

III. DEVELOPMENT OF ANN MODEL

The length, width, height, thickness, feed point location and substrate dielectric constant are affected the resonant frequency of microstrip patch antenna. So these parameters are considered as an input for ANN model. Resonant frequency of microstrip patch antenna is considered as an output function for ANN model. In this work a RBF neural network model is selected as for the prediction of resonant frequency of microstrip patch antenna. The structure of RBF model is selected as 5×30×1, means 5 neurons in input layer, 30 neurons in hidden layer, and 1 neuron in output layer of ANN model. The structure of proposed RBF neural network is shown in Figure 2. A network with single hidden layer and radial basis activation function for hidden layer is known as RBF network.

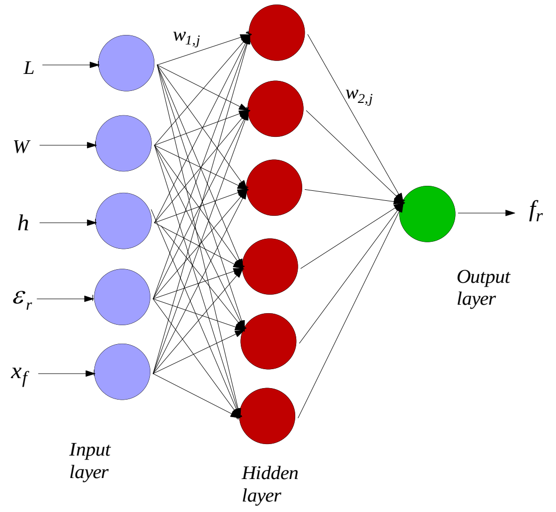

Figure 2. RBF neural network model.

$$O = w_{2,j}^T * y_{1,j} \quad (6)$$

$$y_{1,j} = \exp\left[\frac{(x - w_{1,j})(x - w_{1,j})}{2\sigma_j^2}\right] \quad (7)$$

IV. RESULTS AND DISCUSSION

The RBF neural network model was trained with 30 sets of training data and tested with 5 data sets [13-14] available in the literature. The input layer of the ANN model consists of five parameters as input function L, W, ε_r, h, feed point position (x_f) of microstrip patch antenna. The simulated and ANN results for microstrip patch antenna are compared with experimental results. It is observed that the results predicted by RBF neural network are found in close agreement with the simulated and experimental ones as given in Table 2. ANN model predicted the value of resonant frequency with less computational time after training than the comparison of IE3D simulation software.

Fig. 3 shows the number of epochs to achieve minimum mean square errors (MSE) for the training of ANN model and from here it is observed that, at 31 epochs the level of MSE is minimized.

Fig. 4 (a)-(b) and (c) shows the variation in resonant frequency with respect to the length of microstrip patch antenna at 10, 20, and 30 neurons in the hidden layer respectively. It is observed that, at 30 neurons in hidden layer RBF output best fitted to target data.

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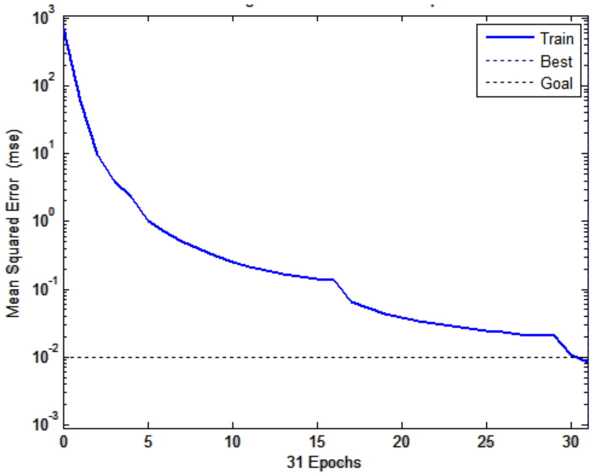
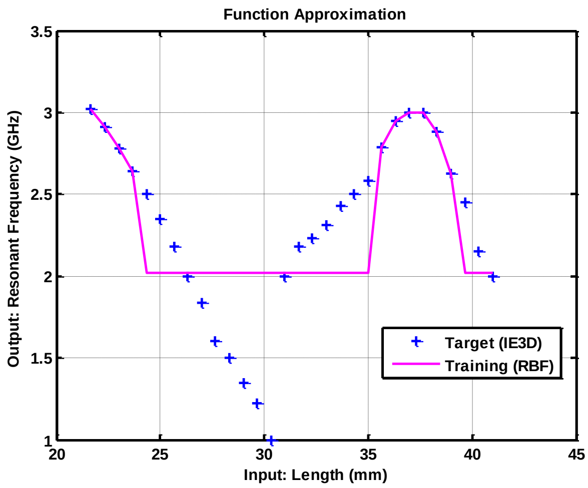
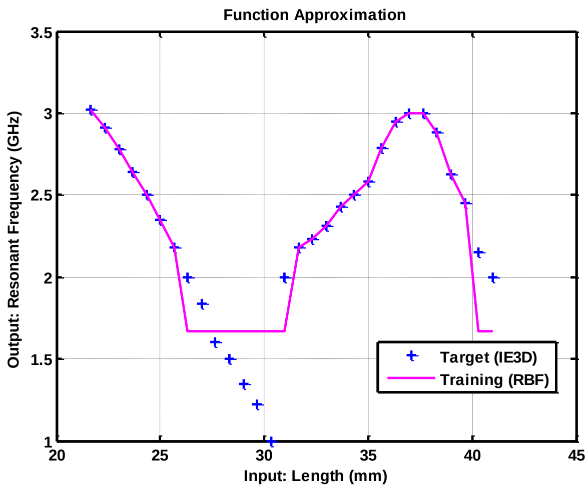


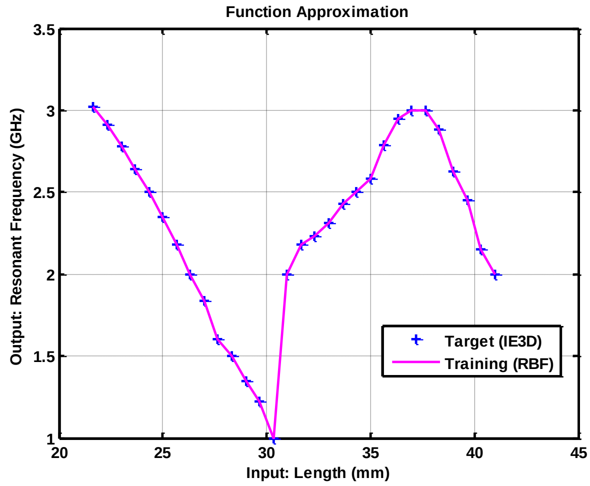
Figure 3. Number of epochs to achieve minimum mean square error (MSE).



(a)



(b)



(c)

Figure 4. RBF output with numbers of neurons in hidden layer (a) 10 neurons (b) 20 neurons (c) 30 neurons.

TABLE II. COMPARISON OF SIMULATED, ANN, AND EXPERIMENTAL RESULTS

f_r (IE3D) GHz	f_r (ANN) GHz	f_r (Experimental) GHz [13-14]
5.60	5.8162	5.820
4.60	4.6594	4.660
3.80	3.9618	3.980
3.85	3.9032	3.900
2.73	2.9646	2.980

IV. CONCLUSION

The proposed RBF neural network successfully predicted the accurate resonant frequency for microstrip patch antenna. RBF neural network model outputs are found in good agreement with simulated and experimental results. Experimental cost and computational time taken by simulation software can be reduced by using this proposed RBF neural network model. The technique presented for the prediction of resonant frequency of microstrip patch antenna is simple, inexpensive, and highly accurate. Thus from this model we can simply and accurately calculate the resonant frequency of microstrip patch antenna.

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