Bandwidth Analysis of I-shaped Microstrip Patch Antenna with Artificial Neural Network (ANN)

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Abstract— In this paper an artificial neural network model is used for analysis of bandwidth of Microstrip antenna. An I-shaped Microstrip patch antenna with operating frequency 2.4 GHz is used to explain analysis. Generating data for ANN model is obtained by varying different parameters of the Microstrip antenna. Simulation is done with IE3D software to measure the bandwidth and this result is compared with artificial neural network results. This ANN model gives more easy calculation and accuracy in the design of Microstrip antenna and analysis the effects of various design parameters. It is shown that possible bandwidth of I-shaped Microstrip antenna with this ANN model is successfully analyzed.

Key words: Microstrip rectangular antenna; IE3D simulation software; Bandwidth (BW); Artificial Neural Network (ANN)

I. INTRODUCTION

Due to their many attractive features, Microstrip antenna has drawn the attention of researchers over the past work. However, in recent year, researchers have offered several new Microstrip patch configuration to increase the bandwidth of the Microstrip antenna [1]. The current focus on electronics packaging and interconnects has led to design of efficient, wide band, low cost and small volume antennas which can rapidly be incorporated into a broad spectrum of systems [2]. The Microstrip antenna became popular because of ease of analysis, fabrication & their attractive radiation characteristics due its light weight, low profile, low manufacturing cost, conformability, reproducibility, reliability, and Integration with solid-state devices and conformable to planar and non-planar surfaces. Microstrip antenna is used in various wireless communication applications like UMTS, WLAN/WiMAX etc. Recently ANN model have acquired tremendous applications in wireless communications due to their ability and adaptability to learn and generalized features. Neural network have been successfully applied to problems in the fields of patterns recognition, image processing, data compression, forecasting, and optimization.

II. ANTENNA DESIGN SPECIFICATION

In this paper the basic structure are shown in Figure 1 is a rectangular patch of dimension 30 mm × 38.7 mm and ground plane length and width is 40 mm × 48.7 mm. Antenna is designed using operating frequency f_r = 2.4 GHz, height h = 1.6 mm, glass epoxy substrate whose dielectric constant ε_r = 4.2 and loss tangent tan∂ = 0.0013. The characteristics of designed antenna such as return loss, bandwidth, directivity, gain and efficiency are investigated. These parameters are calculated by using Zeland IE3D electromagnetic simulator.

III. ANTENNA GEOMETRY AND DESIGN

The Geometry of proposed Microstrip antenna is shown in Figure 1. Feed coordinates of this antenna is (38.9, 34). Various parameters and their corresponding values of I-shaped Microstrip antenna are shown in table 1. For designing of Microstrip antenna patch length L and patch width W, for I-shaped antenna can be calculated using equation (1-4) [6].

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

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2}+\frac{\varepsilon_r-1}{2}\left[1+10\frac{h}{w}\right]-\frac{1}{2} \quad (2)$$

$$\frac{\Delta l}{h} = 0.412\frac{(\varepsilon_{eff}+0.300)\left(\frac{w}{h}+0.262\right)}{(\varepsilon_{eff}-0.258)\left(\frac{w}{h}+0.813\right)} \quad (3)$$

By using the above equations we can find the actual length of the patch.

$$L = \frac{c}{2f_r\sqrt{\varepsilon_{eff}}} - 2\Delta l \quad (4)$$

Now L and W are used to calculate the length and width of ground plane by using equation (5-6).

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

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

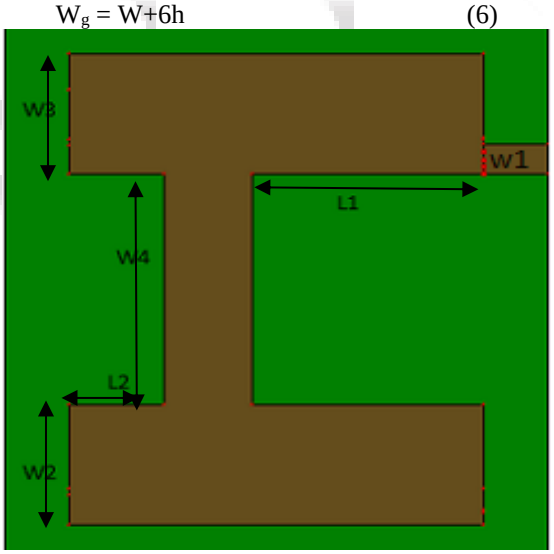

Fig. 1: Geometry of the proposed Microstrip antenna

S.No.	Parameters	Values
1.	h	1.6
2.	ε_r	4.2
3.	W_g	48.7
4.	L_g	40
5.	W	38.7
6.	L	30.1
7.	L_1	16.5
8.	L_2	7
9.	W_1	2.5
10.	W_2	10
11.	W_3	10
12.	W_4	18.7

Table1. Antenna design parameters

This table shows the various parameter of Microstrip antenna.

IV. IE3D SIMULATIN RESULT

The bandwidth of proposed antenna for different values of length L_1, width W_2 and W_4 is determined through IE3D simulation software optimization which is shown in table 2. And this bandwidth is compared with ANN model for analysis which is shown in table 3. Figure 2 shows the return loss versus frequency of proposed antenna.

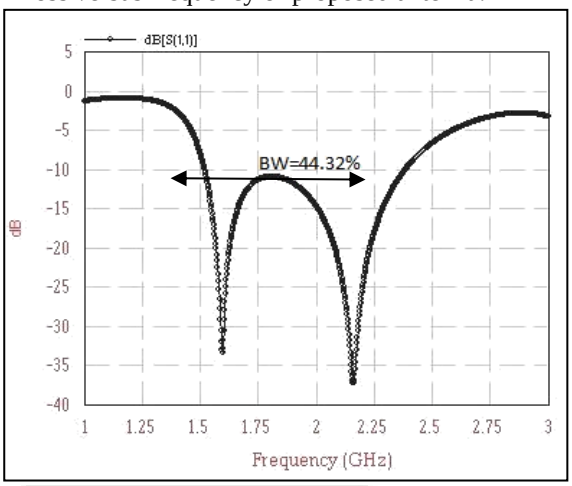

Fig. 2: Return Loss versus frequency graph

This graph shows the bandwidth 44.32% of proposed antenna covering the frequency range from 1.521 GHz to 2.387 GHz. This frequency range is most suitable for WLAN/WiMAX and many other wireless communication applications. It gives the maximum return loss is -37.28 dB at frequency 2.16 GHz.

V. DESIGNING AND ARCHITECTURE OF NEURAL NETWORK

Neural network is consisting of input layer, output layer and single or more than one hidden layers. These layers play different role. The architecture of neural network with three layer is shown in Figure 3. neural network has basic three functions. Firstly training samples (input data set) are generated as shown in Table 2. The training is done with Levenberg-Marquardt (LM) algorithm and epoch 500 as shown in Figure 4. And then structure of hidden layer is selected, and finally weights and biases are adjusted using algorithms. For the testing of neural network model, a set of data is generated for training which are not included in training samples. 70 no. of data sets of proposed antenna are designed for training and testing. Among these 61 data sets of antenna are used for training purpose and 9 data sets are used for testing which are not included in training samples.

A. Generation Of Input Data Set

Input data set for proposed neural network is generated for optimization by varying three parameters L_1, W_2, W_4 of table 1. L_1 is varied from -5 mm (11.5 mm) to +5 mm (21.5 mm) with an increment of 0.5 mm. So it forms 21 (20 + 1 conventional) different antenna. L1 is varied while keeping all other parameter of table 1 is constant. Similarly parameters W_2 and W_4 are varied in same fashion for the range from 5 mm to 15 mm and from 13.7 mm to 23.7 mm respectivily. So it generates a input data set of 61 (20×3 + 1) antennas which is shown in Table 2.

B. Generation Of Target Data Set

Target data set is a bandwidth of proposed antenna for different values of parameters L_1, W_2, and W_4 which is obtained through IE3D simulation software based on methods of moments(MoM). Thus a target data set is generated which is shown in Table 1.

S.No.	Input data			Target Data(IE3D)
	L_1	W_2	W_4	(B.W.%)
1.	11.5	10	18.7	40.72
2.	12	10	18.7	41.04
3.	12.5	10	18.7	41.45
4.	13	10	18.7	41.78
5.	13.5	10	18.7	42.19
6.	14	10	18.7	42.52
7.	14.5	10	18.7	42.84
8.	15	10	18.7	43.14
9.	15.5	10	18.7	43.63
10.	16	10	18.7	43.91
11.	16.5	10	18.7	44.32
12.	17	10	18.7	44.73
13.	17.5	10	18.7	45.09
14.	18	10	18.7	45.33
15.	18.5	10	18.7	45.77
16.	19	10	18.7	46.01
17.	19.5	10	18.7	46.24
18.	20	10	18.7	46.47
19.	20.5	10	18.7	46.66
20.	21	10	18.7	46.64
21.	21.5	10	18.7	46.30
22.	16.5	5	18.7	49.57
23.	16.5	5.5	18.7	48.97
24.	16.5	6	18.7	48.48
25.	16.5	6.5	18.7	47.87
26.	16.5	7	18.7	47.41
27.	16.5	7.5	18.7	46.88
28.	16.5	8	18.7	46.33
29.	16.5	8.5	18.7	45.74
30.	16.5	9	18.7	45.35
31.	16.5	9.5	18.7	44.80
32.	16.5	10.5	18.7	43.71
33.	16.5	11	18.7	43.31
34.	16.5	11.5	18.7	42.78
35.	16.5	12	18.7	42.33
36.	16.5	12.5	18.7	41.72
37.	16.5	13	18.7	41.18
38.	16.5	13.5	18.7	40.73
39.	16.5	14	18.7	40.19
40.	16.5	14.5	18.7	39.69
41.	16.5	15	18.7	39.19
42.	16.5	10	13.7	44.85
43.	16.5	10	14.2	44.77
44.	16.5	10	14.7	44.90
45.	16.5	10	15.2	44.82
46.	16.5	10	15.7	44.78
47.	16.5	10	16.2	44.83
48.	16.5	10	16.7	44.67
49.	16.5	10	17.2	44.72
50.	16.5	10	17.7	44.48
51.	16.5	10	18.2	44.52
52.	16.5	10	19.2	44.49

53.	16.5	10	19.7	44.33
54.	16.5	10	20.2	44.09
55.	16.5	10	20.7	44.06
56.	16.5	10	21.2	43.89
57.	16.5	10	21.7	43.86
58.	16.5	10	22.2	43.70
59.	16.5	10	22.7	43.58
60.	16.5	10	23.2	43.34
61.	16.5	10	23.7	43.30

Table 2: Input and target data

This table shows the input data set which is generated for analysis by varying three parameters L1, W2, W4 and target data set which is obtained throug IE3D simulation software for different values of parameters L1, W2, W4.

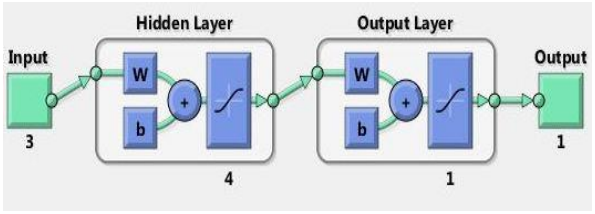

Fig. 3: Architecture of Neural Network

This figure shows the architecture of neural network which is consisting of input layer, hidden layer, output layer.

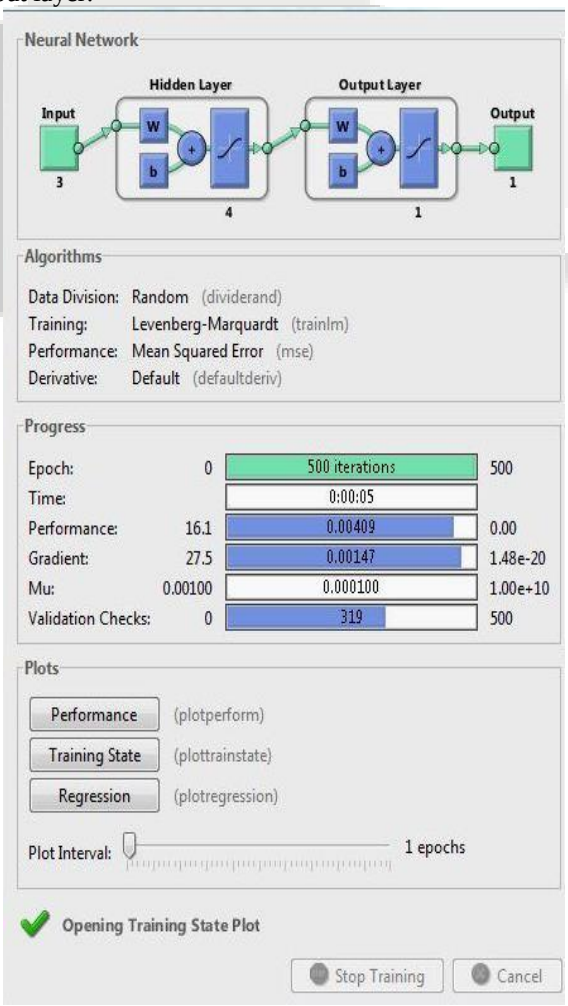

Fig. 4: Training of Neural Network

This figure shows the training of neural netwrk. In this paper for best performances some specifications of proposed neural network like network type = feed forward back propagation, number of layers = 2, number of neurons in hidden layer = 4, transfer function = TANSIG, training function = TRAINLM (Levenberg-Marquardt), adaption learning function = LEARNGDM, performance = MSE (mean square error), error goal = 0 number of epochs = 500, gradient = 1.48e-020 are used. Levenberg-Marquardt algorithm is used because this algorithm gives best accuracy in result.

VI. NEURAL NETWORK RESULT

The Results of neural network is shown in figure 5 and figure 6.

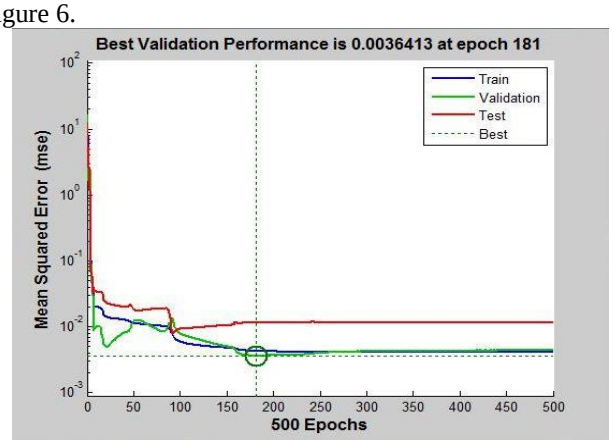

Fig. 5: Training performances showing minimum MSE

This figure shows the training performances of training and test results which are very close to each other. For the best performances configuration of ANN 4 neurons in hidden layer, error goal (e_g) = 0, Levenberg Marquardt (LM) algorithm and network type feed forward back propagation is used.

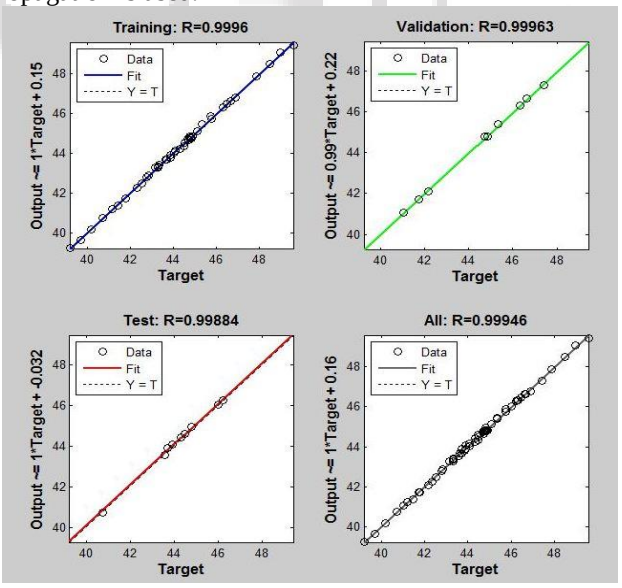

Fig. 6: Regression states

In this figure the three plots represent trainng, validation and testing data. The dashed line in each plot represent the perfect result- output = target. The solid line represents the best fit linear regression line between output and targets. The R value is an indication of the relationship the outputs and targets. If R = 1, this indicates that there is an exact linear relationship between output and targets. If R is close to zero, then there is no relationship between output and targets.

S.No.	L_1	W_2	W_4	%BW through IE3D	%BW through ANN
1.	11.7	10	18.7	40.84	40.89
2.	12.3	10	18.7	41.25	41.30
3.	21.4	10	18.7	46.30	46.39
4.	16.5	5.7	18.7	48.63	48.80
5.	16.5	6.2	18.7	48.18	48.19
6.	16.5	14.3	18.7	39.90	39.80
7.	16.5	10	13.9	44.85	44.81
8.	16.5	10	21.4	44.90	44.83
9.	16.5	10	23.6	43.26	43.36

Table 3: Comparison between the results of IE3D and ANN

This shows the comparison between the results of IE3D and ANN. 70 patterns of proposed antenna is generated for training and testing. 61 data set is used for trainng and the data set of 9 patterns is used for comparison of neural network results with IE3D results is not included in training of neural network.

VII. CONCLUSION

In this paper analysis for bandwidth of rectangular I-shaped microstip patch antenna are achieved with the help of a ANN model trained with Levenberg-Marquadt (LM) algorithm. The bandwidth of proposed antenna is 44.32 % with IE3D. And the results of IE3D and ANN are compared for analysis of proposed design. It is observed that proposed network gives good accuracy with IE3D about 99.89 %. These results show that the ANN network is studied sucessfully for analysis of bandwidth values of rectangular I-shaped microstrip patch antenna.

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