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Analysis Of Bandwidth Of Dual Slit Loaded Microstrip Patch Antenna Using Artificial Neural Network

Archana Lala[1], S. R. Nigam[2], Vinod Kumar Singh[3]

[1,3]S R Group of Institutions, Jhansi, India

[2]AISECT University Bhopal, India

***Abstract*:** This paper presents the use of artificial neural network for the estimation of frequency band and bandwidth of a line feed Dual Slit Loaded Rectangular Shaped Microstrip patch antenna. The different variants of training algorithms of MLPFFBP-ANN (Multilayer Perceptron feed forward back propagation Artificial Neural Network) and RBF-ANN (Radial Basis Function Artificial Neural Network) have been used to implement the neural network model. The simulated data for training and testing the neural network are obtained by analyzing the rectangular microstrip patch antenna using the method of moment (MOM) based IE3D software. The results obtained by using ANNs are compared with IE3D simulation and found quite satisfactory, and also it is concluded that RBF network is more accurate and fast as compared to back propagation training algorithm of MLPFFBP. The designed antenna operates in the frequency range (1.897GHz to 2.222GHz). The example antenna is also designed physically with the FR-4 glass epoxy $\varepsilon_r = 4.4$ between the ground plane and patch for few result for testing artificial neural network model and simulated on the Zeland IE3D software and results are compared with the neural network of tool of MATLAB.

1. INTRODUCTION

Microstrip antenna‘s are being frequently used in wireless communication due to its light weights low profile , low cost, directive with high transmission efficiency and ease of integration with microwave circuit and portable communication equipments, that is why it finds place in much applications since 1970’s. However dual slit loaded rectangular microstrip antenna as the drawback of narrow bandwidth and low gain, Limited power capacity, poor polarization, purity and tolerance power but researchers have been proposed and investigated many techniques to overcome the drawbacks, Such as slotted patch antennas like U-Slot, C-Slot, E-Shaped, H-shaped, electrically thick substrates, modified ground plane and use of many feed techniques & impedance matching techniques and the use of multiple resonators. In the present work an Artificial Neural Network (ANN) is developed to analyze the frequency band and bandwidth of microstrip antenna. Neuro models are computationally much more efficient then EM models once they are trained with reliable learning data obtain from a fine model by either EM simulation or measurement [1-4]. The Neuro models can be used for efficient accurate optimization and designed within the range of training. The Method of Moments (MOM) based IE3D software has been used to generate training and test data for the ANN. It is a computational EM simulator based on Method of Moments numerical methods. It is analysis that a 3D and multi layer structure of general shapes feed point must be located at point on the patch where the input impedance of patch matched the feed for the specific resonant frequency. The return loss is recorded and that feed point is selected as the optimum one where the RL is most negative i.e. less than -10db. It is easy to model and easy to match by controlling the probe feed coordinates [5-10].

The proposed antenna has been designed on glass epoxy substrate to give a wide bandwidth of 15.78**%**, covering the frequency range from 1.897 GHz to 2.222GHz which is best suitable for Universal mobile Telecommunication system. The paper presents a simple and novel design for achieving the frequency band and bandwidth of dual slit loaded rectangular Microstrip antenna using MLPFFBP and RBF ANN.

2. DESIGNING AND DATA GENERATION OF THE PROPOSED ANTENNA

The configuration of the conventional antenna is shown in fig. 1. An antenna has 33.4 mm×40.6 mm modified ground plane and 23.8 mm×31 mm of rectangular patch dimensions. The microstrip antenna that has the patch length *L* along the *x*-axis and the patch width *W* along the *y*-axis is located [11-15].

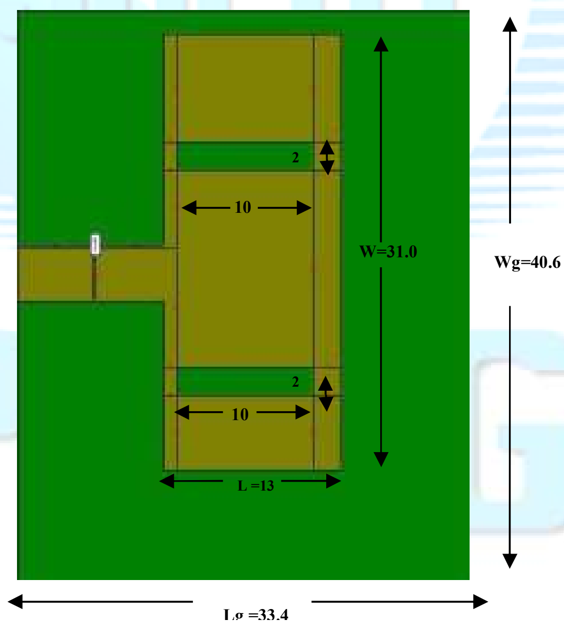


Figure1. Geometry of proposed Microstrip antenna

on the surface of a grounded dielectric substrate with the thickness of *h*. The three essential parameters for the design of a Microstrip Patch Antenna are frequency of operation (f_o), dielectric constant of the substrate (ε_r) and height of dielectric substrate (h). The dielectric material of the substrate (ε_r) selected for this design is FR-4 glass epoxy which has a dielectric constant of 4.4 and loss tangent equal to 0.02.

The substrate selected for this design is FR-4 glass epoxy with dielectric constant (ε_r) = 4.4 and height of the substrate (h) = 1.6 mm. The low value of dielectric constant increases the fringing field at the patch periphery and thus increases the radiated power. Line probe feed is given at the point (x, y). For a single-ended microstrip antenna, the patch width W and length L that support the operation at the required resonant frequency (or the free-space wave length λ_0) can be design using the formulas as given in [10] as.

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

Where **c** is the velocity of light, ε_r is the dielectric constant of substrate, ***f** is* the antenna working frequency, W is the patch non resonant width, and the effective dielectric constant is ε_{eff} given as,

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

The extension length Δ is calculated as,

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

By using the mentioned equation we can find the value of actual length of the patch as,

$$L = \frac{c}{2f\sqrt{\varepsilon_{eff}}} - 2\Delta l$$

For generating data, we simulated the frequency domain response of the antenna for various patch dimensions using methods of moments based software IE3D. For training and testing of the ANN, 86 datasets are generated by simulation using IE3D simulation software. Figure 1 shows the layout of a coaxial probe-fed rectangular patch antenna. By varying the feed position of this geometry the training data for range 5.175mm to 6.875mm and test data for MLPFFBP and RBF-ANN has been generated.

3. ANN MODEL FOR ANALYSIS OF MICROSTRIP PATCH ANTENNA

The artificial neural network model has been developed for rectangular microstrip patch antenna as shown in Figure 2. The feed forward network has been utilized to calculate the frequency band and bandwidth of the patch by inputting the x coordinates of the probe position, substrate dielectric constant ε_r and substrate height h. This is defined as analysis ANN model. So by giving the different x coordinate of the probe position of the rectangular patch at input of the ANN model keeping all other parameter constant, frequency band and bandwidth of patch is obtained at the output accurately without doing, complex calculation using in empirical formula

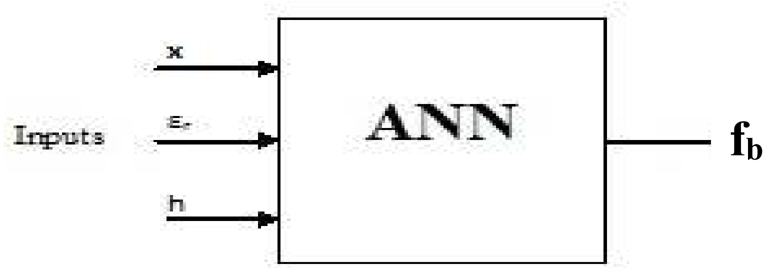


Figure2. Artificial Neural Network Model

4. NETWORK ARCHITECTURE AND TRAINING

For the present work the multilayer perceptron feed forward back propagation neural network (MLPFFBP) [12, 13] and RBF artificial neural network model are used. These networks can be used as a general function approximation. It can approximate any function with a finite number of discontinuities, arbitrarily well given sufficient neurons in the hidden layer.

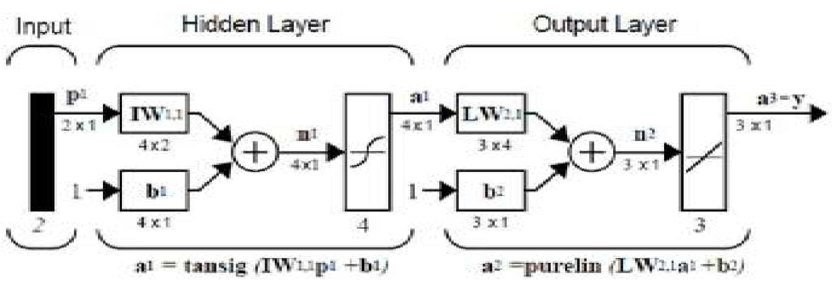


Figure3. Three Layer MLFFBP Network Architecture

5. MULTILAYER PERCEPTRON FEED FORWARD BACK PROPOGATION (MLPFFBP) NEURAL NETWORK

MLP networks are feed forward networks trained with the standard back propagation algorithms to achieve the required degree of accuracy as shown in Figure 3. They are supervised networks, and also they required a desired response to be trained. With one or two hidden layers they can approximate virtually any input output map. The weights of the networks are usually computed by training the network using the back propagation algorithms [15].

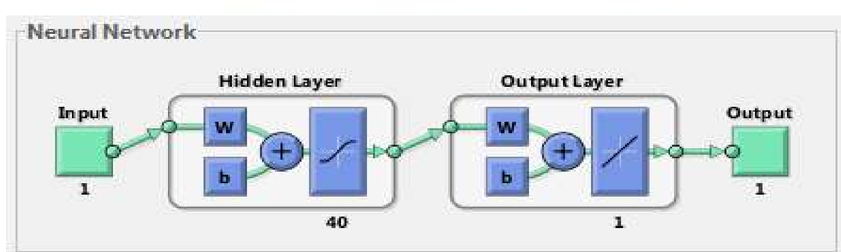


Figure4. Three Layer MLFFBP Network Architecture

In the network there is one input neuron in the input layer, and 40 hidden neurons in the hidden layer and one output neuron in the output layer as shown in figure 4. The input to the network is x coordinate of probe position of rectangular microstrip patch antenna and the output of the network is frequency band and bandwidth. The training time is 9 seconds and training performs in 250 iterations. In order to evaluate the performance of the proposed MLPFFBP ANN based model for the design of Microstrip antenna simulation results are obtain using IE3D simulator and generated 86 input and output training patterns and 8 input and output test patterns to validate the model.

During the training process the neural network automatically adjusts its weights and threshold values such that the error between predicted and sampled outputs is minimized [16]. The adjustments are computed by the back propagation algorithm. The error goal is 1.80e-25 and learning rate is 0.01. The transfer function preferred is tansig and purelin in the architecture. Figure 5 shows the training performance of the developed neural model for proposed antenna using LM training algorithm. Model is trained in 250 epochs and training time was 9 seconds. In table I resonant frequencies obtained using IE3D Software and using L-M Algorithm for different test patterns are compared and the Mean Square Error has been calculated.

Table 1: Comparison of Result obtain using IE3D and MLPFFBP-ANN using Levenberg-Marquardt algorithm for analysis of frequency band and bandwidth of rectangular Microstrip Antenna

Length	Width	Probe(X,Y)	f1	f2	FB IE3D (GHz)	BW IE3D (GHz)	LM ANN (GHz)	BW ANN (GHz)	Absolute Err	MS Err
10.8	4	(5.175,23.9)	1.887	2.168	0.281	13.859	0.28	13.810	0.356	0.0000001
10.8	4	(5.475,23.9)	1.891	2.172	0.281	13.832	0.321	15.801	-14.235	0.0002000
10.8	4	(5.675,23.9)	1.897	2.222	0.325	15.781	0.328	15.927	-0.923	0.0000011
10.8	4	(5.875,23.9)	1.881	2.128	0.247	12.322	0.246	12.272	0.405	0.0000001
10.8	4	(6.175,23.9)	1.868	2.175	0.307	15.187	0.306	15.138	0.326	0.0000001
10.8	4	(6.475,23.9)	1.872	2.068	0.196	9.949	0.195	9.898	0.510	0.0000001
10.8	4	(6.675,23.9)	1.86	2.088	0.228	11.55	0.227	11.499	0.439	0.0000001
10.8	4	(6.875,23.9)	1.858	2.08	0.222	11.275	0.222	11.275	0.000	0.0000000

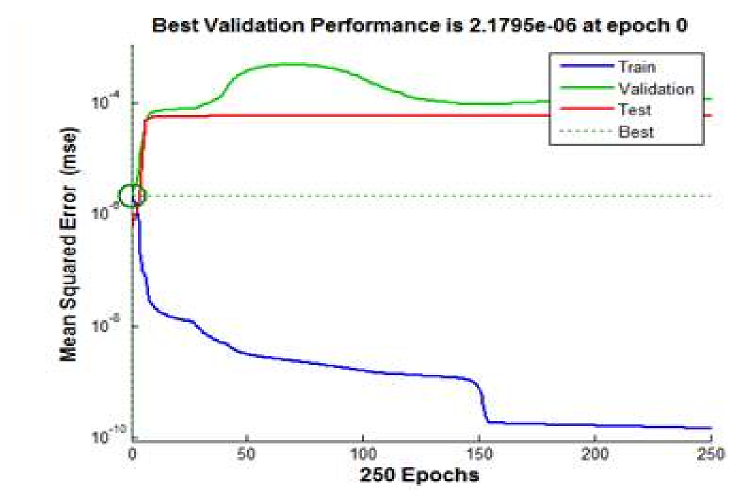


Figure 5. No. of epochs to achieve min. mean square error level in case of MLPFFBP with LM as training algorithm

6. RADIAL BASIS FUNCTION NETWORK

In this paper, radial basis function (RBL) neural networks is used to analyze rectangular shape microstrip patch antenna Radial Basis Function Network is a feed forward neural network with a single hidden layer that used radial basis activation function for hidden neurons. RBF network are applied for various microwave modeling purposes. The RBF neural network has both are supervised and unsupervised components to its learning. It consists of three layers of neurons-input, hidden and output. The hidden layer neuron represents a series of centers in the input data space. Each of these centers has activation functions typically Gaussian. The activation depends on the distance between the presented input vector and the centre [16-20]. The further the vector is from the centre the lower is the activation and vice versa the generation of centers and their widths is done using an unsupervised k-Means clustering algorithm. The centers and the widths created by these algorithms then form the weight of device of the hidden layer which remains unchanged once the clustering has been done. A typical RBF network is given in figure 6.

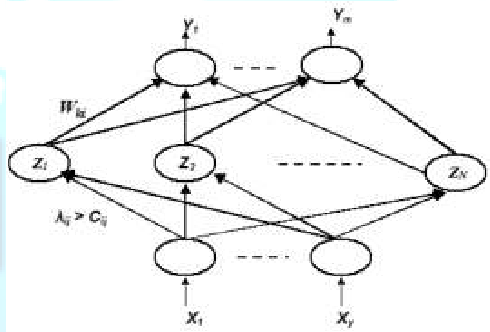


Figure 6. Neural Network approach (Radial Basis Function Network)

The parameters C_{ij} and λ_{ij} a centres and standard deviations of radial Basis Activation Functions Commonly used radial basis activation functions are Gaussian and multi quadratic. Given the input X, the total inputs to the i_{th} hidden neurons Υ_{ij} is given by

$$\gamma_i = \sqrt{\sum_{j=1}^{n}\left(\frac{x_j - c_{ij}}{\lambda_{ij}}\right)^2}, i = 1,2,3............N$$

Where N is the number of hidden neurons, the output value of the i_{th} hidden neurons is $Z_{ij} = \sigma(\Upsilon_i)$ where gama is a radial base function. Finally the output of the RBF network are computed from hidden neurons as

$$y_k = \sum_{i=0}^{N} W_{ik} Z_{ki}$$

where W_{ki} is the weight of the link between the i_{th} neurons of the hidden layer and k_{th} neuron of the output layer Training parameters W of the RBF network include w_{k0}, c_{ij}, λ_{ij}, k = 1,2,….. ,m, i = 1,2,….. , N, j = 1,2,….,n.

In the RBF network the spread value is chosen as 0.2 which gives the best accuracy the network was trained with 86 samples and tested with 8 samples. In the structure there is one input and one output was used for the analysis ANN as shown in figure 7, RBF networks are more fast and effective as compared to MLPFFBP for proposed antenna design. The RBF network automatically adjust the number of processing elements in the hidden layer till the define accuracies reached. The training algorithm is unsupervised k-mean clustering theorem.

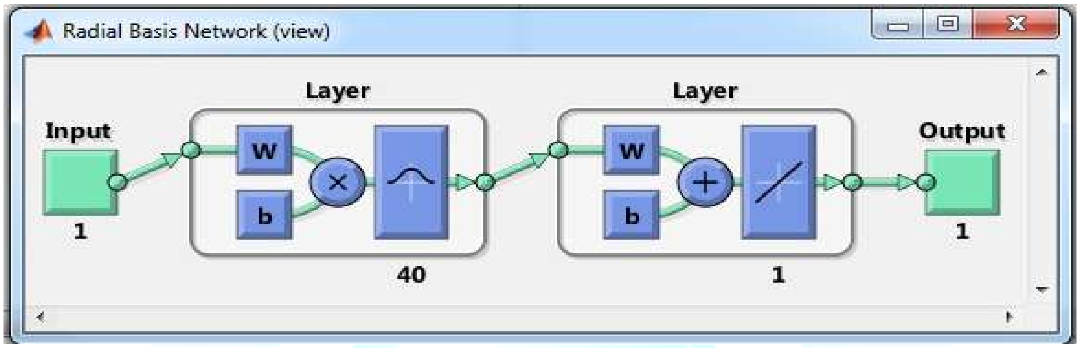


Figure7. Radial Basis Function Network

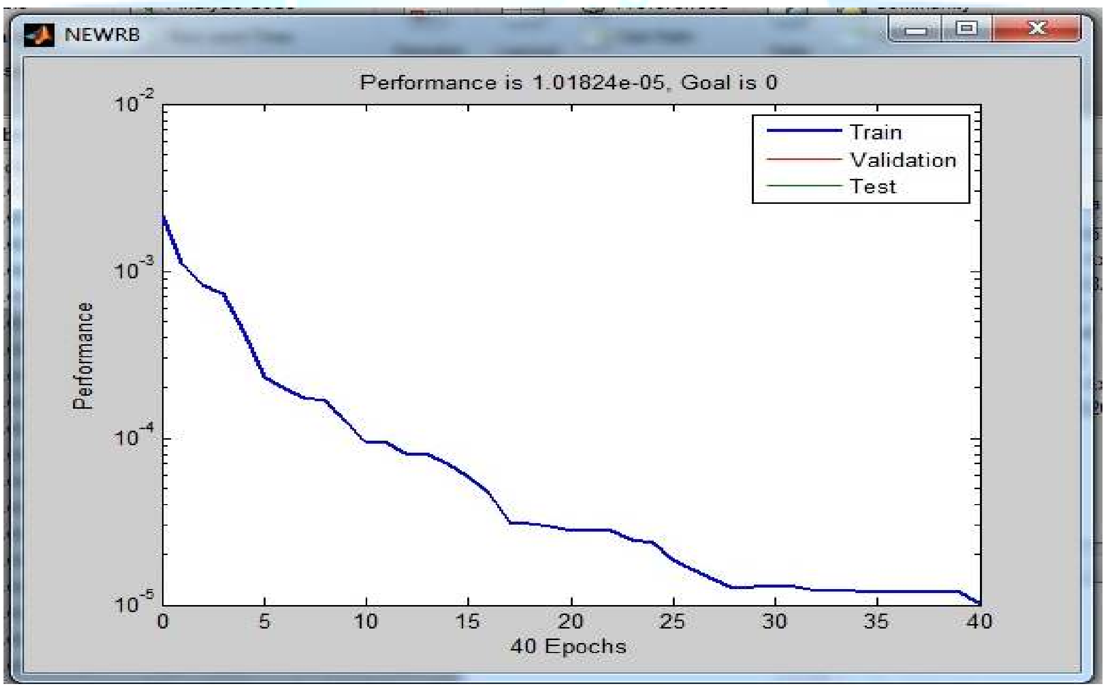


Figure8. No. of epochs to achieved min mean square error level in acase of RBF network

Figure 8 shows the training performance of the developed neural model using RBF network. Model is trained in 40 epochs. It is clear that RBF network is much faster then feed forward network since RBF network is trained in fewer epochs then feed forward network (250 epochs using LM algorithm). In table 2 bandwdth obtained using IE3D software and using RBF network for different test pattern are compared and the mean squre error has been calculate which is almost zero for all the test pattern.

Table 2. Comparison of result obtain using IE3D and RBF ANN algorithm for the analysis of frequency band and bandwidth of rectangular Microstrip antenna

Length	Widt h	Probe(X,Y)	f1	f2	FB IE3D (GHz)	BW IE3D (GHz)	RBFA ANN (GHz)	BW ANN (GHz)	Absolue Err	MS Err
10.8	4	(5.175,23.9)	1.887	2.168	0.281	13.859	0.281	13.859	0.000	0.0000000
10.8	4	(5.475,23.9)	1.891	2.172	0.281	13.832	0.323	15.899	-14.947	0.0002205
10.8	4	(5.675,23.9)	1.897	2.222	0.325	15.781	0.321	15.587	1.231	0.0000020
10.8	4	(5.875,23.9)	1.881	2.128	0.247	12.322	0.245	12.222	0.810	0.0000005
10.8	4	(6.175,23.9)	1.868	2.175	0.307	15.187	0.303	14.989	1.303	0.0000020
10.8	4	(6.475,23.9)	1.872	2.068	0.196	9.949	0.196	9.949	0.000	0.0000000
10.8	4	(6.675,23.9)	1.86	2.088	0.228	11.55	0.228	11.550	0.000	0.0000000
10.8	4	(6.875,23.9)	1.858	2.08	0.222	11.275	0.22	11.173	0.901	0.0000005

7. RESULT AND DISCUSSION

Figure 9 shows the return loss (s_{11}) verses frequency graph of proposed microstrip antenna. The result are also depicted in table 1,2 and 3. From the table it is evident that the result obtain from IE3D and ANN tool is very closed by and hence given accurate result after several trainings the length and width of the patch is kept constant and the probe position of the patch is being changed and the network is trained for the same adjustment. Further in table 3 it is seen that the measured result by network analyzer have almost the same frequency band and bandwidth as obtain from the simulator. The ANN tool is just used to study the frequency band and bandwidth of microstrip antenna which is in good agreement with the results obtains from Zeland IE3D software. As the work signifies MLPFFBP model is also used to model the Co Axial rectangular Microstrip Antenna it has been established from table 1 that LM algorithm is the optimal model to achieved desirable values of speed of conversions. It has been observed that 250 epochs are needed to reduce MSE level to a low value 1.80e-25 for three layers MLPFFBP with Levenberg-Marquardt (LM) training algorithm and Tansig as a transfer function. Achievement of such low value for performance goal (MSE) indicates that trade ANN model is an accurate model for designing the microstrip patch antenna. As the work signifies RBF ANN is also used to model the co Axial feed rectangular Microstrip Patch Antenna a radial basis function neural network has an input layer, a hidden layer and an output layer. The neuron hidden in the layer contains Gaussian transfer function whose outputs are inversely proportional to the distance from the center of the neuron. It is established from table 2 that RBF is given result not only accurate but fast also. The presented RBF network has performed training in less epochs then in MLPFFBP so it is concluded that RBF architecture is better from MLPFFBP and its accuracy is up to 99.91%. Comparison of Mean Square Error (mse1) using L-M Algorithim given in Table1 and Mean Square Error (mse2) using RBF-ANN Algorithim given in table2 for the analysis of bandwidth of Rectangular Microstrip Antenna is shown in graph (figure).It is clear from the graph that accuracy achieved using RBF Network is much better than the accuracy achieved using Levenberg-Marquardt training Algorithim of MLPFFBP Network Figure 9.shows the return loss graph of microstrip antenna which is about -16.2db.The proposed antenna resonates at 2.95 GHz frequency and has frequency range from 1.897GHz to 2.222 GHz giving a wide band width of 15.78% making it universal mobile telecommunication system.

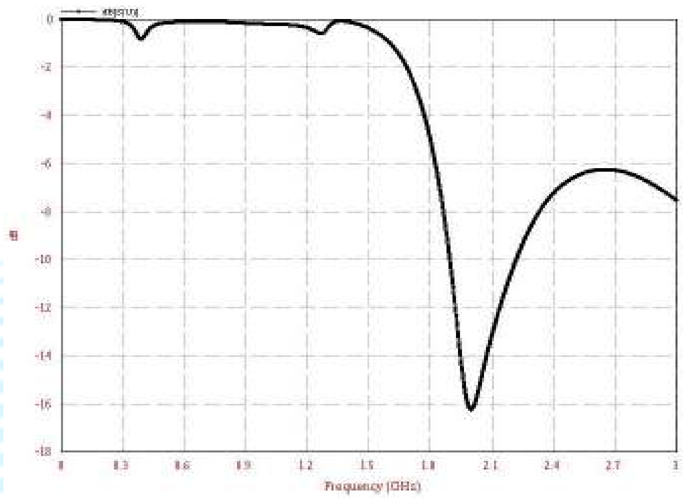


Figure 9. Return loss (S_{11}) vs. frequency of proposed Micrpstrip Patch Antenna

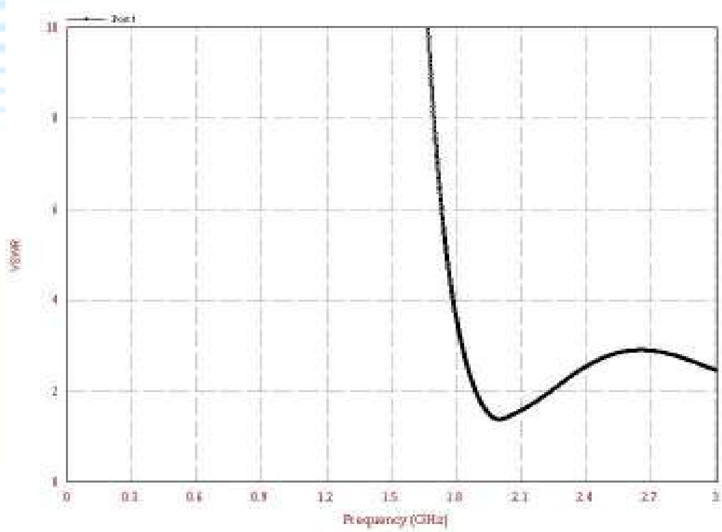


Figure10.VSWR vs. frequency of proposed Micrpstrip Patch Antenna

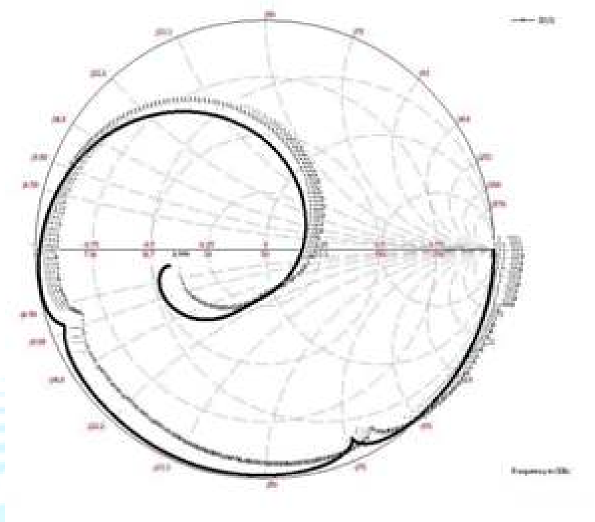
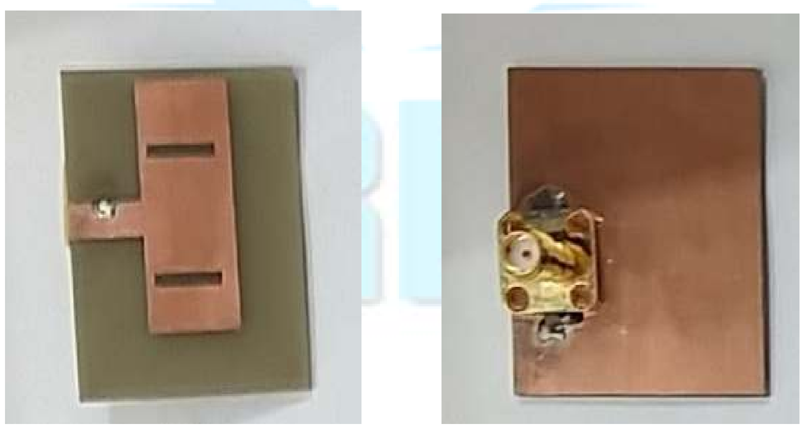


Figure 11.Smith Chart of proposed Microstrip Antenna

8. HARDWARE DESIGN OF ANTENNA FABRICATION

The proposed antenna has been simulated using IE3D software and the prototype of the antenna was fabricated and tested to obtain bandwidth and good radiation characteristics suitable for long range surveillance and operates in the frequency range (1.897GHz to2.222GHz). The photograph of hardware design is shown in figure 13.



(a) Front Face (b) Back face

Figure12. Hardware of Proposed Microstrip Antenna

8. TESTING OF FABRICATED ANTENNA IN IIT KANPUR LAB

Antenna is kept straight with transmission line of vector network analyzer due to continuous fluctuation in results on screen due to change in its orientation with slight movement as shown in figure13.

Figure13. Proposed antenna while measuring result on vector network analyzer in IIT Kanpur Lab

8.1 Simulated and Measured Results

Figure 14 shows a comparison of both simulated and measured result in terms of frequency band and bandwidth of proposed antenna. The slight change between simulated and measured result is due to fabrication tolerance, humidity, and temperature effect.However, simulated and measured shows a good correlation. Figure15 shows a comparison in variation of mean square error with frequency (GHz) for Levenberg-Marquardt Algorithm (mse1) and RBF ANN algorithm (mse2), after getting the result by simulation of IE-3D, ANN and optimization of neural network model and also shows a good correlation of measured and simulated result of proposed antenna by IE-3D and ANN. Comparison of Mean Square Error (mse1) Using L-M Algorithm given in Table I and Mean Square Error (mse2) using RBF-ANN Algorithm given in Table II for the analysis of Bandwidth of Circular Microstrip Antenna shown in graph (Figure 15). It is clear from the graph that accuracy achieved using RBF Networks is much better than the accuracy achieved using Levenberg-Marquardt training Algorithm of MLPFFBP Networks.

Table 3.Comparison of Measured and Simulated Result

Parameters	Measured Result	Simulated Result (IE3D)	Simlted Result (ANN)	
			MMLPFFBP	RBF
Frequency Band	0.291	0.325	0.328	0.321
Bandwidth	14.19%	15.78%	15.92%	15.58%

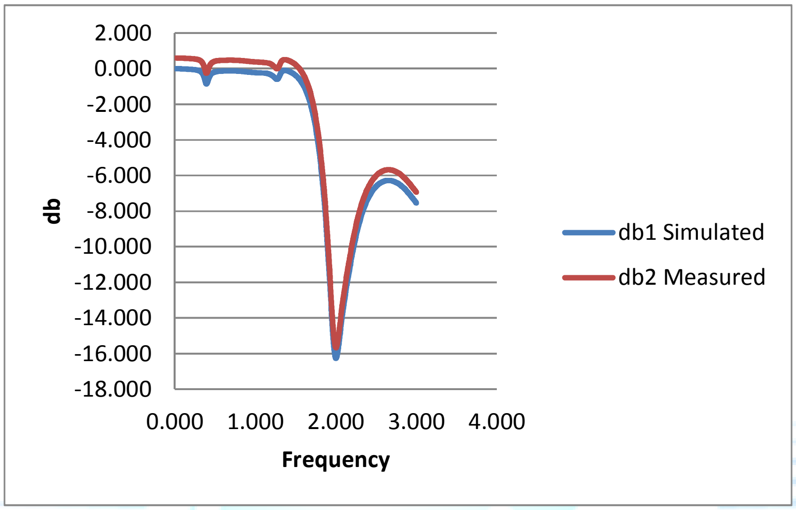


Figure14. Simulated and Measured Results

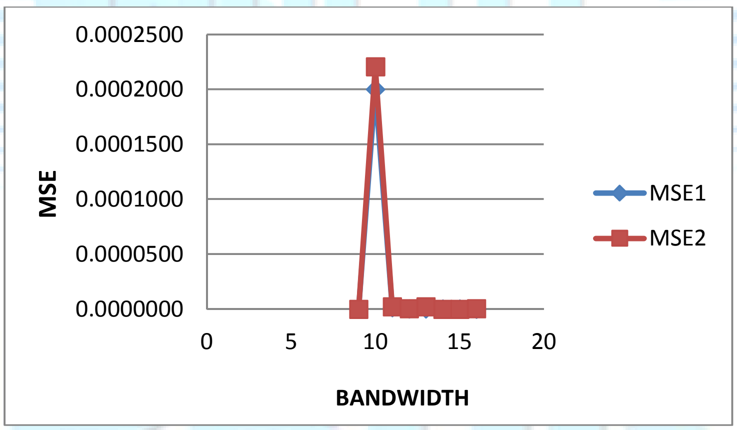


Figure15. Graph showing variation of mean square error with frequency (GHz) for levenberg-Marquardt Algorithm (mse1) and RBF ANN algorithm (mse2)

9. CONCLUSION

This paper presents a design of a microstrip patch antenna with line probe feed for use in digital communication system application.FR-4 Glass epoxy substrate with dielectric constant 4.4 is used which gives a wide bandwidth of 15.78%. In this work ANN is used as a tool to study the frequency band and bandwidth of Microstrip Antenna.The results obtain from IE3D and those obtain from ANN are in good agreement and shows almost 99.89% with MLPFFBP and 99.91% accuaracy with RBF. The training and test set has been designed with the data obtain from IE3D simulator.

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