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ANALYSIS OF DIRECTIVITY AND BANDWIDTH OF COAXIAL FEED SQUARE MICROSTRIP PATCH ANTENNA USING ARTIFICIAL NEURAL NETWORK

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ABSTRACT
In this paper the use of artificial neural network for the estimation of Directivity and Bandwidth of coaxial feed square shaped microstrip patch antenna is presented. Multilayer Perceptron Feedforward Back Propagation Network (MLPFFBP-ANN) with Levenberg-Marquardt (L-M) training algorithms has been used in order to implement the neural network model. The results obtained from the Artificial Neural Network Model are equated with the results obtained from the Computer Simulation Technology (CST) Studio Software, and the results show satisfactory agreement, and also it is noted that the neural network model is not trained very well using one hidden layer so more than one hidden layers are used for training the neural network model.

KEYWORDS: Artificial Neural Network (ANN), Multilayer Perceptron Feedforward Back Propagation (MLPFFBP), Levenberg-Marquardt (L-M) algorithm, Directivity (D), Bandwidth (BW), Computer Simulation Technology (CST) Studio Software.

INTRODUCTION
Microstrip antennas are low profile antennas because of its size, weight, cost and ease of installation. These types of antenna are very popularly used in space craft, aircraft, defence applications and many government organisation where narrow bandwidth requires[1]. So this needs very precise calculation of various design parameters of microstrip patch antennas. A part from patch measurements of microstrip antenna other parameters like Directivity and Bandwidth are also very important in deciding the utility of a microstrip antennas.

Artificial Neural Networks (ANNs) are appropriate models for estimation of microwave circuits and statistical models. Neuro models are computationally much more efficient than Electromagnetic (EM) models, once they are trained with true learning data obtained from a fine model by either Electromagnetic (EM) simulation or measurment, the neuro computational model can be used for effective and precise optimization and design with in the range of training. ANNs provide very fast and precise models for microwave modeling, simulation and optimization[2, 3][15]. A number of papers [2-9]indicates that how ANN models can be efficiently used for the estimation of various parameters of microstrip antennas, filters, resonators and couplers, analysis and synthesis of various microwave circuits.

Sufficient amount of work has been done using ANN in designing of rectangular and circular microstrip patch antennas[2][4][5][6], but some other important performance parameters are not analysed. In this paper an attempt has been made to exploit the capability of ANN to calculate the directivity and bandwidth of coaxial feed square shaped microstrip patch antenna using two hidden layers for the specified range of patch dimension (10mm-49mm), using Multilayer perceptron feedforward backpropagation network (MLPFFBP-ANN) with levenberg-Marquardt (L-M) training algorithm.

DATA DICTIONARY
For the designing of microstrip patch antennas different types of simulation software can be used. We have used here CST software for collecting the data for learning and Validation of different ANN models. Design of square shaped microstrip patch antenna have specified information about the dielectric constant of substrate (ε_r) resonant frequency (f) and height of the substrate (h) for the dominant mode. As the performance of ANN particularly depends on the training, validation and testing of data, so many times a rigorous training is given to the network

in order to improve its performance. So collection of data is the first step in the designing process. The data collected should be in sufficient amount so that the ANN is properly validated and tested. Here we have collected 79 different values from the CST Software and used them for training, validating and testing of ANN model.

DESIGN AND DATA GENERATION

The coaxial feed square shaped microstrip patch antenna is made up of the sides of ‘s’ mm above the ground plane with substrate thickness ‘h’ mm having dielectric constant "ε_r"

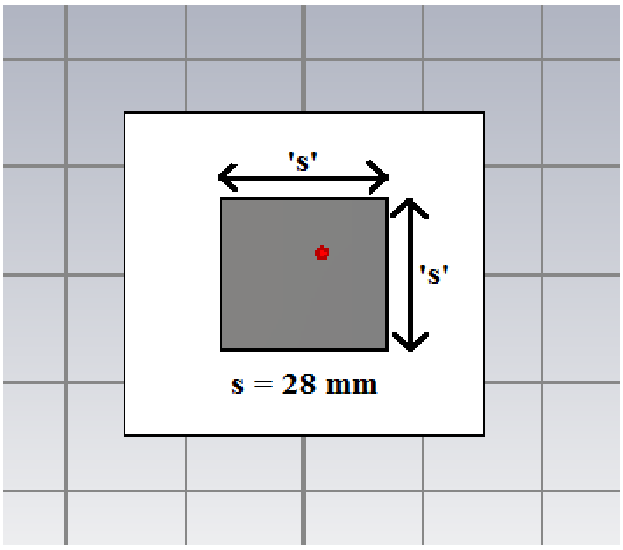

Figure 1: Coaxial feed Square Shaped Microstrip Patch Antenna

There are various substrate that can be used for the design of microstrip antennas and their dielectric constants are usually in the range of $2.2 < \varepsilon_r < 12$[1].

The Software here is used to model and simulate the proposed square shaped microstrip patch antenna is Computer Simulation Technology Studio Suit Software [11]

As an example (Fig.1) we consider a coaxial feed microstrip patch antenna of side length s = 28 mm is simulated using CST Microwave Studio Software which is resonate at frequency 2.45 GHz. We used FR4 (Lossy) substrate with dieclectric constant (ε_r) = 4.3, substrate thickness (h) = 1.6 mm above the ground plane. The material is used for ground plane and square patch is Perfect Electric Conductor (PEC). Height of the ground plane and square patch is 0.038 mm and loss tangent $\delta = 0.025$.

Figure 1 shows the geometry of coaxial feed square shaped microstrip patch antenna. By varying the side of this geometry the training data for range (10mm-49mm) and test data for validate artificial neural network models has been generated.
Figure 2 shows the graph between return loss (S_{11}) verses frequency (f) for the above example antenna.

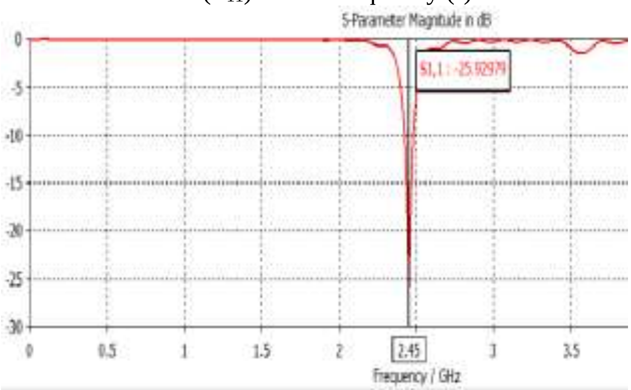

Figure 2: The return loss (S_{11}) in dB vs. resonance frequency of the microstrip patch antenna.

ANN MODEL FOR ANALYSIS OF PERFORMANCE PARAMETER OF MICROSTRIP PATCH ANTENNA

The artificial neural network model[10][12][13] has been developed for coaxial feed square shaped microstrip patch antenna as shown in Figure 3. Multilayer perceptron feedforward back propagation artificial neural network (MLPFFBP-ANN) has been used to analyse the Directivity (D) and Bandwidth (BW) of square shaped patch antenna for the given value of patch 's' (mm), resonant frequency (f), substrate dielectric constant (ε_r) and height of the substrate (h) without doing complex calculations using any formulas.

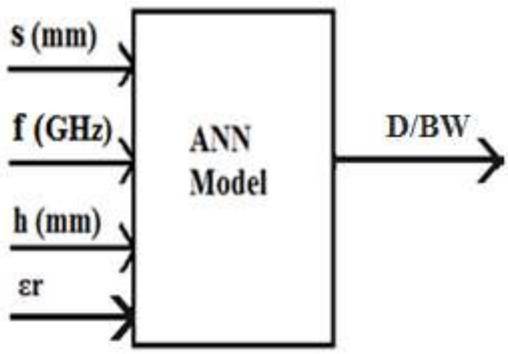

Figure 3: Analysis Model of ANN[13]

NETWORK ARCHITECTURE FOR ANALYSIS OF VARIOUS PERFORMANCE PARAMETERS OF MICROSTRIP PATCH ANTENNA

Multilayer Perceptron networks are feed forward network that just happened to be trained with back propagation algorithms to achieve the required higher degree of accuracy. MLPFFBP neural network are supervised networks, they also required desired response to be trained. With one or two hidden layers this type of network can appoximately virtually any input output map. The weights of the network are generally computed by training the network using back propagation algorithm[12][13][14].

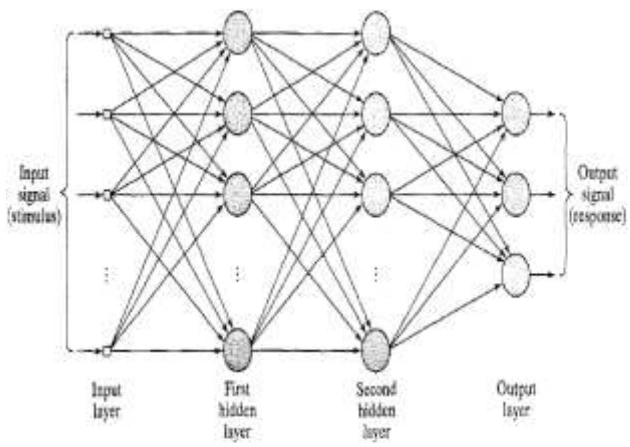

Figure 4: 4 Layer feedforward artificial neural network[12]

Among the various available algorithms, Levenberg-Marquardt algorithm (LMA), 'trainlm' training function has been used with Multi Layer Perceptron Feed Forward Back Propagation Neural Network. The training function is preferred in this architecture is 'tansig' and 'purelin'.

In order to estimate the performance of proposed MLPFFBP-ANN model for the desgin of square shaped patch antenna, simulation results are obtained using CST Microwave Studio Software and generated 64 input output training patterns and 15 samples values to validate the model. The network has been trained for the specified range (10mm – 49mm).

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Firstly the ANN model has been trained using one hidden layers but the model was not validate for testing pattern values so we trained the model using two hidden layer.

A. DIRECTIVITY

Directivity (D) defines how 'directional' antennas radiation pattern is. Directivity (D) measures the power density in a given direction of an antenna, versus the power density radiated by an ideal isotropic radiator (which emits uniformly in all directions) radiating the same total power[1].

Figure 5 shows the graph between directivity (D) versus resonant frequency (f) of microstrip patch antenna. From figure it has been clearly shows that Directivity is 6.5308 dB at resonant frequency 2.45 GHz.

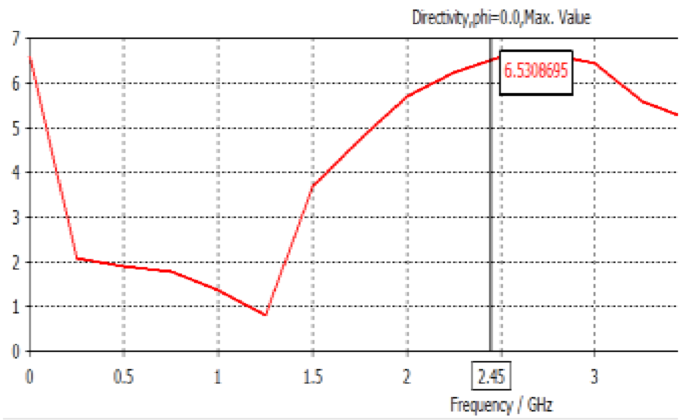

Figure 5: The directivity (D) in dB vs. resonant frequency of microstrip patch antenna.

In the present work the neural network model is developed for analysis of directivity of square shaped patch antenna, two hidden layers have been used here to trained the model. There are 4 neurons in the first hidden layer, 30 neurons in the second hidden layer and 3 output neurons. The model is trained in 8 epochs and training time was 1 sec. to achieve least mean square error. The transfer function used to trained the model is 'tansig' and 'purelin'.

In table 1 Directivity (D) obtained using CST Studio Software and MLPFFBP-ANN using Levenberg-Marquardt algorithm for different test patterns are compared and mean square error has been calculated.

Table 1: Comparision of results obtained using CST Software and MLPFFBP-ANN using Levenberg-Marquardt Algorithm for the analysis of Directivity of Square Shaped Microstrip Patch Antenna.

Side of Square Patch (mm)	f (GHz) CST	Directivity (dB) CST	Directivity (dB) MLPFFB ANN	Mean Square Error (MSE)
15.5	4.32	6.9265	6.9572	0.00094249
16.5	4.08	6.8645	6.9175	0.002809
17.5	3.85	6.9053	6.8936	0.00013689
18.5	3.67	6.9800	6.8795	0.01010025
19.5	3.48	6.9569	6.8705	0.00746496
20.5	3.32	6.9063	6.863	0.00187489
21.5	3.18	6.9284	6.8536	0.00559504
22.5	3.03	6.8757	6.8374	0.00146689
23.5	2.90	6.7913	6.8068	0.00024025
24.5	2.79	6.7270	6.7575	0.00093025
25.5	2.68	6.6908	6.7017	0.00011881
26.5	2.59	6.5973	6.6383	0.001681

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27.5	2.49	6.5910	6.5586	0.00104976
28.5	2.41	6.4984	6.5049	0.00004225
29.5	2.33	6.4164	6.4552	0.00150544

Figure 6 shows the best validation performance of the developed neural model for the directivity of square shaped microstrip patch antenna using L-M training Algorithm. Model is trained in 8 epochs and the training time was 1 sec.

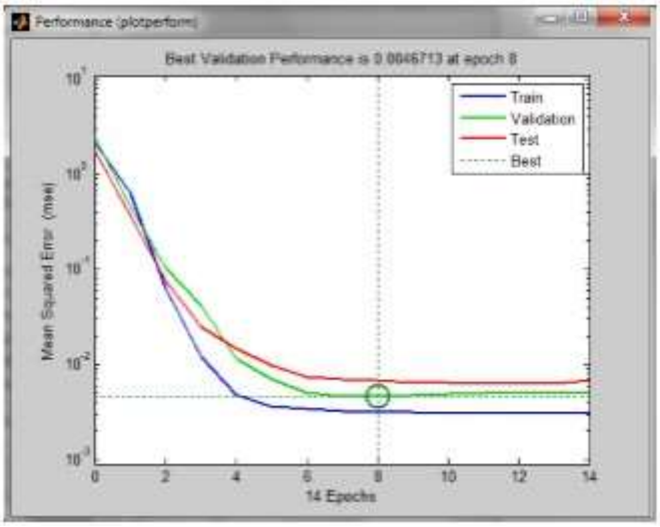

Figure 6: Number of epochs to achieve minimum mean square error level in case of MLPFFBP-ANN using L-M as training algorithm for directivity.

B. BANDWIDTH

Bandwidth (BW) of an antenna is defined that the range of frequenices over which antenna can radiate or receive the information in form of electromagnetics waves[1]. In the present work the neural network model is trained for analysis of Bandwidth of square shaped patch antenna by using two hidden layer. In first hidden layer there are 4 neurons, 30 neurons in second hidden layer and 3 output neurons.

Bandwidth is obtained by measure the difference between lower cut-off frequency and higher cut-off frequency. As an example in figure 7 curve marker1 represents the lower cut-off frequency (f_l) and curve marker2 represents the higher cut-off frequency (f_h) so, by subtracting f_h from $f_{l,}$ bandwidth at resonant frequency (f=2.45 GHz) is obtained i.e. 0.579GHz.

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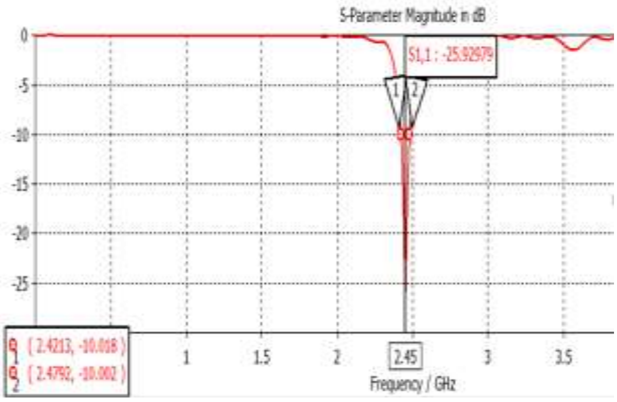

Figure 7: Curve marker1 and curve marker2 shows the lower cut-off frequency and higher cut-off frequency

The model is trained in 6 epochs and training time was 1 sec. The transfer functions we preferred to trained the model is 'tansig' and 'purelin'.

In table 2 Bandwidth (BW) obtained using CST Software and MLPFFBP-ANN model with Levenberg-Marquardt (L-M) algorithm are compare and mean square error has been calculated.

Table 2: Comparision of results obtained using CST Software and Multilayer Perceptron feed forward back propagation Network with L-M training algorithm for the analysis of Bandwidth of square shaped microstrip patch antenna.

Side of Square Patch (mm)	f (GHz) CST	Bandwidth (GHz) CST	Bandwidth (GHz) ANN	Mean Square Error (MSE)
15.5	4.32	0.1650	0.1569	0.00006561
16.5	4.08	0.1428	0.1411	0.00000289
17.5	3.85	0.1220	0.1293	0.00005329
18.5	3.67	0.1128	0.1193	0.00004225
19.5	3.48	0.1097	0.1091	0.00000036
20.5	3.32	0.0893	0.0973	0.000064
21.5	3.18	0.0898	0.0835	0.00003969
22.5	3.03	0.0439	0.0697	0.00066564
23.5	2.90	0.0575	0.0606	0.00000961
24.5	2.79	0.0652	0.0617	0.00001225
25.5	2.68	0.0676	0.0658	0.00000324
26.5	2.59	0.0651	0.0624	0.00000729
27.5	2.49	0.0636	0.0588	0.00002304
28.5	2.41	0.0602	0.0557	0.00002025
29.5	2.33	0.0560	0.0563	0.00000009

Figure 8 shows the best valid performance of developed neural model for the bandwidth of square shaped patch antenna using Levenberg-Marquardt as a training algorithm. Model is trained in 6 epochs and the training time was 1 sec.

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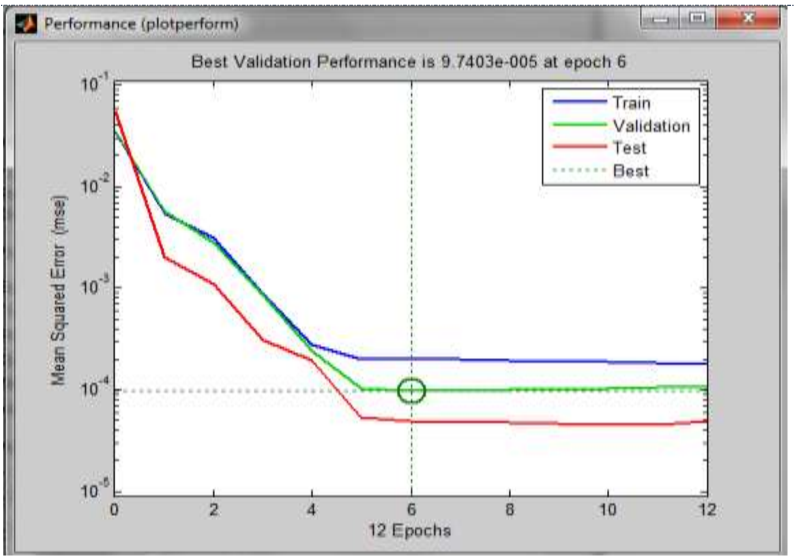

Figure 8: Number of epochs to achieve minimum mean square error level in case of MLPFFBP-ANN using L-M as training algorithm for bandwidth.

RESULTS

From table 1 and 2 it has been clearly see that Levenberg-Marquardt Algorithm is the best algorithm and also it is observed that most suitable transfer function is 'tansig' and 'purelin' for achieving the low value of Mean Square Error. It has been observed that in the analysis of directivity and bandwidth of coaxial feed square shaped microstrip patch antenna, Mean Square Error (MSE) level has been reduced to a low value using MLPFFBP Network. Achievment of such a low value of MSE indicates that the trained ANN Models is an accurate Models for the analysis of directivity and bandwidth of coaxial feed square shaped microstrip patch antenna.

CONCLUSION

In this paper, Multilayer Perceptron feedforward neural network model has been developed for the analysis of directivity and bandwidth of coaxial feed square shaped microstrip patch antenna. The result obtained using our trained MLPFFB-ANN model are closer to the experimental results generated by simulating a large number of square shaped microstrip patch antennas using CST Studio Software. The paper concludes that results obtained using present techniques are valid and quite satisfactory and followed the experimental results with minimum number of epochs and gives least mean square error.

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