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Comparative Analysis of Different Artificial Neural Networks for Circular Microstrip Antenna Design

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Abstract - *In this paper a detailed analysis comparing the various Neural Networks that are applicable in the designing of Circular Microstrip Antenna using Artificial Neural Networks has been proposed. The Artificial neural network is used in predicting the radius of the Circular Microstrip Antenna as a function of the resonant frequency. Here three different kinds of Artificial Neural Networks have been used namely Feed Forward and Backward Propagation Network, Layer Recurrent network and Non-linear Autoregressive Exogenous network in order to provide a comparative overview. LMA algorithm is used in the designing of neural network. Simulated values for training and testing the ANN were obtained by analyzing the design of antenna in CST software. The results for the designing of Circular Microstrip Antenna obtained from the Artificial Neural Networks are compared with the results obtained from the simulating software, (here CST) and both the results show good agreement. This paper is an attempt to show that how ANNs are faster, more accurate and highly applicable than the EM simulators. The results from the neural networks show good agreement with simulated results, though among the three networks Non-linear Autoregressive Exogenous network has outperformed with least mean square error.*

Key Words: **Artificial Neural Networks (ANN), Feed Forward Back Propagation (FFBP), Levenberg-Marquardt Algorithm (LMA), Non-linear Autoregressive Exogenous (NARX), Computer Simulation Technology (CST).**

1. INTRODUCTION

This is the era of wireless technology in which every system is now converted in a form as compact as possible. Since wireless technology is leading the innovation industry hence the need of antenna can't be denied, which has led the path of innovation in designing efficient, wideband, low cost and small volume antennas which can readily be incorporated into a large number of systems. RF and microwave frequencies are the one leading the communication industry and communication has now become the backbone of human civilization. In modern communication systems like cellular phones, personal computer cards, for wireless local area networks microstrip antennas are preferred as compared to other radiators [1]. The major antenna parameters are resonant frequency, patch dimensions, directivity, gain, radiation efficiency and bandwidth. These parameters play an important role in deciding the utility of the microstrip patch antenna. Here in this paper resonant frequency and patch dimensions are the main topics of discussion.

Microstrip antennas are called patch antennas because of the radiating element or patch photo etched on the dielectric substrate. This patch can be of any shape like square, rectangular, circular, elliptical, triangular, and any other. Because of their narrow bandwidths and effective operation in the vicinity of resonant frequency, the choice of the patch dimensions giving the specified resonant frequency is very important [2]. Here in this paper circular antenna design is discussed.

Artificial Neural Networks (ANNs) are a family of models inspired by biological neural networks (the central nervous systems of animals, in particular the brain) and are used to estimate or approximate functions that can depend on a large number of inputs and are generally unknown. ANNs are generally presented as systems of interconnected "neurons" which exchange messages between each other. The connections have numeric weights that can be tuned based on experience, making neural nets adaptive to inputs and capable of learning. It comprises of three layers namely input, hidden and output layer. These layers are connected through weights which adapt themselves according to inputs. This feature of ANNs make them more reliable and capable as compared to other simulation softwares as it doesn't work on ON and OFF basis but learns from given inputs and targets and later on when given new inputs it gives results with its own logic which makes it think in a manner similar to biological brain.

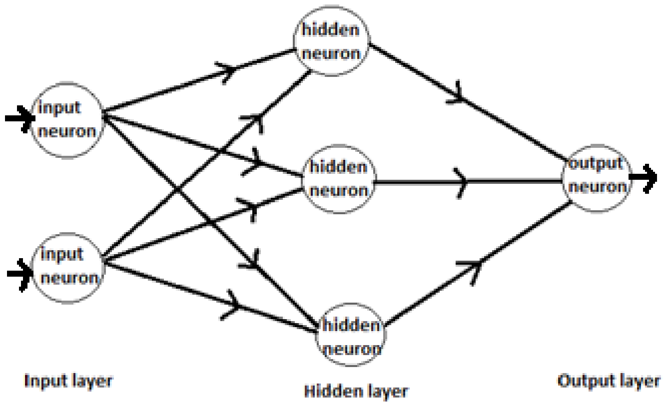

Figure 1 Basic Model of ANN

A number of papers indicate how ANNs can be used efficiently in analyzing and synthesizing various microwave circuits. This paper is also an attempt to showcase that ANNs are computationally much more efficient than EM simulators once they are trained with reliable learning data obtained from a fine model by EM simulation. The ANNs can be used for efficient and accurate optimization and design within the range of training. ANN provides fast and accurate models for microwave modeling, simulation and optimization. With their adaptive behavior ANNs become a preferable option in case of designing and optimizing the patch antennas.

2. DATA DICTIONARY

For the designing of microstrip antennas different kinds of simulation software can be used but here we have used CST software [3] for collecting data for the training and validation of proposed ANN model. Design of circular microstrip antenna includes the specified information of dielectric constant of substrate ($\mathcal{E}_r$), the resonant frequency (fr) and height of substrate (h) for dominating mode. As the performance of ANN majorly depends on the training, validation and testing, the network is rigorously trained in order to improve its performance. Hence, the collection of data is the first step in the designing process. The data collected should be in ample amount so that the ANN is properly trained, validated and tested. The reason behind using large amount of data is that many a times the ANN doesn't learn properly and it don't draw the logic properly as a result the outputs obtained will not be much accurate. The data dictionary is built by designing the circular antenna in the above mentioned software and collecting the outputs. Here we collected nearly 50 different values from the CST software and used them for ANN training, validating and testing.

3. ANTENNA DESIGN

A. Circular Patch Microstrip Antenna

For designing a circular patch microstrip antenna, the calculations are done as below [9]:

$$a = \frac{F}{\sqrt{1 + \left(\frac{2h}{\pi \mathcal{E} F}\right) [\ln\left(\frac{\pi F}{2h}\right) + 1.7726]}}$$

$$F = \frac{8.791 \times 10^9}{f_r \sqrt{\mathcal{E}}}$$

Where,

h=height of dielectric substrate

$\mathcal{E}_r$=dielectric constant

f_r=resonating frequency of antenna

Here in this paper we have kept the values of h and $\mathcal{E}_r$ constant and have varied the radius of the circular patch for collecting different values of data. The value of radius was varied from 1cm to 5cm with a difference of 0.1 in between two successive values resulting in 50 values which were used as data for training, validating and testing.

The circular antenna can be designed using different kinds of feeding techniques like microstrip line feed, center feed, coaxial probe feed etc. Here we are using center feed technique in the circular patch microstrip antenna as shown in the figure 2.

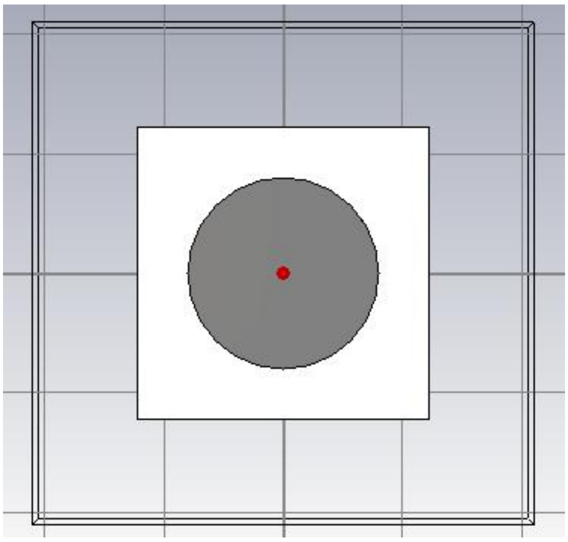

Figure 2 The Designed Antenna Geometry[8]

B. Artificial Neural Networks

Here the structures of the ANNs are described briefly.

The ANN designing procedure is broadly divided in 2 parts:

Forward part or synthesis:

The patch dimensions (here radius of circular patch, a) of the microstrip antenna is obtained as a function of input variables, which are height of the dielectric material (h), dielectric constants of the substrate material (ε_r), and the resonant frequency (f_r), using ANN techniques as shown in figure 3

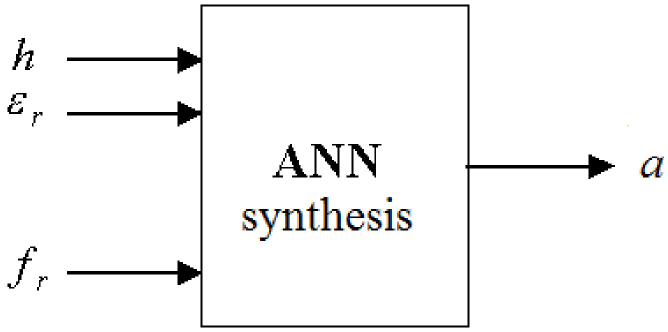

Figure 3 Synthesis

Reverse part or analysis:

In the analysis ANN, the resonant frequency of the antenna is obtained as a function of patch dimensions (here radius of circular patch, a), height of the dielectric substrate (h), and dielectric constants of the material (ε_r) as shown in figure 4.

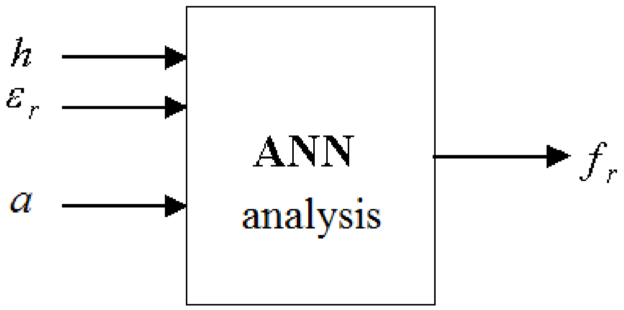

Figure 4 Analysis

Among the various available algorithms Levenberg-Marquardt training algorithm (LMA) has been used here. The number of neurons is kept 10 in all the networks.

Also to get more accurate and comparable results instead of using one kind of neural network, here three different neural networks have been used.

1. FFBP
2. Layer Recurrent
3. NARX

FFBP- A feed forward backpropagation is a feed forward network that just happened to be trained with a backpropagation training algorithm. In this network connections between the units don't form a cycle and the information moves in only one direction, forward. There are no cycles or loops in this network.

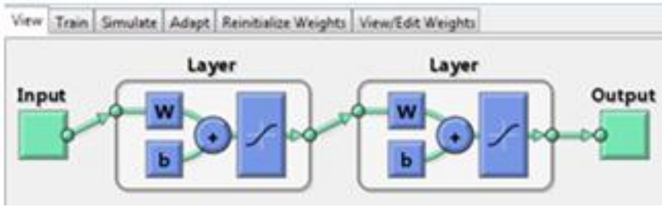

Figure 5 FFBP Network [10]

Layer Recurrent- A layer recurrent is a class of ANN where connections between units form a directed cycle. This creates an internal state of the network which allows it to exhibit dynamic temporal behavior.

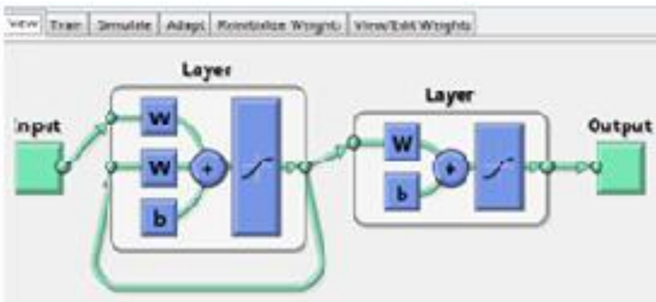

Figure 6 Layer Recurrent Network [10]

NARX- NARX is a nonlinear autoregressive model which has exogenous inputs. An exogenous change is one that comes from outside the model and is unexplained by the model. This means that the model relates the current value of data, where one would like to explain or predict to both:

- past values and
- current and past values of the exogenous data which effects the data of interest

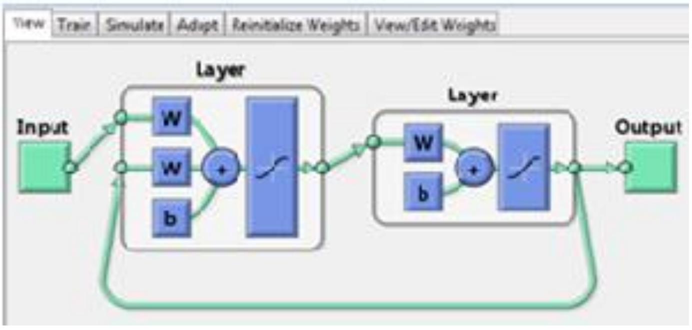

Figure 7 NARX Network [10]

4. TRAINING AND TESTING

Data is generated by varying the radius of circular microstrip antenna and then, it is analysed by three different ANN networks using nntool.

Following are three tables showing the comparison of CST software outputs and ANN outputs. The last column in every table shows the square error.

The square error is obtained by squaring the error calculated by using the relation-

$$Error = Simulated\ output - ANN\ output$$

In previous papers there have been ANN developed for determining the cut off frequency for a given circular patch antenna of a fixed radius, in this paper an attempt has been made to find out the radius for a given resonant frequency and the same has been compared with the results obtained from CST software by designing circular antenna of the obtained radius (from ANN) and obtaining the resonant frequency (from CST).

Table 1 Comparison of radii when calculated using CST software and FFBP ANN

Cutoff frequency in GHz	Radius of the circular patch antenna in cm in CST software	Radius of the circular patch antenna in cm calculated using ANN(FFBP)	Square error
4.2280	2.0	2.0002	0.00000004
3.3850	2.5	2.5004	0.00000016
2.9200	2.9	2.8982	0.00000324
2.7120	3.1	3.1132	0.00017424
2.5500	3.3	3.3054	0.00002916
2.2840	3.7	3.6989	0.00000121
2.1140	4.0	4.0022	0.00000484
1.9260	4.4	4.3926	0.00005476
1.8450	4.6	4.6015	0.00000225
1.6980	5.0	4.9421	0.00335241

The Table 1 shows the comparison of radius obtained using CST Software at different resonant frequencies and FFBP network for 10 different test patterns. The mean square error is also shown in the table.

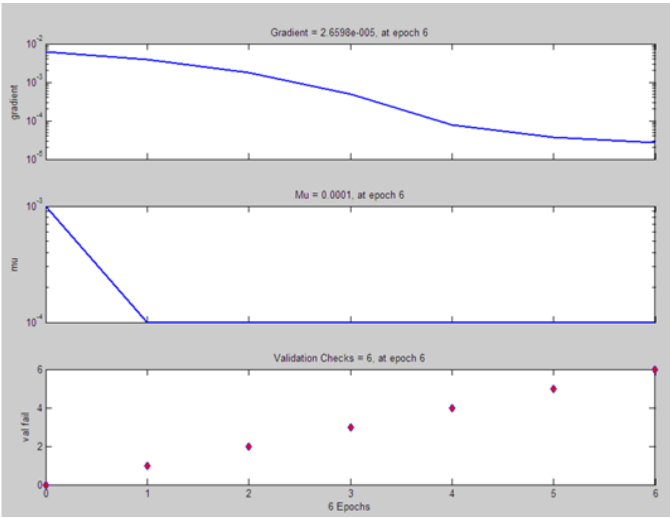

Figure 8 Training plot of FFBP network [10]

Figure 8 shows the training plot for FFBP-ANN with Levenberg – Marquardt training algorithm. The training plot consists of 3 different graphs showing the gradient and validation checks for different epochs.

Table 2 Comparison of radii when calculated using CST software and Layer Recurrent ANN

Cutoff frequency in GHz	Radius of the circular patch antenna in cm in CST software	Radius of the circular patch antenna in cm calculated using ANN(Layer Recurrent)	Square error
4.2280	2.0	2.0174	0.00030276

3.3850	2.5	2.5008	0.00000064
2.9200	2.9	2.8921	0.00006241
2.7120	3.1	3.1076	0.00005776
2.5500	3.3	3.3019	0.00000361
2.2840	3.7	3.6959	0.00001681
2.1140	4.0	4.0024	0.00000576
1.9260	4.4	4.3938	0.00003844
1.8450	4.6	4.5962	0.00001444
1.6980	5.0	4.9447	0.00305809

The Table 2 shows the comparison of radius obtained using CST Software at different resonant frequencies and Layer recurrent network for 10 different test patterns. The mean square error is also shown in the table.

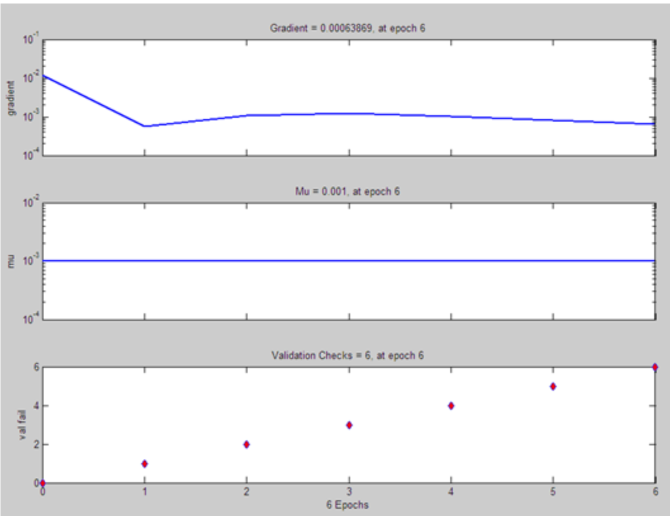

Figure 9 Training plot of Layer Recurrent network [10]

Figure 9 shows the training plot for Layer Recurrent network with Levenberg – Marquardt training algorithm. The training plot consists of 3 different graphs showing the gradient and validation checks for different epochs.

Table 3 Comparison of radii when calculated using CST software and NARX ANN

Cutoff frequency in GHz	Radius of the circular patch antenna in cm in CST software	Radius of the circular patch antenna in cm calculated using ANN(NARX)	Square error
4.2280	2.0	2.0188	0.00035344
3.3850	2.5	2.5037	0.00001369
2.9200	2.9	2.8963	0.00001369
2.7120	3.1	3.1066	0.00004356
2.5500	3.3	3.3062	0.00003844
2.2840	3.7	3.7046	0.00002116
2.1140	4.0	3.9968	0.00001024
1.9260	4.4	4.4021	0.00000441
1.8450	4.6	4.5938	0.00003844
1.6980	5.0	4.9810	0.000361

The Table 3 shows the comparison of radius obtained using CST Software at different resonant frequencies and NARX network for 10 different test patterns. The mean square error is also shown in the table.

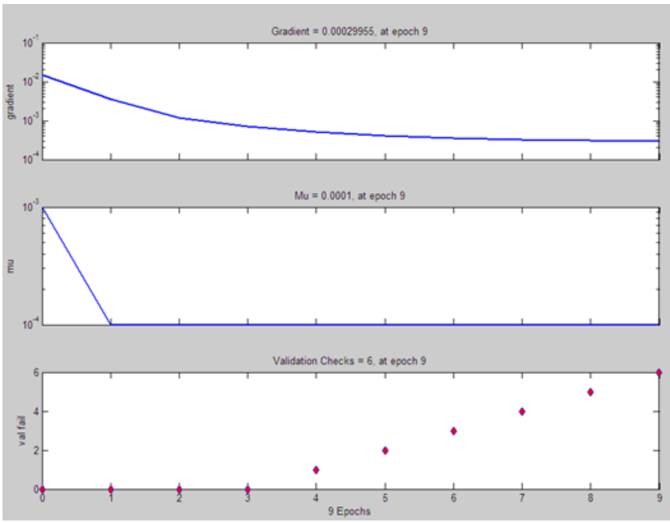

Figure 10 Training plot of NARX network [10]

Figure 10 shows the training plot for NARX netwrok with Levenberg – Marquardt training algorithm. The training plot consists of 3 different graphs showing the gradient and validation checks for different epochs.

5. RESULT AND ANALYSIS

The MSE is calculated by averaging the total sum of all the square errors of the respective network.

Table 4 Comparison of the MSE of all the three networks

Name of the ANN	FFBP	Layer Recurrent	NARX
MSE	0.000362231	0.000356072	0.000089807

The table 4 shows the comparison of the mean square error of the 3 artificial neural networks FFBP, Layer Recurrent and NARX respectively.

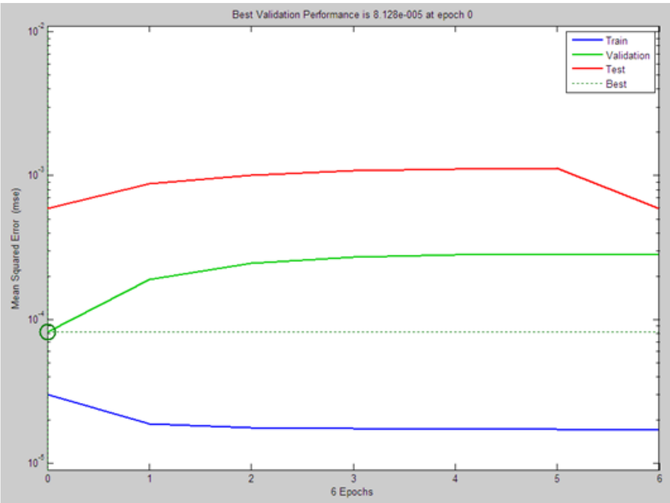

Figure 11 Performance plot of FFBP network [10]

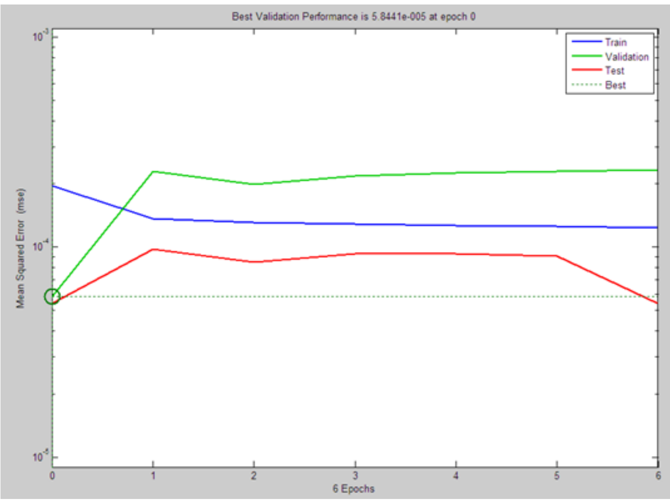

Figure 12 Performance plot of Layer Recurrent network[10]

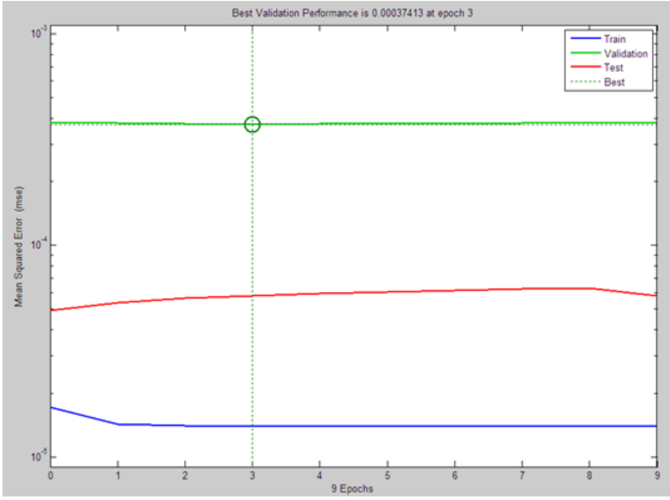

Figure 13 Performance plot of NARX network [10]

The training performance of radius in case of FFBP, layer recurrent and NARX network with Levenberg – Marquardt training algorithm and the transfer function tansig is shown in figures 11, 12 and 13 which shows the graph between mean square error and no. of epochs. The minimum MSE is achieved in 0, 0 and 3 epochs for FFBP-ANN, Layer Recurrent and NARX respectively.

6. CONCLUSIONS

An efficient design procedure for circular microstrip antenna based on ANN has been discussed here. In the analysis network, one can obtain geometrical parameters (radius) of antenna by using resonant frequency, height and dielectric constant of the substrate as inputs. In synthesis network, the results are determined by reversing the input-output data of analysis network. A neural network based CAD model can be developed for the design and analysis of a circular patch antenna for a given resonant frequency, which is robust both from the angle of time of computation and accuracy. The major advantage of ANN model is that, after proper training, a neural network completely bypasses the repeated use of complex iterative processes for the new design presented to it. This ANN model is suitable for Computer Aided Designing applications. Non-linear Autoregressive Exogenous (NARX) network which specializes in non-linear problems has outperformed among all the three networks with least MSE which signifies more accurate results.

From Table 3 and 4, it is concluded that in the analysis of radius and mean square error of NARX network with Levenberg-Marquaradt (LM) training algorithm and tansig as a transfer function is minimum. Achievement of such a low value of performance goal (MSE) indicates that trained

ANN model is an accurate model for analysing the radius of a circular patch antenna for a given resonant frequency.

REFERENCES

[1] Rakesh kumar maurya, Ajay kumar maurya & Rabindra Kumar Singh, "ARTIFICIAL NEURAL NETWORK MODEL FOR ANALYSIS OF ELLIPTICAL MICROSTRIP PATCH ANTENNA", International Journal of Research in Engineering & Technology (IMPACT: IJRET),ISSN(E): 2321-8843; ISSN(P): 2347-4599, Vol. 2, Issue 4, Apr 2014, 185-192

[2] "Artificial neural design of microstrip antennas" Turk J ElecEngin, VOL.14, NO.3 2006, c_ T¨UB˙ITAK

[3] Vandana Vikas Thakare, Pramod Singhal, "Artificial Intelligence in the estimation of patch dimensions of Rectangular Microstrip Antennas" Circuits and Systems, Oct. 2011, Vol. 2, pp.330-337.

[4] Thakare V. V., Singhal P. K., "Bandwidth Analysis by introducing slots in microstrip antenna design using ANN", Progress In Electromagnetic Research M., Vol. 9, 107 – 122, 2009.

[5] Thakare, V. V., Jadon, Shalendra Singh, Kumari, Ritesh, "Analysis of Circular Microstrip Patch Antenna Using Radial Basis Artificial Neural Network", IJECSE, ISSN-2277-1956

[6] Thakare, V. V., Singhal, P. K., "Neural Network based CAD model for the design of rectangular patch antennas", Journal of Engineering and Technology Research Vol.2 (7), pp.126-129, July 2010.

[7] Vandana Vikas Thakare, Pramod Singhal, "Artificial Intelligence in the estimation of patch dimensions of Rectangular Microstrip Antennas" Circuits and Systems, Oct. 2011, Vol. 2, pp.330-337.

[8] CST (Computer Simulation Technology) Microwave Studio Suit Software 2010.

[9] C.A. Balanis, Antenna Theory, John Wiley & Sons, Inc., 1997.

[10] Neural Network Tool, Matlab7.2 version 2009a