Artificial Neural Network Based analysis of Circular Multiband Antenna

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***Abstract*-Designing the effectual shape of microstrip patch antenna for UHF band and C band is meant in this paper. Artificial neural network is used for optimizing the resonating frequencies of circular microstrip patch antenna. Levengberg-Marquardt(LM) and Quasi-Newton BFG are used in this paper to achieve the different resonating frequencies. Development and implementation of ANN algorithm is finished in matlab. Which convert parameters containing dielectric constant, height of the substrate, radius of the circle to achieve resonating frequencies of antenna. The error and validity analysis of neural network results are execute in matlab. Good accord is their amoung the results available in literature and the results calculated through these algorithms.**

***Keywords*- ANN, LM, Quasi-Newton BFG, Matlab, HFSS.**

I. INTRODUCTION

In 1995, Huynh and Lee presents U-slot microstrip patch antenna [1]. Wideband applications are examined with U-slot antenna plus dual and triple band applications are also examined with it. WIFI, GPS, Military, Biomedical, Aerospace are some applications of wireless technology in which microstrip antenna plays an vital role [2]. A range of shapes like rectangular, triangular, circular, square, elliptical etc in which microstrip patch antenna can be developed [3][4]. Microstrip antenna plays an imperative task in wireless communication applications [5]. As an instant solution of loads of wireless antennas, microstrip antennas have drawn consideration of industries and researches due to their many striking features. Such advantages are easy fabrication, multiband operation, low cost, light weight, low profile nature and compatible with monolithic microwave integrated circuits. Demand of large distance communication is is pleased by Microstrip patch antenna [6]. Commercialization of microstrip antenna design require wide bandwidth and high gain. Microstrip patch antennas having key drawbacks such as narrow bandwidth [7] and low gain. Researchers and scientists have developed numerous methods to increase bandwidth. Microstrip feed line, coaxial probe feed, proximity coupled and aperture coupled feed are for providing power supply. Microstrip feed line is easy to match by controlling inset position and fabrication is also trouble-free. Coaxial probe's fabrication and matching is also simple and easy but complex to model. In the case of aperture coupled, feed is stuck between two substrates and separated with ground plane. For the lower substrate high dielectric material is used. Whereas the feed line is introduce between two substrate in case of proximity coupled feed. The proposed antenna with DGS operates at different frequency bands which are used for several applications such as weather radar system, satellite communication, GPS and 4G Long term equipment(LTE).

In this paper, ANN model is designed to estimating the different resonating frequencies of circular patch antenna. Using equation (1-3) radius of the circular patch is calculated. Dimensions and geometry of antenna is described in section II. HFSS software is used for the simulation of antenna, and gain is calculated for respective resonating frequencies. Different resonating frequencies are estimated for dimensions of antenna using ANN discussed in section III. After comparing both the results, close accord is their amoung ANN results and simulated results of HFSS as mentioned in section IV. Thus this ANN model can be used for calculating the resonating frequencies of circular patch antenna.

II. DESIGN SPECIFICATIONS

Parameters of microstrip patch antenna depends upon the dimensions of the patch and the properties of the material. Different types of substrates can be used for the design of patch antenna and range of their dielectric constant is usually as $2.2 \leq \varepsilon_r \leq 12$h. Bandwidth of the microstrip patch antenna can be increased by increasing the height of substrate [10], but it lies between the $0.003\lambda_o \leq h \leq 0.05\lambda_o$[1]. Surface waves are introduced when the height of substrate is increased further which leads to fringing effect, due to which patch dimensions are extended outwards. Now for circular patch effective radius a_e including fringing effect is given by the equation 1 :

$$a_e = a\{1 + \frac{2h}{\pi\varepsilon_r a}[\ln\left(\frac{\pi a}{2h}\right) + 1.7726]\}^{1/2} \quad (1)$$

Radius without fringing effect is given by equation below:

$$a = \frac{F}{\{1+\frac{2h}{\pi\varepsilon_r F}[\ln\left(\frac{\pi F}{2h}\right)+1.7726]\}^{1/2}} \quad (2)$$

where

$$F = \frac{8.791\times10^9}{f_r\sqrt{\varepsilon_r}} \quad (3)$$

Radius of the Circular patch is 33mm as shown n figure 1. Circular patch is given as shape by etching different slots from its center. Material of substrate FR4 epoxy ($\varepsilon_r = 4.4$) is used and 'a' is radius of circular patch. Proposed design requires triple frequency operation at 0.46GHz, 4.62GHz, and 6.73GHz. Both 0.46GHZ and 6.73GHz having gain more than 6dB and 4.62GHz have gain near to 4dB. Equations (1)-(3) are general formulae that listed above, used for designing circular disk patch antenna.

Fig. 1: Top View of Proposed Antenna

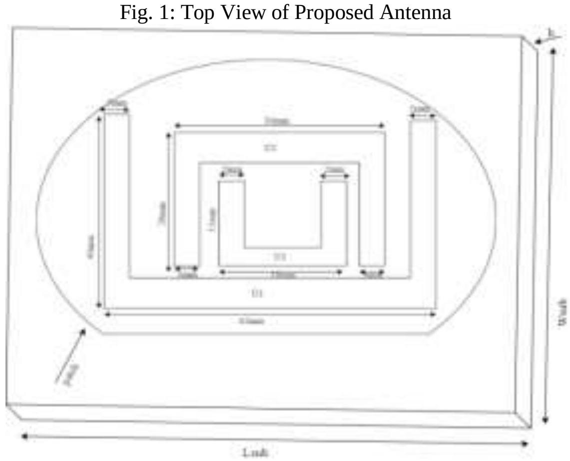
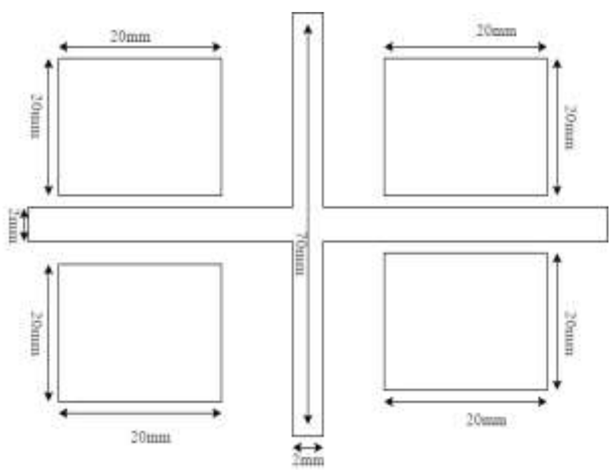


Fig. 2: Ground View of Proposed Antenna



The operating frequency obtained from these values is 1.24GHz. Coaxial probe feed is used. Final design parameters are given below in Table 1.

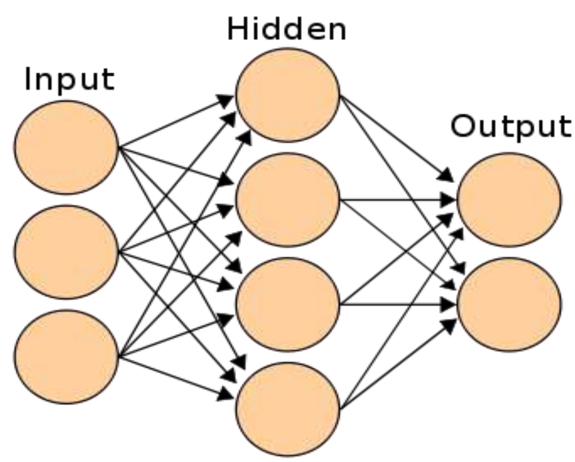
Table 1: Design Specifications

Design parameters	Final value
'a' Radius of the circular patch	33
'h' Thickness of substrate	1.58
Length of substrate L_{sub}	80
Width of substrate W_{sub}	80
'ε_r' Dielectric constant	4.4
Loss Tangent	0.02

III. ANN (ARTIFICIAL NEURAL NETWORK)

Since 1990's concept of Artificial neural network has been used in many applications. Alternate approaches are provided by Artificial Neural Network to conventional computing approaches. A feed forward back propagation is a simple and effective three layer model that are input layer, hidden layer and output layer. All the elements which form ANN are well organized in layers. Point at which communication amoung two neurons takes place is known as connections. Further, strength of the connection is defined by its weights. No explicit programming is needed in ANN to achieve complicated input output mapping and extract relationship amoung the input data and output data sets through a learning process, as the modification is takes place in synaptic weights to grab a desired objective[8].

Fig. 3. FFBP-ANN



MSE is given by

$$MSE = \frac{1}{m}\sum_{i=1}^{m}[y_i - F_{ANN}(x_i)]^2$$
(4)

m = number of training samples

y_i= target output

$F_{ANN}(x_i)$ = output of ANN

A. Data Generation

Collection of large amount of data is the most important thing for creating and network. Which results in more efficient and more accuracy in the network but cost may be the complexity. By varying the dimensions of proposed antenna around its initial value, collection of huge amount of data is done. Ansoft HFSS software is used for simulation to collect the data. Gain respective to the resonanting frequenicies are noted down. Data set of 99 samples is prepared.

A feed forward back propagation is a simple and effective three layer model that are input layer, hidden layer and output layer. Data set of antenna dimensions are given at input layer as shown in figure 4. Now artificial neural network is trained with data samples. 15% data is used for testing and 15% for validation. Remaining 70% data is used for training. Learning of the system is done by training data, best fitting of the system is done by test samples. Over fitting is is stoped by validation by neglecting the repetition of samples.

Fig. 4. Basic structure of artificial neural network for proposed antenna structure

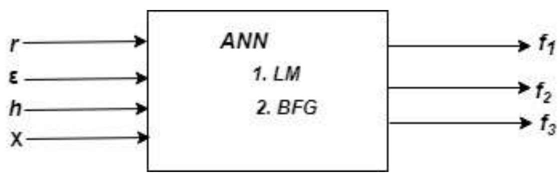


Table 1

Neural Network Parameters

S.No	Parameter	Value
1	Number of Inputs	4
2	Number of Outputs	3
3	Number of Hidden Neurons	10
4	Number of Epochs	1000
5	Training Algorithm	Levengberg-Marquardt(LM) and Quasi-Newton BFG

B. Artificial Neural Network Model

Artificial neural network model for microstrip patch antenna is revolution mechanism amoung the dimensions of antenna and its resonant frequency and their gain. Levengberg-Marquardt(LM) and Quasi-Newton BFG both are used to train the artificial neural network model. LM algorithm is simple and fast and having the ability to solve non-linear least square problems without solving the hessian matrix. As shown in figure 4, learning of neural network is done with input data and target data. This learning is called as supervised learning. Desired output is provided by the learned neural network with the help of target data. Radius of the circular patch, dielectric constant of substrate, height of the substrate and X i.e rectangular slot cut from circular patch are the inputs of the network. Estimated output of the network are f1, f2, f3 i.e different resonating frequencies. Parameters of neural network are shown in the above table. More number of hidden neurons results in high accuracy of the network.

IV. RESULTS AND DISSCUSSIONS

Ansoft HFSS software is used for the simulation of modified shaped patch antenna which falls under UHF band and C band. Proposed design requires triple frequency operation at 0.46GHz, 4.62GHz, and 6.73GHz. Both 0.46GHZ and 6.73GHz having gain more than 6dB and 4.62GHz have gain near to 4dB. Moreover return loss is also very less. By these defects in the ground as shown in above Figure 2, the proposed antenna gives various resonance which operates at different bandwidths 96.5MHz, 70MHz, 136MHz. As compared to the simple antenna with no defects, this antenna reduces size. So from the obtained results it is suitable to use for weather radar system, satellite communication and GPS. Results of the HFSS is compared with the results of neural network. Results are shown in the figures 5-8.

A. Performance Plot

Plot between the mean square error and number of iterations in indicated as performance plot. Best results for validation, testing and training is plotted in this. Mean square error is the average squared difference between the targets and outputs. Lower the value of MSE more is the effectiveness of the network. Performance plot is shown in figures 5 and 6 rbelow. For Levengberg-Marquardt(LM) best validation performance is 0.017582 at epoch 2, whereas for Quasi-Newton BFG best validation performance is 0.028907 at epoch 20. Number of times vectors are used to update the weights is known as epoch. Mean square error for Levengberg-Marquardt(LM) for training is 00.000 and for Quasi-Newton BFG it is 00.000.

Fig.5 Performance plot for Levengberg-Marquardt(LM)

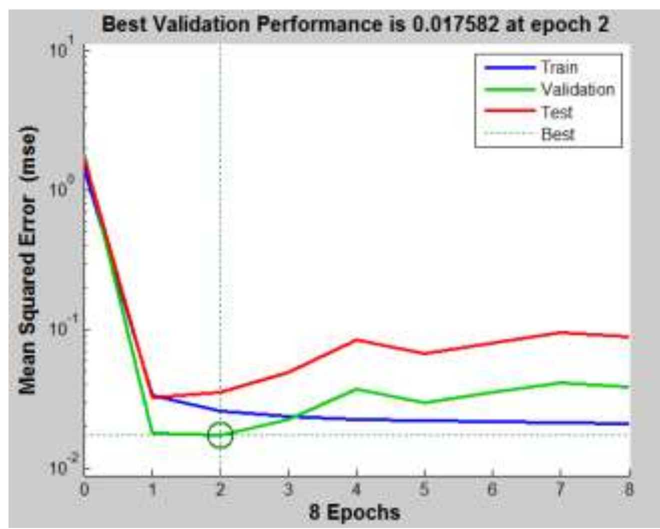
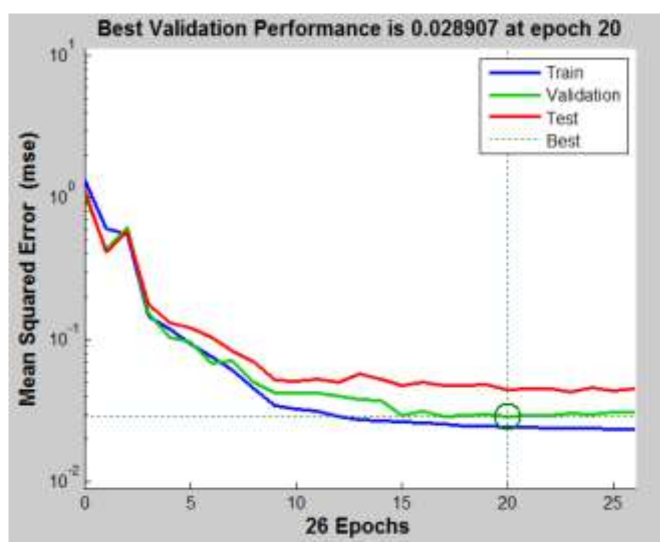


Fig. 6 Performance plot for Quasi-Newton BFG



B. Regression

Correlation amoung the outputs and targets is known as regression. If the value of regression is 1, it results in a close relationship amoung input and output. Regression obtained for both Levengberg-Marquardt(LM) and Quasi-Newton BFG are shown in figure 7,8 respectively. Which almost approaches to 1. Best relationship between output and target value is represented by dashed line, whereas solid line shows best fit for outputs and targets.

Table II

Results obtained from Performance and Regression Plot

Mean Square Error			
	Training	Validation	Testing
Levengberg-Marquardt(LM)	2.60e-2	1.7582e-2	3.58e-2
Quasi-Newton BFG	2.44e-2	2.8907e-2	4.48e-2

Regression			
	Training	Validation	Testing
Levengberg-Marquardt(LM)	0.998	0.99881	0.99724
Quasi-Newton BFG	0.99815	0.99787	0.99657

Fig. 7 Regression plot for Levengberg-Marquardt(LM)

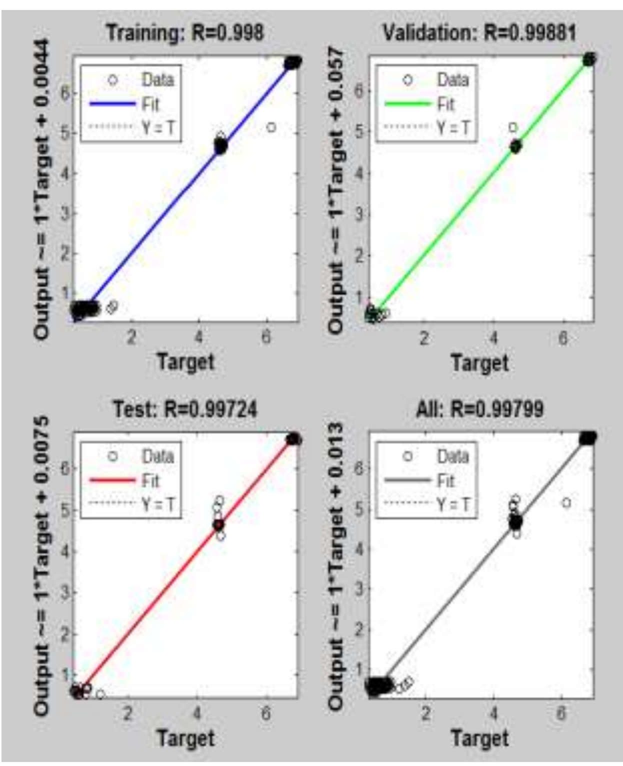
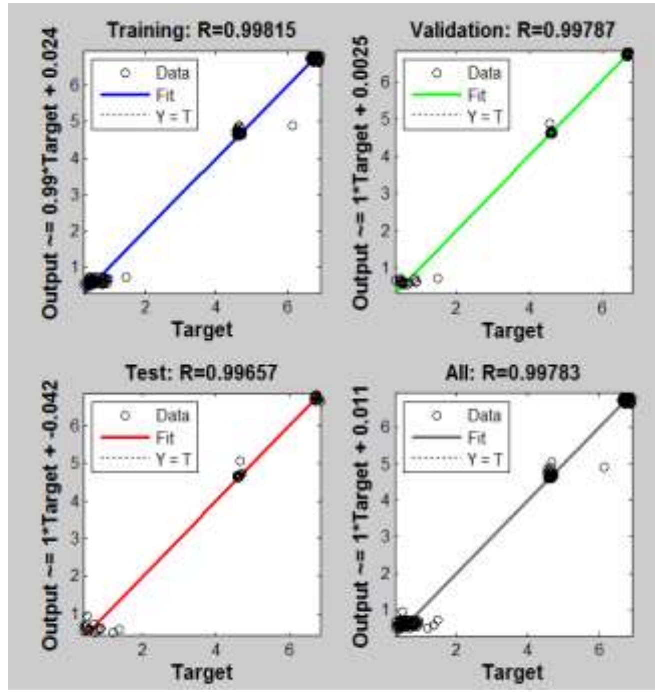


Fig. 8 Regression plot for Quasi-Newton BFG



C. Training State Plot

Plot for gradient, mu and validation check is plotted in training state. Minimum value for which training occurs is known as gradient. Where as convergence error is directly effected by Mu. Validation vectors are used to check the network further without effecting the training. For Levengberg-Marquardt(LM) value of gradient is 0.0024347 at epoch 8, Mu is 0.0001 and validation checks is equal to 6 at epoch 8. For Quasi-Newton BFG 0.010564 at epoch 26 is the value of gradient, value of validation checks is 6.

Table III Comparison of Artificial Neural Network and HFSS Results

HFSS			Levengberg-Marquardt(LM)			Quasi-Newton BFG		
0.77	4.61	6.67	0.7076	4.6238	6.7344	0.7228	4.6562	6.7485
0.64	4.56	6.72	0.7074	4.6307	6.7461	0.7367	4.6429	6.6671
0.68	4.64	6.84	0.7023	4.6489	6.7524	0.7337	4.6300	6.6401
0.42	4.72	6.81	0.4508	4.7457	6.8194	0.5231	4.7393	6.6921
0.50	4.72	6.85	0.4547	4.7257	6.8198	0.5254	4.7182	6.6932
0.55	4.71	6.85	0.4589	4.7054	6.8201	0.5271	4.6986	6.6943
0.47	4.70	6.79	0.4677	4.6639	6.8203	0.5286	4.6639	6.6969
0.66	4.65	6.77	0.6642	4.6348	6.7219	0.5658	4.6174	6.8075

Table II represents the value of all performance plots and all regression plots, this means that the results obtained meet the conditions of artificial neural network, further this indicates a good agreement between the results of ANN and HFSS results. Hence neural network can be designed for estimating the resonating frequency of the antenna structure.In table III comparison amoung the results of artificial neural network and HFSS is presented. Good argument is their in this comparison. Results of neural network is falls under the UHF and C band. Estimated results of ANN is equivalent to the simulated results of HFSS.

V. CONCLUSION

For modified shaped circular patch antenna of UHF and C band, artificial neural network is proposed. Also advantage of superior computational ability is offered by neural network due to high interconnectivity to solve complex problems, which is further used in this paper for obtaining resonating frequencies. Both the algorithms Levengberg-Marquardt(LM) and Quasi-Newton BFG shows equivalent results to Ansoft HFSS. But Levengberg-Marquardt(LM) is more faster and shows little more accurate results than Quasi-Newton BFG. Hence Artificial neural network can be used to estimating the resonant frequencies of circular microstrip patch antenna.

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