ANALYSIS OF MICROSTRIP PATCH ANTENNA WITH THE HELP OF ARTIFICIAL NEURAL NETWORK

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In this paper an artificial neural network (ANN) model has been developed for design of circular microstrip patch antenna. The major advantage of the proposed approach is that, after proper training, proposed neural model completely bypasses the repeated use of complex iterative process for design of such types of antennas, thus resulting in an extremely fast solution with high accuracy. In order to circumvent this problem, an alternative solution is achieved using artificial neural networks. The proposed technique used feed-forward back-propagation artificial neural network (FFBP-ANN) with one hidden layer & trained by Levenberg-Marquardt back propagation learning algorithm as an approximate model for design of circular microstrip patch antennas with reasonable accuracy.

INDEX TERMS: Micro-strip patch antenna, Artificial Neural Network, Circular Patch, IE3D.

INTRODUCTION

Microstrip antennas are widely used in satellite and ground based systems because of small size, less weight, low cost. The limitation of microstrip antennas are narrow bandwidth, low gain and poor efficiency [1]. These limitations can be overcome by using multilayered microstrip antennas. Multilayer Microstrip patches are also useful to provide protection to patch from heat, rain and physical damage [2-3], wide band width and high gain. In study [4] a comparative evaluation of different variants of back propagation training algorithm has done for the design of rectangular microstrip antenna. ANN can also be used to calculate different parameters of circular microstrip antenna such as resonant frequency [5], input impedance [6] etc. Sufficient amount of work indicates how ANN can be used efficiently to design circular and rectangular microstrip antennas [7-10]. Also ANN can be used to calculate different parameters of rectangular microstrip antenna such as radiation efficiency [11], resonating frequency [11], directivity [12], feed position [13], resonant frequencies of triangular and rectangular microstrip antennas [14], resonant resistance calculation of electrically thin and thick rectangular microstrip antennas [15] input impedance of rectangular microstrip antennas [16].

DATA GENERATION DICTIONARY

Data dictionary for the design of circular microstrip antenna is generated using IE3D software for the training and validation of proposed ANN model. Design of circular microstrip antenna includes the specified information of dielectric constant of substrate (ε), the resonant frequency (f_r) and height of substrate (h) for dominating mode. For example for the design of circular micostrip antenna for radius of patch a = 10.1 mm, height of substrate h = 1.59 mm and dielectric constant $\varepsilon_r = 2.3$ results of return losses versus frequency are shown in fig. 1. The return loss has a minimum value – 35.32 at frequency of 5.31868 GHz. So for resonant frequency 5.31868 GHz, height of substrate h = 1.59 mm and dielectric constant $\varepsilon_r = 2.3$, the radius of circular microstrip antenna is 'a' = 10.1 mm, So in this way a set of 20 input-output pair is generated for the training and another set of 54 input-output pair for the validation of ANN using IE3D software. Theoretically the radius of circular patch antenna as in equation (1) given by

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

where $$F = \frac{8.791 \times 10^9}{f_r\sqrt{\varepsilon}}$$

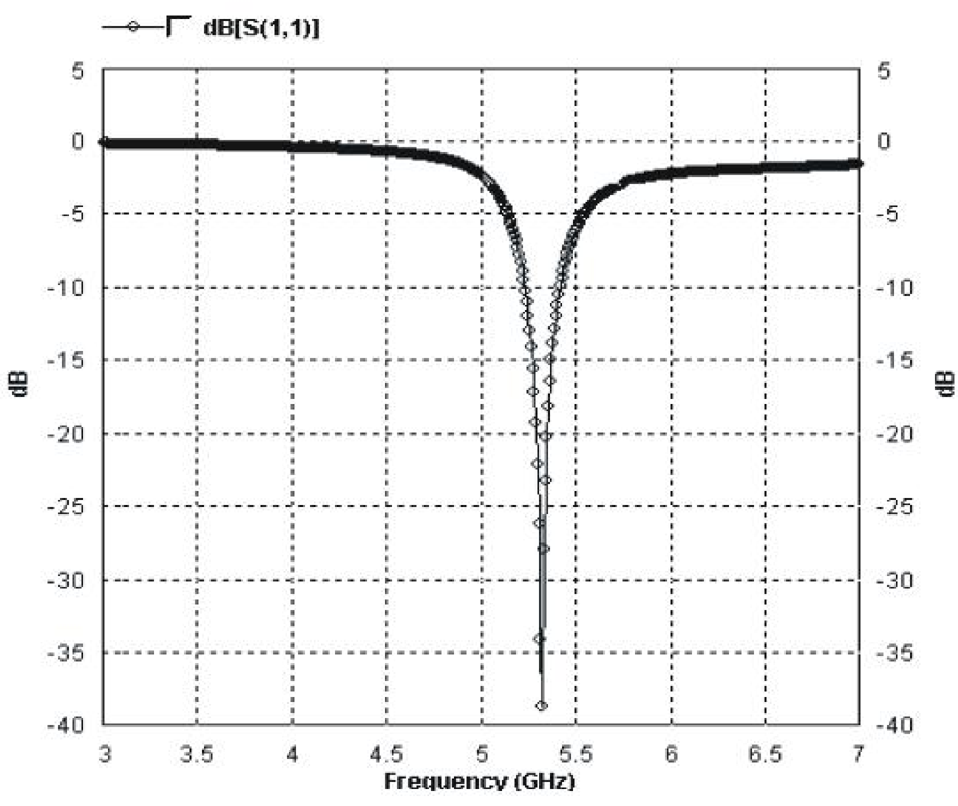

Fig.1. Return losses versus frequency calculated by IE3D software for circular microstrip patch antenna '*a*' =10.1mm, *h* = 1.59 mm and ε_r = 2.3.

DESIGN OF MICROSTRIP PATCH ANTENNA USING ANN

Artificial neural networks (ANNs) are one of the popular intelligent techniques in solving engineering problems. Neural processing presents a different way to store and manipulate knowledge. It uses a connectionist approach, where connections emphasize the learning capability and discovery of representations. Despite its capability to act as a black box and model systems using learning, domain knowledge is required to apply neural networks successfully in antenna design. In this paper, feed-forward backpropagation artificial neural network with one hidden layer & trained by Levenberg-Marquardt back propagation learning algorithm is used as an approximate model for design of circular microstrip patch as shown in Fig. 2. Neural network trained on data dictionary have been applied to calculate the radius of patch antenna, *i.e.* 'a' for given value of 'h', 'ε_r' and 'f_r' (GHz) as shown in Fig. 2. FFBP-ANN with proper biases, a sigmoid hidden layer and a linear output layer are capable of approximating any function with definite number of discontinuity and arbitrary accuracy. An algorithm is written by using MATLAB programming and MATLAB neural network tool box to synthesize a FFBP-ANN. An algorithm is implemented to minimize the final MSE of the ANN training phase. The MSE is minimized for 3-11-1 architecture if the ANN is trained with a predefined target and learning rate. Highly sophisticated separate MATLAB code of the implemented algorithm for the training, validation and production phases are developed. The MSE, *i.e.* performance index [17] is given by

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

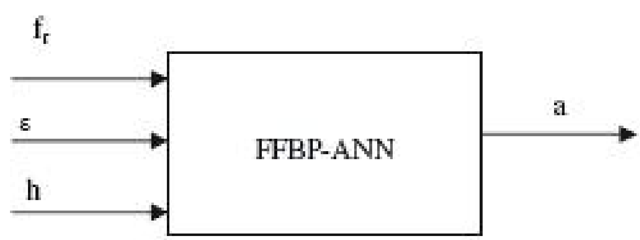

Fig.2. ANN model for design of circular antenna

During training, a set of input values corresponding to some selected points in data dictionary help to adjust the weight and biases of neurons to minimize the difference between the ANN output and actual output. However, the best ANN structure (number of layers, number of neurons in each layer, neurons activation transfer function, learning algorithm and training parameters) is not known in advance. Proposed ANN strcucture with three neurons in input layer, eleven neurons in hidden layer and one neuron in output layer (3-11-1) as shown in Fig. 3 is found best fit structure of ANN.

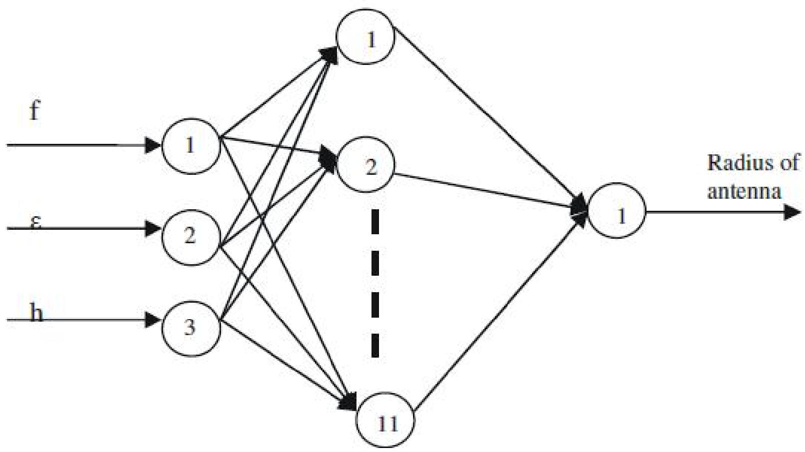

Fig. 3. Proposed FFBP-ANN based model for design circular microstrip antenna

RESULTS AND DISCUSSION

A. FFBP-ANN Training

In order to evaluate the performance of proposed FFBP-ANN based model for the design of circular microstrip antenna, simulated results are obtained using equation IE3D software. 20 input-output training patterns are used for training the proposed 3-11-1 ANN structure with learning parameters: performance goal Mean Square Error (MSE) = 9.99488e – 008/1e – 006, learning rate = 0.05 and maximum number of epochs = 2657. ML FFBN-ANN model has been observed that total no. of 2657 epochs are needed to reduce MSE level to a low value 9.99488e – 008. Achievement of such a low value of performance goal (MSE) indicates that trained ANN model is an accurate model for designing the microstrip patch antennas. The absolute error and error (% FS) at each value of radius of circular microstrip antenna are shown in Fig. 4 and Fig. 5. It is observed that maximum absolute value of absolute error between target data and estimated data of microstrip antenna is found to be only 9.4571e – 004 and that of error (%FS) is 0.0177. Achievement of such low value of these errors (absolute and % FS) further authenticates that the ANN model is accurate model for designing microstrip antenna.

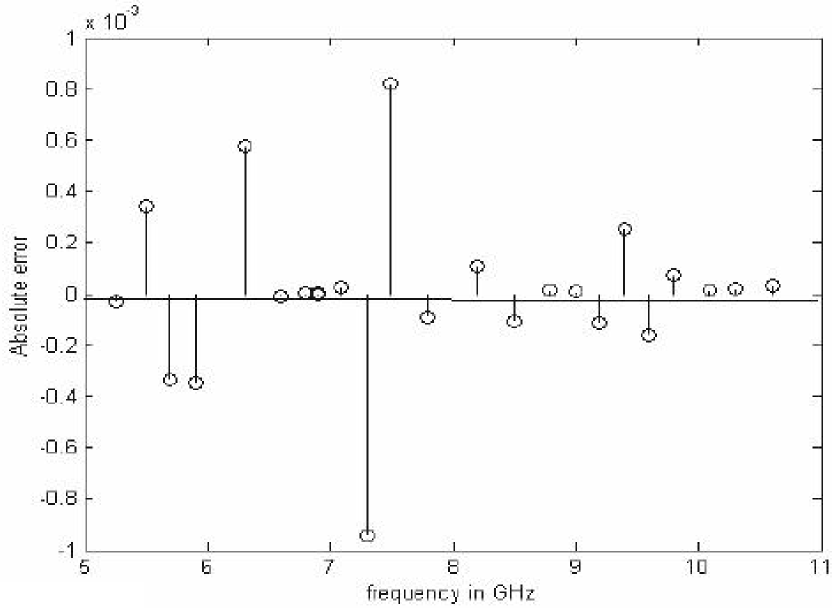

Fig. 4. Absolute Error between actual radius and estimated radius of micro strip patch as a result of training study

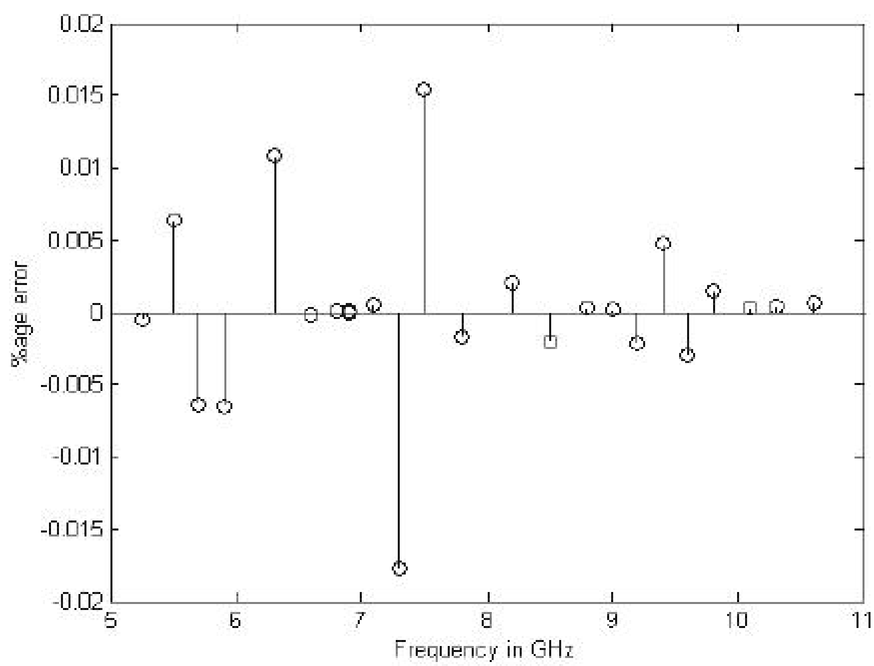

Fig. 5. % age error between actual radius and estimated radius of microstrip patch as a result of validation study.

B. Results of Validation Study

In order to validate the results for design of microstrip antenna using proposed 3-11-1 ANN structure, the 54 inputs–output patterns generated for testing proposed structure sing IE3D software. The absolute error and error (%FS) at each value radius and radius of circular microstrip antenna as result of validation study are shown in fig. 6 & fig. 7. It is observed that maximum absolute value of absolute error between actual radius and estimated radius of microstrip antenna as a result of validation study is found to be only 0.1198 and that of error (%FS) is 2.0898. The proposed radius and radius estimated by using FFBP-ANN based mode for microstrip antenna are very close to the simulated results as shown in Fig. 7 for given value of resonant frequency, dielectric constant and height of substrate.

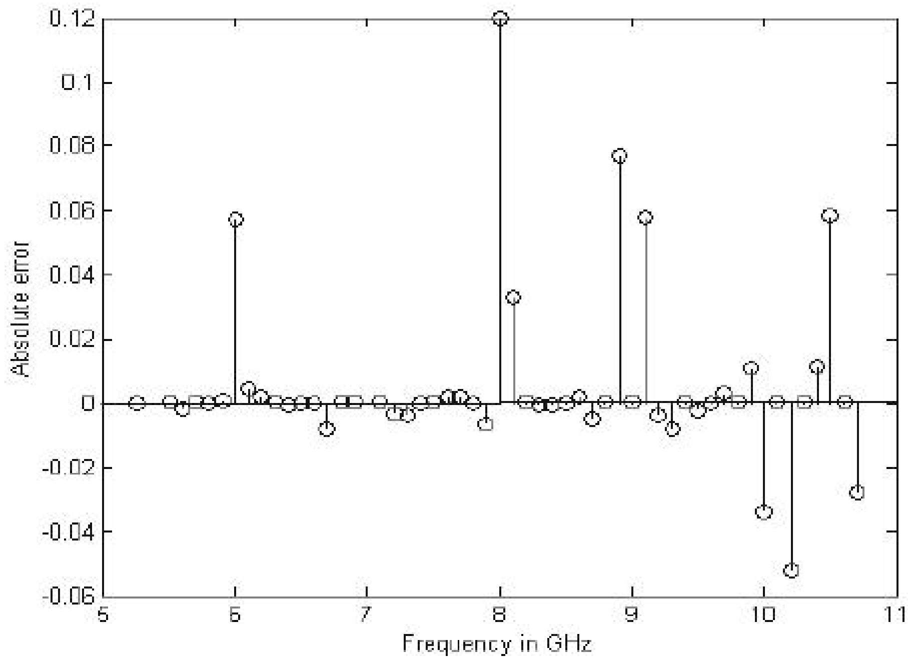

Fig. 6. Absolute Error between actual radius and estimated radius of micro strip patch as a result of validation study

Results of maximum absolute value of absolute error between actual radius and estimated radius by using FFBPANN with 3-11-1 structure trained with Levenberg-Marquard learning rule of microstrip antenna for validation data are shown in Table 1. Thus proposed FFBP-ANN based model with 3-11-1 ANN structure is a best accurate structure for designing of circular microstrip patch.

Table I. Comparison of error obtained for finding radius antenna using validation of data

Parameter	Maximum absolute error (Absolute value)	Maximum absolute error (%FS) (Absolute value)
Radius of antenna	0.1198	2.0898

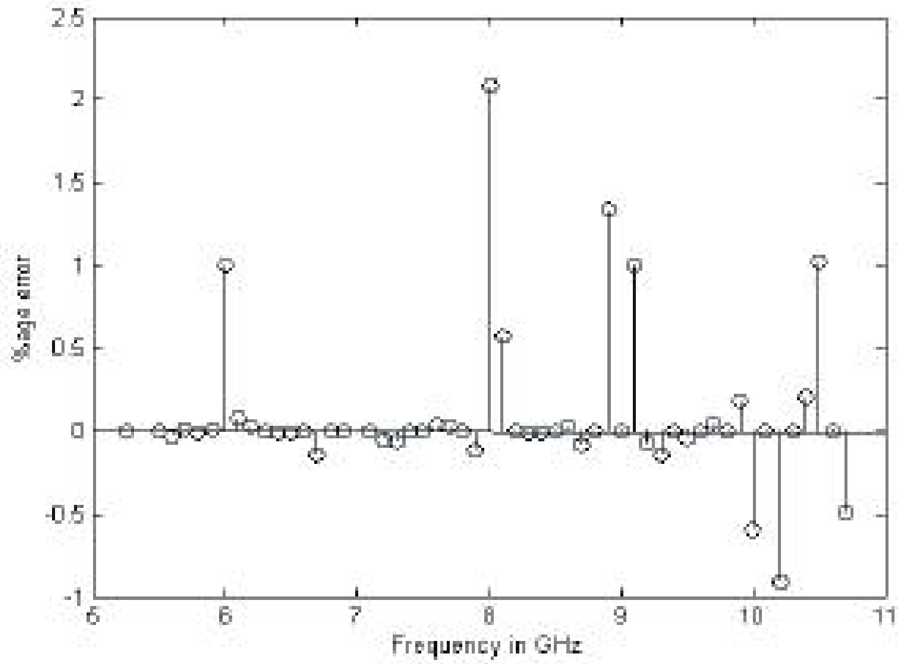

Fig. 7. % age error between actual radius and estimated radius of micro strip patch as a result of validation study

Conclusion

Neural model presented in this work gives almost accurate results for the design of a circular microstrip patch antenna. One can obtain the geometrical dimensions of microstrip patch antenna with high accuracy. The results of present study are quite promising. From the results, it is observed that the proposed modeling technique is very convenient to implement neural models for predicting the design parameters under specified conditions because an extremely small number of epochs are required to train the network. It has a wide possibility of applicability in the design of other types of antennas and parameter estimation also.

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