Application of Neural Network Model for designing Circular Monopole Antenna

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ABSTRACT
In this paper, Neural network model has been used to estimate the feedgap which is one of the design parameters of circular monopole antenna (CMA) required to make it operate in a particular frequency band. A Neural Network (NN) model is prepared using Feed Forward Back Propagation Algorithm which can be further used for designing a CMA operating between 2GHz and 12 GHz. The results obtained by the NN model are compared with the results of IE3D software which shows good agreement between the two. The model is accurate enough to measure the feedgap parameter of the monopole antenna which can be used to design the antenna. Thus this model eliminates the long time consuming process of finding the value of feedgap parameter using costly software packages.

General Terms
Circular Monopole Antenna, Feedgap ,Neural model.

Keywords
Back Propagation Algorithm, and Neural Network, Circular Monopole Antenna

1. INTRODUCTION
Neural network as the name sounds is interconnection of nerve cells. The artificial neural network technology is built up with an inspiration of functioning of human nervous system. Many of human intelligent behavior which is the direct functioning of human nervous system are implemented artificially in artificial neural network.

It is inspired by the way biological nervous systems works. It is composed of a large number of highly interconnected processing elements called neurons working in union to solve specific problems. Like human, artificial neural network also learn by example. It is configured for specific application, such as pattern recognition or data classification through learning process. Learning involves adjustments to the synaptic connection known as weights that exist between the neuron. In artificial neural network, the information processing elements are known as nodes. The first layer of nodes is known as input layer. Whereas the last layer is known as output layer. The layers in between which may or may not exist is known as hidden layer(s).The information is transmitted by means of connecting links. The links possess an associated weight, which is multiplied with the incoming signal for any typical neural network. The output is obtained by applying activations to the net. Artificial neural network is used to train computers to do various operations which need human intelligence. There are various categories of artificial neural networks used for training computers for specific category of work. Among the single layered networks there are Perceptron Model, Associative Network, Adaline Network Madaline Network, Hoffield Network whereas in multilayered network we have Back Propagation model, radial basis network, self organizing map, learning vector quantization etc. One of the most recent field where the neural network finds its application is the field of wireless communication. The demand for wireless communication services is increasing with the increasing need for transferring the information which requires the need of antenna capable to operate in wideband frequency ranges. It is now a challenge for the researchers to develop antennas which meet the requirements of simple structure, dual or multiband operation and wide bandwidth for use in the modern wireless communication.

Several antenna design like planer inverted F-antennas (PIFAs) [4], the aperture stacked patch antennas, the meander like chip antennas, and the planer monopole antennas are recent developments which are presently used in modern wireless communication system. Among these the most commonly used antenna is monopole antenna.

Conventional Monopole Antenna is used mostly in wireless communication systems due to its simplest structure, low cost, omni directional radiation pattern and ease for matching to 50Ω. Beside this it is unbalanced and so there is no need of balun, which may limit the bandwidth [3].

2. ANTENNA DESIGN
A circular plate simple monopole structure is shown in Fig.1. The circular plate monopole with a radius R and a 50Ω microstrip feed line are printed on the same side of the substrate. The substrate chosen is FR4 (Flame Resistant 4) of thickness of *H*.

Conducting ground plane is on the other side of the substrate whose length is L, feed line is L_f,, width of the ground plane is W and width of microstrip feed line is W_f, . The height of feed gap between the feed point and the ground plane is h. Thus the several antenna design parameters are L, W, L_f, W_f, R and h. In the proposed work set of data is collected by IE3D simulation where the positions of feedgap is varied for attaining different operating frequency, f_r, keeping other parameters constant.

The set of simulated data is then used to develop the ANN model whose design is elaborated in the next secion.

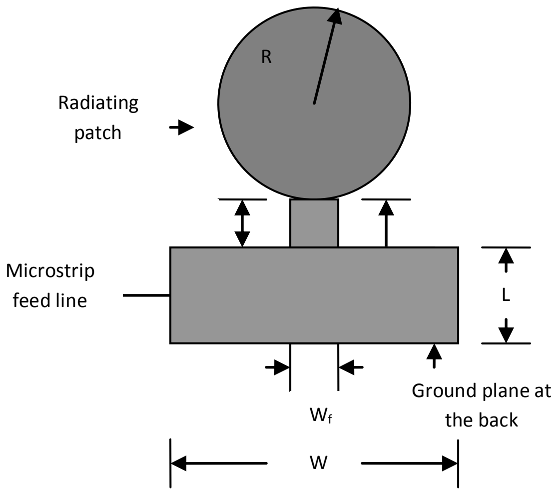


Fig. 2. A Feed Forward Network

3. DESIGN OF THE ANN MODEL:

The model that is used here to determine the characteristic of circular monopole antenna is Back Propagation model. This model has three layers i.e. one input layer, one hidden layer and the output layer. The model is trained with 400 sets of input/output data, which are obtained by interpolating 100 simulated data obtained from IE3D software, a commercial simulator based on MoM. The model is trained for different values of h to get a desired frequency, ranging from 2 GHz to 12 GHz, keeping all other designing parameters (L, L_f, R and W_f) constant at a fixed position. The change in h also changes the position of circular radiating element (X_r, Y_r).

The whole process consists of the following steps:

3.1 Developing training patterns

The input parameters i.e the resonant frequencies are used as inputs using the IE3D software which is based on moment of methods, and corresponding computed parameters i.e feedgap form the output targets. An input pattern and an output target give a training pattern together. All the training patterns form the training set.

3.2 Formation of the network

The net is formed using back propagation model. We create a neural network consisting of three layers and of an estimated number of neurons in the layers. The input layer consist of four hundred values of resonant frequencies with which the network is trained and the output layer will consist of four hundred computed values of h. The number of hidden layers and hidden neurons has to be estimated. Initial synaptic weights and biases are set randomly.

3.3 Training neural network model

The training of the back propagation involves four stages,
1. Initialization of weights
2. Feed forward
3. Back propagation of errors
4. Updation of the weights and biases.

During first stage which is the initialization of weights, some small random values are assigned. During the feed forward stage each input unit receives an input signal and transmits this signal to each of the hidden units. Each hidden unit then calculates the activation function to form the response of the net for the given input pattern.

During back propagation of errors, each output unit compares its computed activation with the expected values to determine the errors for that pattern with that unit. The error is propagated back to get the expected outputs. The weights are updated accordingly.

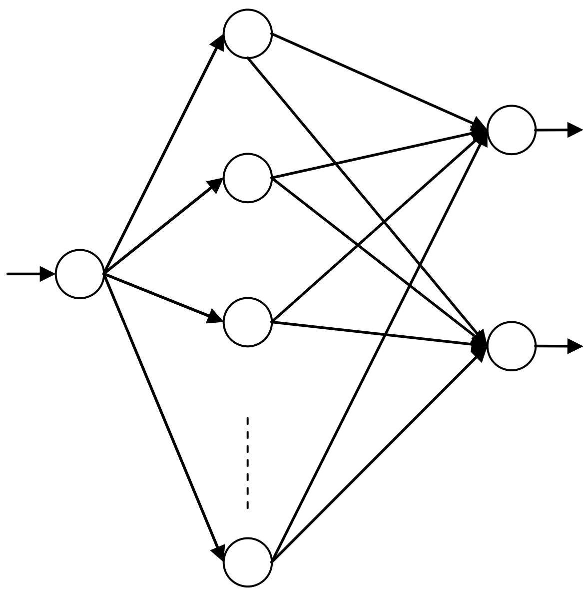
3.4 Testing the performance of the network

The net is provided with test input data that are not the values with which the net is trained. Then the actual expected output is calculated with help of numerical methods. Error is found out by finding the difference between calculated values and the actual output of the net. To reduce this error, the number of epochs needs to be increased.

3.5 Using the neural network model

The neural model is trained to give the required value of feedgap for a given resonant frequency.

The trained neural network provides a special approximation where the exact results of the numerical analysis, which are hidden in the training patterns, are used for neural computation and give us directly all the required designing parameter of an antenna for a desired frequency. That way, a computationally modest neural network model can replace a numerical analysis for parameters differing from training patterns.



Here, when the network is ready after training, it is used to determine the output parameter i.e feedgap of a monopole antenna for a desired resonant frequency between 2 GHz and 12 GHz. The output parameters achieved from the network can be used for designing the CMA for wideband application. The comparison of different CMAs designed with different parameters and performance of the prepared model is discussed below.

4. RESULTS AND DISCUSSIONS

The training of the network and testing the performance of the net is done in matlab platform. The training is done with four hundred set of data and the testing is done with five set of data. The output is again compared with the simulated values using IE3D software and the error percentage is calculated by finding out the difference between the simulated value and the output given by the network. Reviewing the literatures [5,6,9] it was found that the characteristic of antenna depends strongly on the value of feedgap which is also evident from Fig.3. shows that operating bandwidth changes significantly with varying feed gap, h, keeping all other parameters fixed.

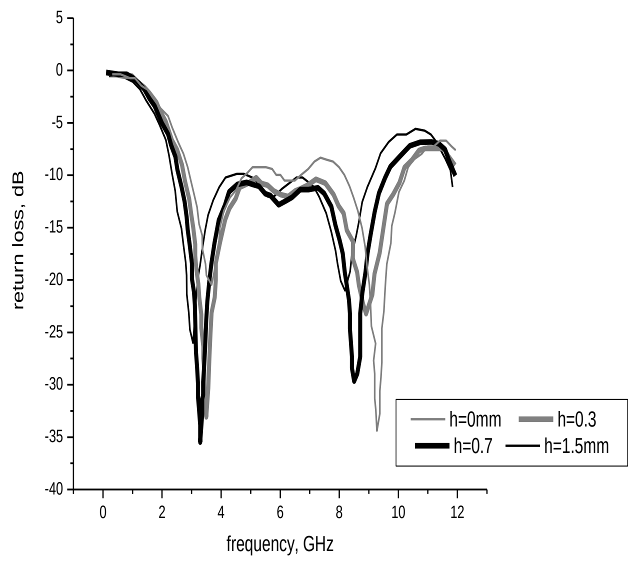


Fig. 3. Simulated return loss for different radius of circular radiating disc with h= 0.3mm and W=42mm.

Using the aforementioned facts and the simulated values from IE3D software, a model is created which gives the feedgap design parameter for a desired operating frequency ranging between 2 GHz and 12 GHz. Keeping the dielectric constants of both the substrate fixed at 4.4, the model is developed using feed forward Back Propagation algorithm [2,10,11, 14].

The relation between feed gap, h, and resonating frequency (f_r) is shown in Fig4. This is due to the sensitivity of the impedance matching to the feed gap. The ground plane, serving as an impedance matching circuit, tunes the input impedance and the operating bandwidth while the feedgap is varied.

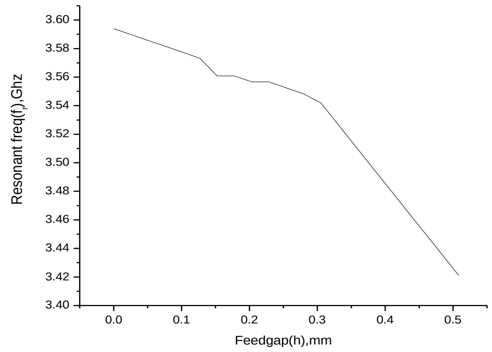


Fig.4. Relation between resonant frequency and feedgap.

The back propagation algorithm is used to train the network. It has one hidden layer whose performance goal was taken as 10^{-5} and number of epochs as 50000. It takes almost 45 minutes to train the network with 400 inputs and outputs and % error is found to lie within 0.4 to 4.6 %. Where % error is calculated by the following formula:

% Error = (Simulated Value – ANN Value)/Simulated value * 100

The network is tested for 5 random frequencies. Those input frequencies are compared with the resonant frequencies obtained from IE3D software for the corresponding output parameters given by the network. The results from the ANN model is tabulated in Table 1 which gives the feedgap design parameters for a particular antenna for the corresponding frequency. The design parameter obtained from the developed model is used to simulate the value of resonant frequency using IE3D software.

Table 1. Comparison of the result given by ANN model with the simulated results:

Result given by ANN model		**Result given by IE3D software**	**Error percentage**
Resonant freq.(F_R),GHz	**Feedgap (h),mm**	**Resonant freq(F_r), Ghz**	
5.70210	1.4167	6.12	6.82
9.24070	0.0127	9.22	0.22
8.90750	0.3306	9.17	2.86
3.56070	0.1884	3.4	4.72
6.2450	0.0865	6.33	1.34

The simulated value of resonant frequency is then compared with the values obtained from the trained ANN model and the error percentage is calculated. From Table 1, one can estimate that the prepared network or model is accurate enough for determining the feedgap design parameters of a CMA operating between 2 GHz and 12 GHz. The above mentioned characteristic of the CMA obtained from the ANN model is found to be acceptable within the error limit.

By increasing the number of training patterns and the hidden layers of the network, the network can be made more accurate. In the proposed work a simple interpolation technique is used to add up more number of training data by interpolating more number of points lying between 100 simulated data obtained from the IE3D simulation, to get 400 data for training.

5. CONCLUSION

The trained network is very successful in computing the design parameter i.e feedgap for CMA for any desired resonant frequency. A distinct advantage of neural computation is that, after proper training, a neural network completely bypasses repeated use of complex iterative processes for new design presented to it. This work can be further extended for variable dielectric constants and for different shapes of the radiating patch. Beside feedgap there are others parameters of CMA like width, length, radius which effect the radiant frequency. Antenna performance is heavily dependent on width of the ground plane because the current is mainly distributed and transmitted on the upper edge of the ground plane along the y-direction. Radius of the circular disc also has a great effect on antenna performance. The frequency band increases and shifts towards the lower end with the increase in radius of the disc. So network can be trained with all these design parameters to get the total characteristics of CMA at a particular resonant frequency. But when all the characteristics are included then the error percentage can be high due to cumulative summation of errors due to each parameter. More methods can be explored to reduce such errors to minimum limit.

6. REFERENCES

[1] A. W. Rudge, K. Milne, A. D. Olver and P. Knight, "The Handbook of Antenna Design", vol. 2, 1982, by Peter Peregrinus Ltd., London, UK.

[2] A. Patnaik and R. K. Mishra, "ANN Techniques in Microwave Engineering", IEEE Microwave Magazine,, March 2003, pp. 55.

[3] Constantine A. Balanis, "Antenna Theory Analysis and Design", 2005, by John Wiley & Sons, INC.

[4] Chao-MingWu, "Wideband dual-frequency CPW-fed triangular monopole antenna for DCS/WLAN application", C.-M. Wu / Int. J. Electron. Commun. (AEÜ) 61 (2007) 563 – 567.

[5] E. Antonino-Daviu, M. Cabedo-Fabre´s, M. Ferrando-Bataller and A. Valero-Nogueira, "Wideband double-fed planar monopole antennas", *ELECTRONICS LETTERS* 13th November 2003 Vol. 39 No.23.

[6] J. Liang, C.C. Chiau, X. Chen and C.G. Parini, "Printed circular disc monopole antenna for ultra wideband applications", *ELECTRONICS LETTERS,* 30th September, 2004 ,Vol. 40 No. 20.

[7] Jihak Jung, Wooyoung Choi, and Jaehoon Choi, "A small wideband microstrip fed monopole antenna", *IEEE Microwave and Wireless Components Letters,* vol. 15, NO. 10, October 2005.

[8] Kin-Lu Wong, *Senior Member*, *IEEE*, Chih-Hsien Wu, and Saou-Wen (Stephen) Su, "Ultrawide-Band Square Planar Metal-Plate Monopole Antenna With a Trident-Shaped *IEEE Transactions on Antennas and Propagation,* vol. 53, NO. 4, April 2005.

[9] Qiu Jinghui, Qi Jiaran, "Study on the Properties of Circular Monopole Antenna" , 2006 6th International Conference on ITS Telecommunications Proceedings.

[10] R. K. Mishra and A. Patnaik, "Neural Network-Based CAD Model for the Design of Square Patch Antennas", *IEEE Ttransactions on Antennas and Propagation,* Vol. 46, No. 12, December 1998, pp. 1890 – 1891.

[11] R. K. Mishra and A. Patnaik. "Neorospectral Computation for Complex Resonant Frequency of Microstrip Resonators", *IEEE Microwave and Guided Wave Letters,* Vol. 9, No. 9, September 1999.pp 351 – 353.

[12] Simon Haykin, "Neural Networks A Comprehensive Foundation", 2004, by Pearson Educartion (Singapore) Pte. Ltd.

[13] S.N. Sivanandam, S. Sumathi, S.N. Deepa, "Introduction to Neural Networks using Matlab 6.0", 2006, by Tata McGraw-Hill.

[14] T. Bose and N. Gupta, "Neural Network Model for Aperture Coupled Microstrip Antennas", Microwave Review, September 2008.