# Neurocomputational Approach for Feed-Position Estimation in Circular Micro-strip Antenna

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## ABSTRACT

This paper presents a neurocomputational model for estimation of feed-position in circular microstrip antenna. The difficulty in computing the feed position in circular micro-strip antenna lies due to the involvement of a large number of physical parameters including their associated optimal values. It is indeed very difficult to formulate an exact numerical solution merely on practical observations based empirical studies. In order to circumvent this problem, an alternative solution is achieved using neurocomputational model. The proposed technique used feed-forward back-propagation artificial neural network (FFBP-ANN) trained with Levenberg-Marquardt algorithm. The results of neural estimation are quite promising.

## Keywords

Circular, feed, neurocomputational, microstrip, impedance, antenna

## 1. INTRODUCTION

Microstrip antennas are one of the popular type antennas, since they are light weight, has simple geometry, inexpensive to fabricate & can easily be made conformal to host body [1]. These antennas are popular for low profile applications at frequency above 100 MHz. A microstrip antenna consists of a very thin metallic patch placed a small fraction of a wavelength above a conducting ground plane as shown in fig.1. The strip and ground are separated by a dielectric sheet referred as substrate. The radiating element and feed lines is normally photo etched on dielectric substrate. The radiating patch conductor is generally of copper and can assume any shape square, rectangular, circular, elliptical, triangular or any other desired configuration [2]. As the thickness of microstrip is normally very small, the waves generated within the dielectric substrate undergo reflections to some extent when they arrive at the edge of strip, resulting radiations. Methods to feed microstrip antenna are microstrip line, coaxial probe, aperture coupling and proximity coupling [3-4]. These antennas are used in various applications such as mobile radio and wireless communications. The input impedance plays a very important role in the design of microstrip antenna. The antenna impedance depends upon the dimensions of the patch and feed position as well [5].So it is necessary to find the position of feed for proper impedance matching. There are many impedance matching techniques like quarter wave transformer at single frequency.

Artificial neural networks (ANN) 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. An ANN consists of a few types of many, simple, nonlinear functional blocks, which are called *neurons.* Neurons are organized into layers, which are mutually connected by highly parallel synaptic weights. The ANN exhibits a learning ability synaptic weight can be strengthened or weakened during the learning process, and in this way, information can be stored in the neural network [6-7]. Each neuron has internal state, called activation, which is function of inputs it has received. A neuron sends its activation as a signal to several other neurons .It is important to note that a neuron can send only one signal at a time, although signals are broadcasted to several other neurons. Neural networks have recently gained attention as a fast and flexible vehicle to EM/Microwave modeling, simulations and optimization. Sufficient amount of work indicates how ANN can be used efficiently to design rectangular microstrip antenna [8-11].Also ANN can be used to calculate different parameters of rectangular microstrip antenna such as radiation efficiency [12], resonating frequency [13], resonant frequencies of triangular and rectangular microstrip antennas [14], resonant resistance calculation of electrically thin and thick rectangular microstrip [15], input impedance of rectangular microstrip antennas [16]. Similarly Artificial Neural Networks have been used for the design of circular antenna [17-18], calculating different parameters such as resonant frequency [1], directivity [19] and input impedance [20] of circular microstrip antenna. Study available in [21] used neural network based model for computing the feed position of rectangular micro-strip antenna. However, this model suffers from the problems of slower learning, higher computational load and higher computational complexity. In order to circumvent these problems as well as to achieve an optimal neural solution, the authors of the present paper reported a comparative evaluation of different variants of back propagation training algorithm for estimation of feed position in rectangular microstrip antenna [22]. The results of this study proved that the Levenberg-Marquardt training algorithm is the best algorithm. In continuity with this work, the present paper reports an optimal neural estimation of feed position in circular microstrip antenna.

## 2. DATA-DICTIONARY GENERATION:

Feed position calculation of circular microstrip antenna is divided in two steps. In first step resonant frequency of circular microstrip antenna is calculated. The resonant frequency of circular microstrip antenna can be calculated using ANNs [16]. In this paper firstly for different values of radius of patch ‘a’, height of substrate ‘h’ and dielectric constant $\varepsilon_r$ , the effective radius of circular microstrip antenna is calculated by using [1].Then by using [2] resonant frequency of antenna is calculated.

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

$$f_r = \frac{1.8412 v_o}{2\pi a_e \sqrt{\varepsilon_r}} \qquad [2]$$

Then IE3D software is used for calculating the position of feed at given resonant frequency as shown in fig.3a. For example for the design of circular microstrip antenna with radius of patch a = 9.1mm, height of substrate h = 1.59 and dielectric constant = 2.3, resonant frequency is calculated by using equation [1] and [2] is given by $f_r$ = 5.9GHz.Then feed position point is calculated by IE3D software and is given by $f_p$ (5.75mm, 0mm) from centre of this antenna. Fig. 2.a shows the geometry of circular microtrip antenna with feed at centre and fig.2b shows the structure of circular microstrip antenna with feed point $f_p$ (5.75mm, 0mm) from centre of this antenna, at this feed point, feed impedance and antenna impedance becomes equal of value 50 Ω. Return loss versus frequency in GHz of circular micostrip antenna for radius of patch a=9.1mm, height of substrate h= 1.59mm ,dielectric constant $\varepsilon_r$ =2.3 and feed position $f_p$ (5.75mm,0mm) from centre are

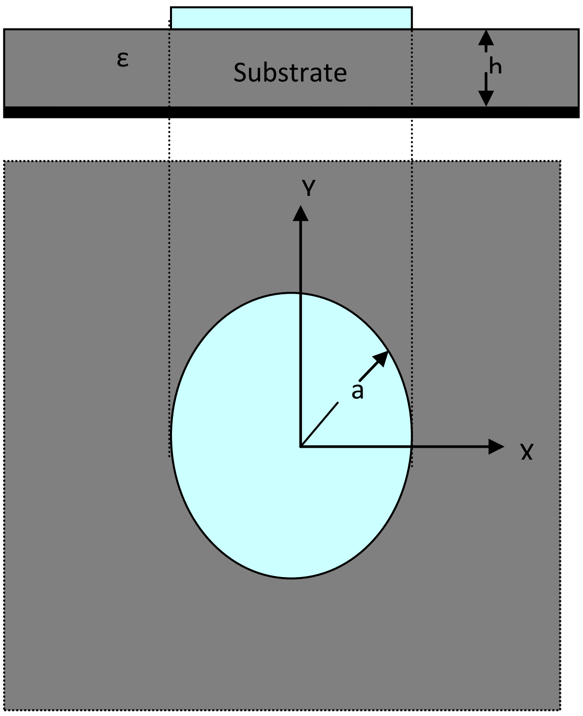


**Fig 1: Geometry of Circular Microstrip Antenna**

shown in fig.4. Return loss has minimum value of -35.3705db at frequency of 5.87086GHz .In this way by using IE3D software different values of feed position of circular microstrip antenna is obtained for different dimensions of circular microstrip antenna. A set of 27 input (‘a’, ‘h’ and $\varepsilon_r$).- output ($f_p$) pair is generated for the training set and another set of 58 input-output pairs for the validation set.

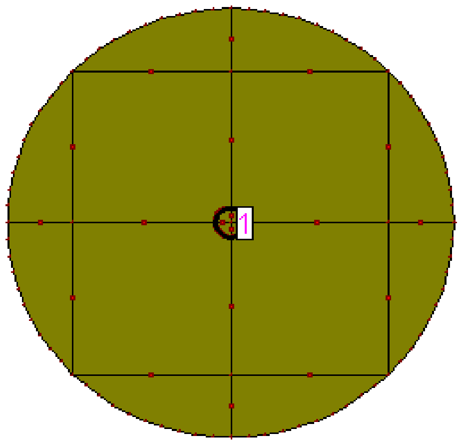


**Fig 2a: Geometry of circular microstrip antenna when feed position at centre.**

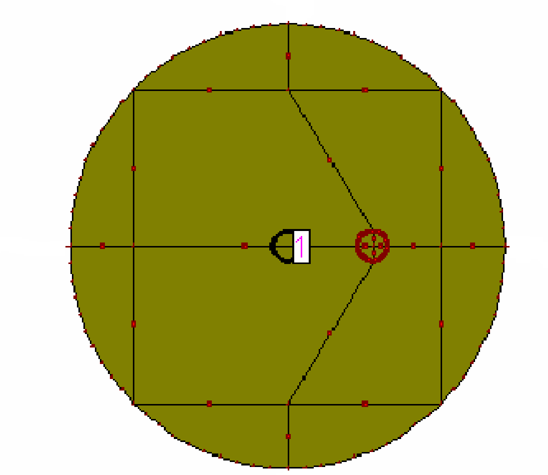


**Fig 2b: Geometry of circular microstrip antenna after optimization of feed position.**

## 3. DESIGN AND IMPLEMENTATION OF NEUROCOMPUTAIONAL MODEL:

A neurocomputaional model trained with Levenberg–Marquardt algorithm is used as an approximate model for estimating the exact feed position of antenna. It has three inputs, radius of an antenna ‘a’, height of substrate ‘h’, dielectric constant ‘$\varepsilon_r$’ and single out put i.e. position of feed $f_p$ as shown in fig.3b.ANN structure ( number of layers ,number of neurons in each layer ,neuron activation function ,learning algorithm and training parameters) is not known in advance. In this paper feed-forward back-propagation artificial neural network (FFBP-ANN) with one hidden layer is used as an approximate model for estimation of feed position of microstrip patch antenna for impedance matching with reasonable accuracy. An algorithm is implemented using MATLAB programming and neural network tool box to synthesize a FFBP-ANN to minimize mean square error (MSE). The MSE is minimized for 3-9-1 architecture when it is trained with

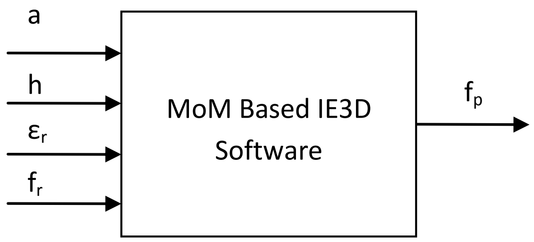


**Fig 3a: IE3D software for calculating feed position of circular microstrip antenna.**

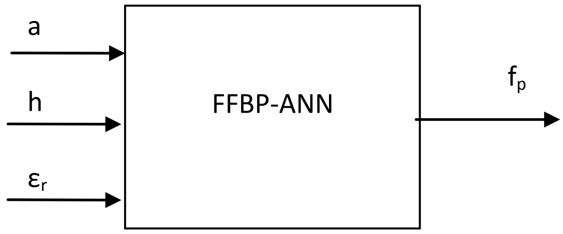


**Fig 3b: Neurocomputational Model for estimation of feed position of circular microstrip antenna.**

Levenberg –Marquardt learning algorithm. During training, a set of input values corresponding to some selected points in data dictionary help to adjust the weights and biases of neurons to minimize the difference between the ANN output and actual output. Proposed neurocomputaional model, represented in Figure.5 includes one hidden layer of transigmoid neuron with activation function( $f_1$ ).The first layer receives input from input layer and its output is given to output layer of single liner neuron with activation function( $f_2$) that computes the network output as given below .Using matrix representation, the output of ANN is given by

$$X=f_2([OW](f_1([FW][Y]+[FB])+[OB]) \quad [3]$$

$$Y=\begin{bmatrix} a_i \\ h_i \\ \varepsilon_i \end{bmatrix} \quad [4]$$

$$X=[f_p] \quad [5]$$

$$FW=\begin{bmatrix} fw_{11} & fw_{12} & fw_{13} \\ fw_{21} & fw_{22} & fw_{23} \\ . & . & . \\ . & . & . \\ fw_{9,1} & f_{9,2} & fw_{9,3} \end{bmatrix} \quad [6]$$

$$[FB]=\begin{bmatrix} fb_1 \\ fb_2 \\ . \\ . \\ . \\ fb_9 \end{bmatrix}, \quad [7]$$

$$[OB]=[ob_1] \quad [8]$$

$$[OW]=\begin{bmatrix} OW_{11} & OW_{12} & . & . & OW_{1,9} \end{bmatrix} \quad [9]$$

$$MSE=\frac{1}{n}\sum_{i=1}^{n}[x_i - F_{ANN}(y_i)]^2 \quad [10]$$

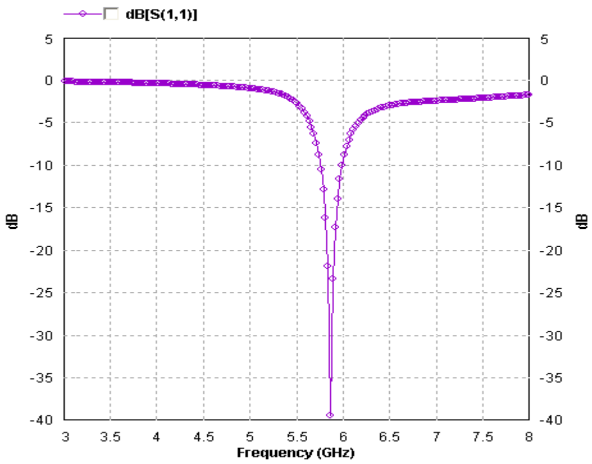


**Fig 4: Return losses versus frequency calculated by IE3D software for circular microstrip patch antenna'a'=9.1mm, h=1.59mm, εr=2.3 and feed $f_p$ (5.75mm, 0mm) from centre.**

## 4. RESULTS AND DISCUSION:

The results of proposed ANN model structure (3-9-1), trained with Levenberg as result of training study and validation study for estimating the feed position of circular microstrip patch antenna are discussed in this section. In order to evaluate the performance of proposed neurocomputaional model for estimating the feed position of micro strip patch antenna simulation results are obtained using IE3D software. ANN is trained with 27 input-output training patterns. This training data is used for training the proposed 3-9-1 ANN structure with Levenberg Marquardt algorithm. The learning characteristic of proposed neurocomputaional based model trained with Levenberg Marquardt training algorithm is shown in Fig.6. It has been observed that total no. of only 180 epochs are needed to reduce MSE level to a low value 9.16136e-008.

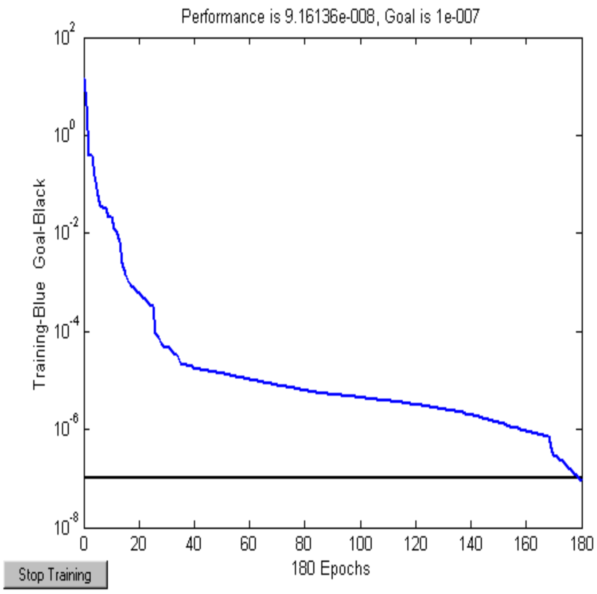


**Fig 6: Learning Characteristics of proposed neurocomputaional model**

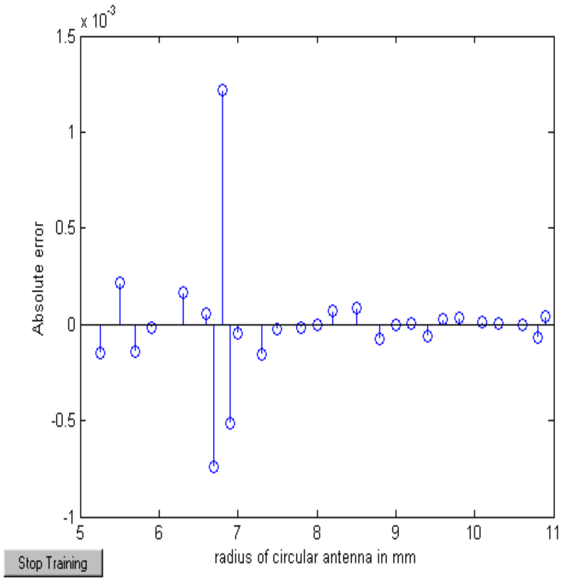


**Fig 7: Absolute Error between target value and estimated value of feed position by neurocomputaional model as a result of training study**

It can be seen from the Table.1. that neurocomputaional based model is capable of approximating the input-output relationship for dependent parameter feed position with independent parameters such as radius of patch 'a', height of substrate 'h', dielectric constant '$\varepsilon_r$' of the substrate. The absolute error at each value of feed position of micro-strip antenna as result of training study with Levenberg-Marquard algorithm is shown in Fig.7. It is observed that maximum absolute value of absolute error between target value and estimated value of feed position by neurocomputaional model is found to be only 0.00121891747241 and that of Percentageage error is 0.05131808451160 as summarized in Table-1.

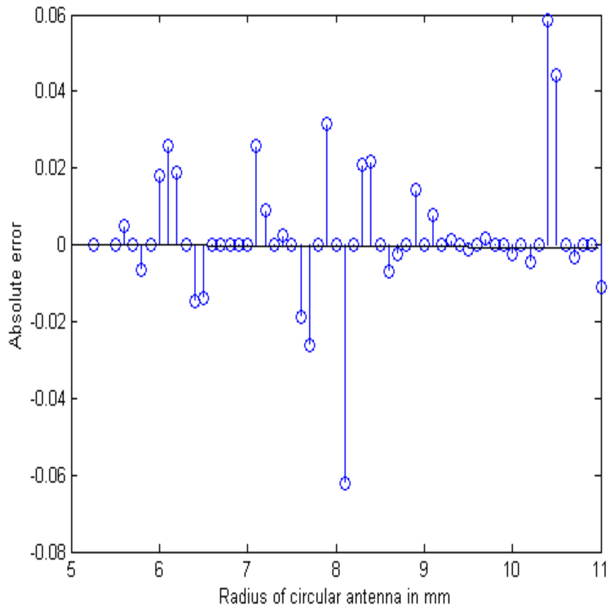


**Fig 8: Absolute Error between target value and estimated value of feed position by neurocomputaional model as a result of validation study**

In order to test the results for estimation of feed position of circular micro strip antenna using proposed 3-9-1 ANN structure, another set of 57 input–output patterns generated using IE3D software. The absolute error and Percentageage error at each value of feed position of micro-strip antenna as result of validation study for Levenberg Marquardt algorithm are also shown in Table-1. ANN Structure 3-9-1 trained with Levenberg Marquardt training algorithm is a best fit structure for estimation of feed position of circular micro strip patch antenna. The absolute error at each value of feed position of micro-strip antenna as result of validation study is shown in Fig.8. It is observed that maximum absolute value of absolute error between target value and estimated value of feed position by neurocomputaional model as a result of validation study is found to be only 0.06236584255917 and that of Percentageage error is 2.62220316275188. Achievement of such low value of these errors (absolute and Percentage FS) further authenticates that neurocomputaional model is an accurate model for estimating the feed position of micristrip antenna.

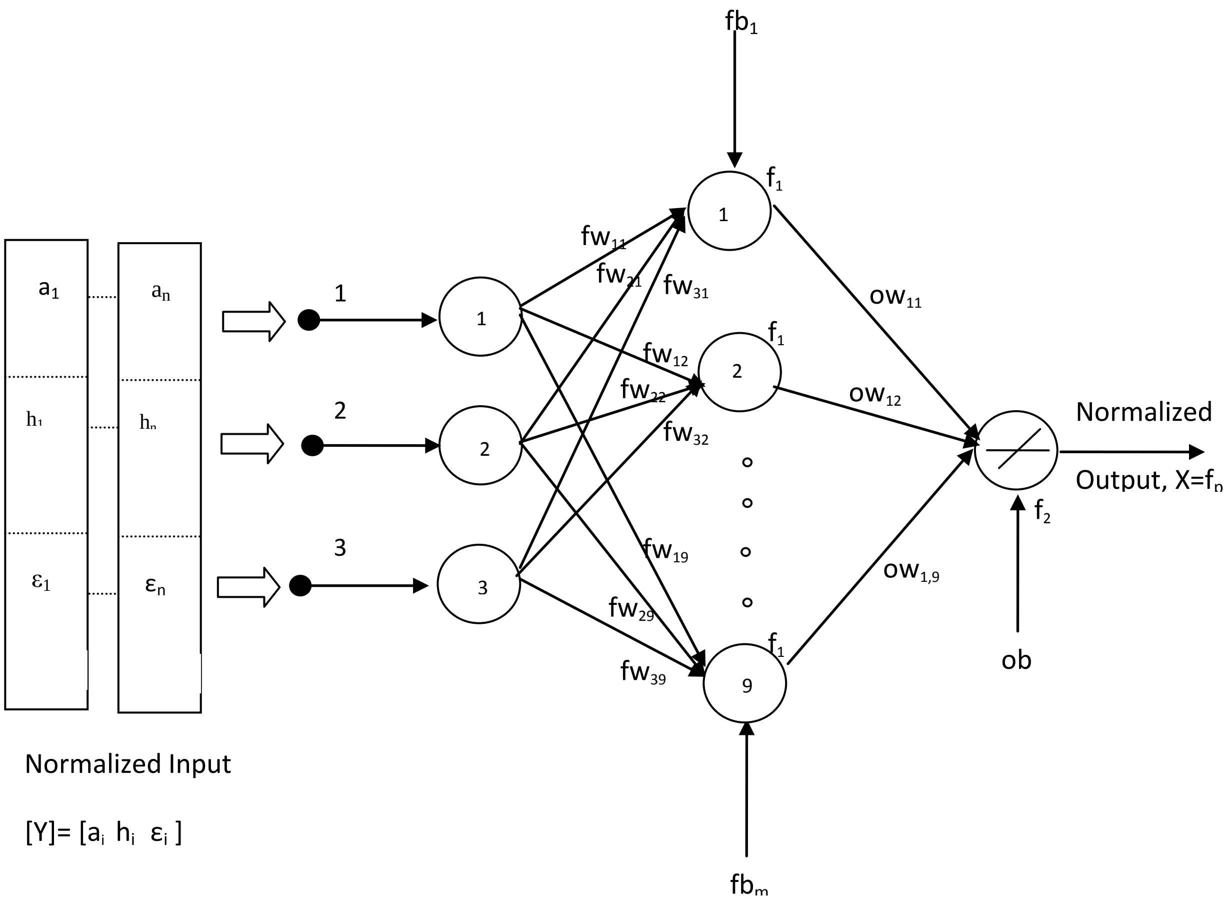


**Fig 5: Proposed Neurocomputaional model for estimating feed position of circular microstrip patch antenna**

## 5. CONCLUSION

The paper proposed an optimal neural solution for estimation of feed position in circular microstrip 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 finding feed position of such types of antennas, thus resulting in an extremely fast solution with high accuracy. The results of present study are quite promising. The values of feed position estimated by the proposed neural model are in close agreement with the simulated results. This close agreement further supports the validity of the proposed model.

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