Artificial Neural Network Employed To Design Annular Ring Microstrip Antenna

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Abstract- Neural network computational modules have recently gained as an unconventional and useful tool for RF and microwave modeling and design. Neural network is trained to learn the behavior of Annular Ring Microstrip Antenna's equivalent circuit parameters. A trained neural network is used for designing fast and less error answers to the task that has to be learned. In this paper, structure of Annular Ring Microstrip Antenna (ARMSA) is studied and sets of datum are collected for the training of the Multilayer Perceptron (MLP) Neural Network.

Keywords: Artificial Neural Networks, Multilayer Perceptron Neural Network, and Annular Ring Microstrip Antenna.

I. Introduction

Neural networks, also called artificial neural network (ANN), is information processing system with their design inspired by the studies of the ability of the human brain to learn from observations and to generalize by abstraction[7]. The fact that neural networks can be trained to learn any arbitrary nonlinear input–output relationships from corresponding data has resulted in their use in a number of areas such as pattern recognition, speech processing, control, biomedical engineering etc. Recently, ANNs have been applied to RF and microwave computer-aided design (CAD) problems as well. Neural networks are first trained to model the electrical behavior of passive and active components/circuits. These trained neural networks, often referred to as neural-network models (or simply neural models), can then be used in high-level simulation and design, providing fast answers to the task they have learned [9], [1]. Neural networks are efficient alternatives to conventional methods such as numerical modeling methods, which could be computationally expensive, or analytical methods, which could be difficult to obtain for new devices, or empirical models, whose range and accuracy could be limited. Neural-network techniques have been used for a wide variety of microwave applications such as embedded passives [8], coplanar waveguide (CPW) components [5], transmission-line components [2, 3, 10], bends[6], vias [4], spiral inductors [24], FETs [26], amplifiers [29], [34], etc. Neural networks have also been used in impedance matching [36]. The rectangular and circular patches are probably,
the most extensively studied patch shapes [11,27], the annular ring patch has also received considerable attention [14,17]. There are several interesting features associated with this patch, first, for a given frequency; the size is substantially smaller than that of the circular patch when both operated in the lowest mode. Second, it can be easily designed for dual band operation by using a concentric ring structure [15], or by employing another circular patch [16]. The lowest mode has a very narrow operating band, but the bandwidth is substantially increased when operated in some high modes [13, 30, 20]. In [14, 15], the authors analyzed the annular ring structure by using an equivalent circuit modal based on a transmission line analysis. A spectral domain approach was carried out in [28], but no attempt was made to model the feed structure. In [30], the authors treated the structure as a magnetic wall cavity and, the vector integral equations were established and the

resonant wave number has been strictly evaluated, but the input impedance has been calculated rather crudely by employing the single mode approximation (SMA) method.

II. Annular Ring Microstrip Antenna (ARMSA) [33, 18]

The annular ring microstrip antenna is used by cavity model which is expected to precisely predict the antenna performance. The equivalent circuit of the annular ring microstrip antenna can be expressed as parallel combination of an inductor L, a capacitor C and a resistance R which is shown in figure-2. The L and C represent the magnetic and electric energies stored in the fields below the patch metallization and in the fringing fields around the radiating aperture at radius =a and radius' =b. The resistance R represents the power loss through the radiating apertures and couplings between them.

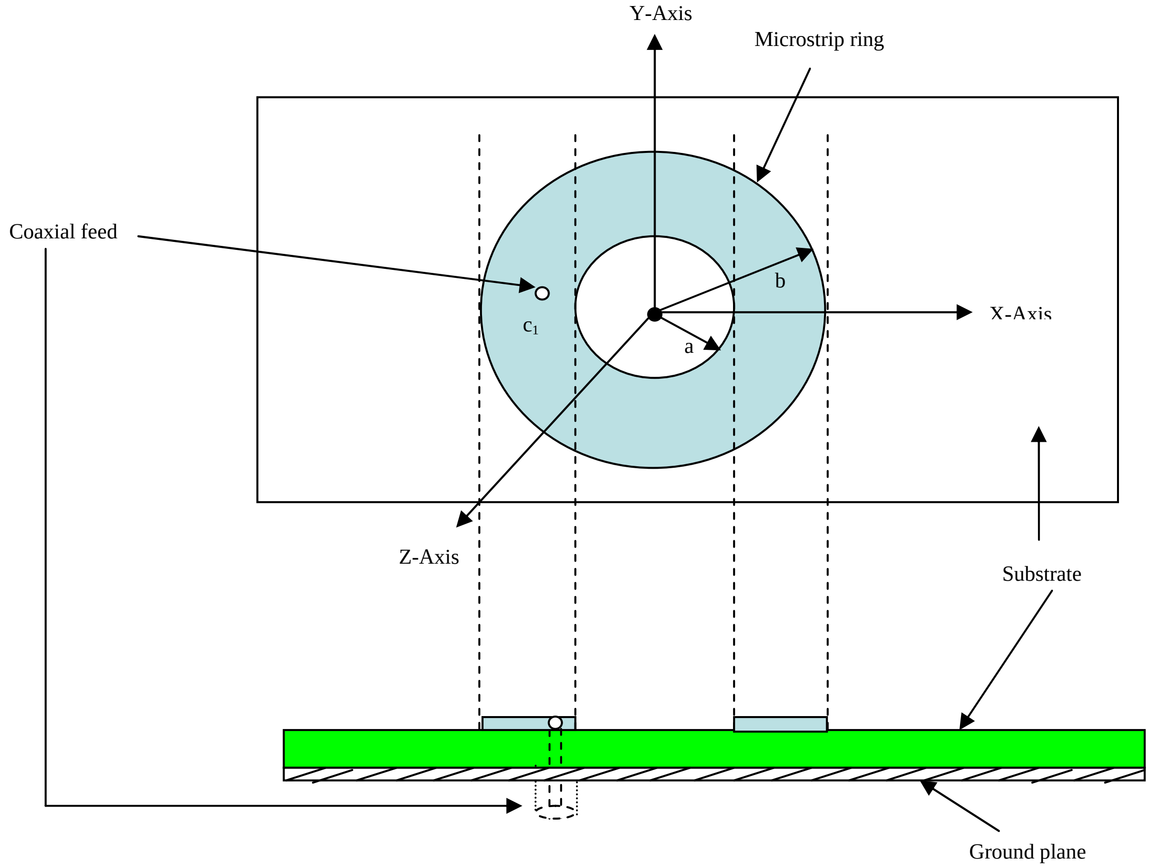

Figure1: Annular Ring Microstrip Antenna

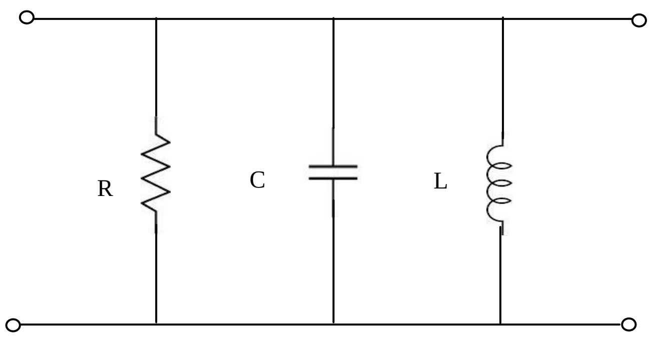

Figure2: Equivalent circuit of Annular Ring Microstrip Antenna

The annular ring microstrip is shown in figure1, above and can be equated to a parallel combination of an inductance *L*, a capacitance *C* and resistance *R* i.e. $\left(\frac{1}{Y}\right)$ as shown in figure in 2.The expression of these *L*, *C*, *R* can be obtained as -

$$L = \frac{\mu h}{\pi k_1^2 [n,m]} \left\{ J_n(k_1 c_1) Y_n'(k_1 a_e) - Y_n(k_1 c_1) J_n'(k_1 a_e) \right\}^2 \tag{1}$$

$$C = \frac{\mu \varepsilon_0 \varepsilon_r}{L k_1^2} \tag{2}$$

$$Y = \left[\frac{\pi}{h} \left\{ \left(\frac{E_a}{E_{c_1}} \right)^2 g(a,a) + \left(\frac{E_b}{E_{c_1}} \right)^2 g(b,b) - \frac{2 E_a E_b}{E_{c_1}^2} y(a,b) \right\} \right] \tag{3}$$

With

$$[n,m] = \frac{1}{2k_1^2} \left[\left(k_1^2 b_e^2 - 1\right) \left\{ J_n(k_1 b_e) Y_n'(k_1 a_e) - Y_n(k_1 b_e) J_n'(k_1 a_e) \right\}^2 - \frac{4}{\pi^2 k_1^2 a_e^2} \left(k_1^2 a_e^2 - 1\right) \right] \quad [22]$$

And $E_a = E_{nm}(a,\phi)$, $E_b = E_{nm}(b,\phi)$ and $E_{c_1} = E_{nm}(c_1,\phi)$ field at different point.

In the above equation following parameters are denoted as:

a = Inner radius of the patch
a_e = Effective inner radius of the patch
b = Outer radius of the patch
b_e = Effective outer radius of the patch
μ = Permeability of the substrate
h = Thickness of the dielectric substrate
k_1 = Resonant wave number
ε_r = Relative permittivity of the substrate
ε_e = Effective relative permittivity
W = (b-a) = Width of the patch

The effective outer radius (b_e) is given as

$$b_e = b\left(1 + \frac{2hx}{\pi b \varepsilon_r}\right)^{\frac{1}{2}} \tag{4}$$

where

$$x = \ln\left(\frac{b}{2h}\right) + 1.41\varepsilon_r + 1.77 + \frac{h}{b}\left(0.268\varepsilon_r + 1.65\right)$$

Similarly one can find the effective inner radius of the antenna.

The electric field distribution of ARMSA for TM_{nm} mode is given by

$$E_{nm}(\rho,\phi) = \hat{z}\left\{ J_n(k_1\rho) Y_n'(k_1 a_e) - Y_n(k_1\rho) J_n'(k_1 a_e) \right\} \cos n\phi$$

Where (c_1,0) is the feed location in ARMSA
And

g (b, b) = Edge conductance at outer radius.
g (a, a) = Edge conductance at inner radius.
y (a, b) = Mutual admittance between the apertures.

The coupling between outer ring and inner ring is given as [21],

$$y(a,b)=\frac{jabh}{2\pi^2\mu\omega}\int_0^{2\pi}\cos\phi\left[\int_0^{2\pi}\cos\alpha\,\frac{e^{-jk_0r_1}}{r_1^{3}}\left\{\begin{array}{l}2\cos(\phi-\alpha)(1+jk_0r_1)\\+\dfrac{(b\cos(\phi-\alpha)-a)(b-a\cos(\phi-\alpha))}{r_1^{2}}\times\\(k_0^{2}r_1^{2}-3jk_0r_1-3)\end{array}\right\}d\alpha\right]d\phi \quad (5)$$

where

$$r_1=[a^2+b^2-2ab\cos(\phi-\alpha)]^{\frac{1}{2}}$$

The value of edge conductances g(a, a) and g(b, b) are obtained by substituting b = a and a = b respectively in equation (5) and retaining the real part only.

The equivalent input impedance of annular ring microstrip resonator is the parallel combination of R, L and C (Figure2) and hence

$$Z_{in}=\frac{R\omega^2L^2+jR^2\left(\omega L-\omega^3L^2C\right)}{X} \quad (6)$$

Where

$$X=R^2\left(1-\omega^2LC\right)^2+\omega^2L^2$$

III. Multilayer Perceptron (MLP) Neural Network

MLP is a popularly used neural network structure. In the MLP neural network, the neurons are grouped into layers. The first and the last layers are called input and output layers, respectively, and the remaining layers are called hidden layers. Typically, an MLP neural network consists of an input layer, one or more hidden layers, and an output layer, as shown in Figure3 For example, an MLP neural network with an input layer, one hidden layer, and an output layer, is referred to as three-layer MLP (or MLP). nature of the –relationship. Non dynamic modeling problem can be solved using MLP. The most popular choice is the MLP since its structure and training are well-established. nonlinear and localized phenomena (e.g., sharp variations). Time-domain dynamic responses such as those in nonlinear modeling can be represented using recurrent neural networks[29] and dynamic neural networks [34]. One of the most recent research directions in the area of microwave-oriented ANN structures is the knowledge-based networks [3, 4, 6, 10,]. The neural network does not represent any annular ring microstrip antenna component unless we train it with annular ring microstrip antenna data. It is developed a neural-network model, input and output parameters of the component in order to generate and preprocess data, and then use this data to carry out ANN training.

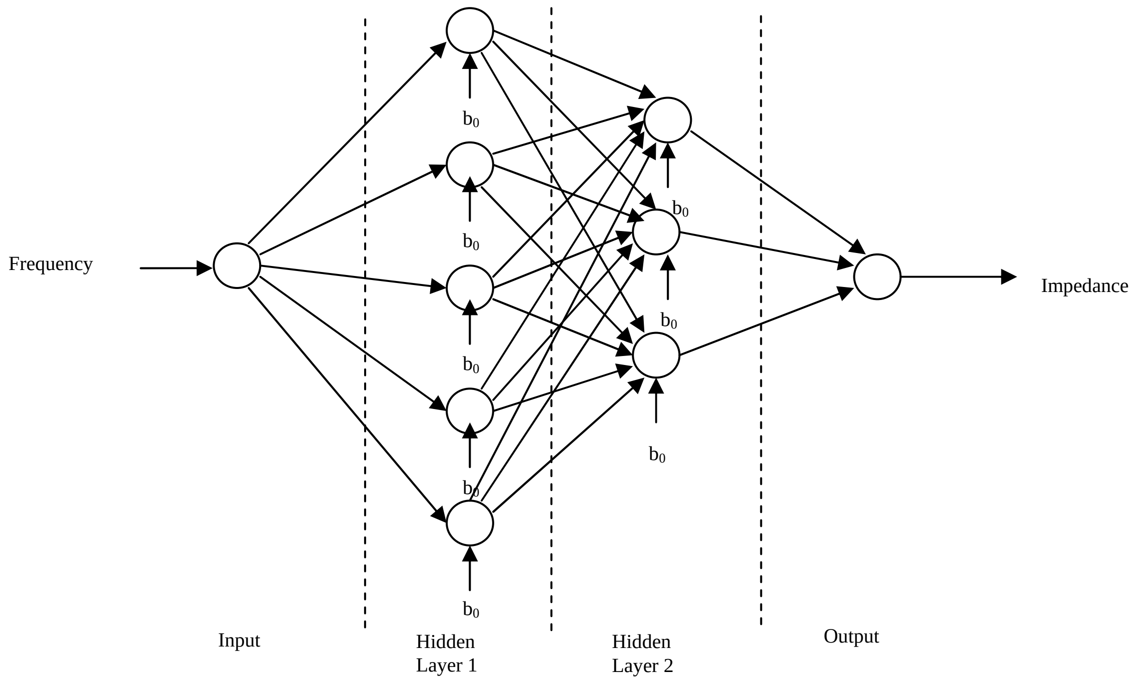

Figure3: Multilayer Perceptron Neural Network

Mathematical model of a neuron

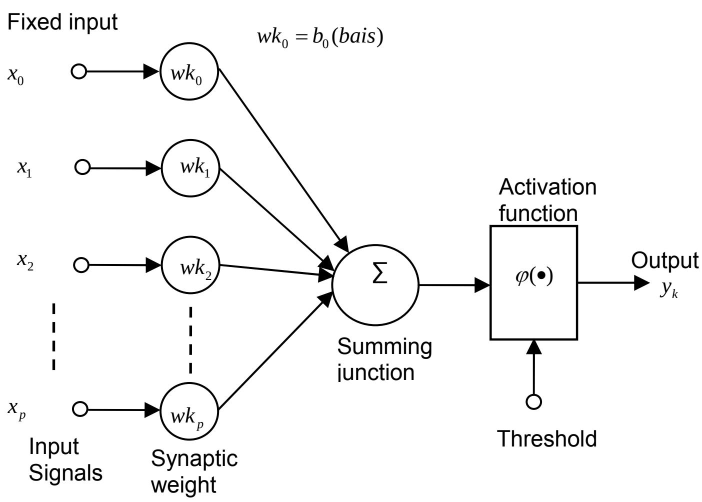

Figure4: Mathematical model of a neuron network

The model of each neuron in the network includes a nonlinear activation function.

$$v_k = \sum_{j=1}^{p} w_{kj} x_j \qquad (7)$$

The important point to emphasize here is that the nonlinearity is smooth (i.e., differentiable everywhere). A commonly used form nonlinearity that satisfies requirement is a sigmoidal nonlinearity defined by the logistic function:

$$y_j = \frac{1}{1 + \exp(-v_j)} \qquad (8)$$

Where v_j is the induced local field (i.e., the weighted sum of the all synaptic inputs plus the bias) of neurons *j*, and y_j is the output of the neuron. The presence of nonlinearities is important because otherwise the input output relation of the network could be reduced to that of single layer perceptron. Moreover, the use of logistic function is biologically motivated, since it attempt to account for the refractory phase of the real neurons.

IV. Result and Discussion

The multilayer neural network has made an input layer, an output layer, and two hidden layer. Layer one transfer function as logsigmoidal and layer two has transfer function as pure linear, weights has taken randomly by the network.

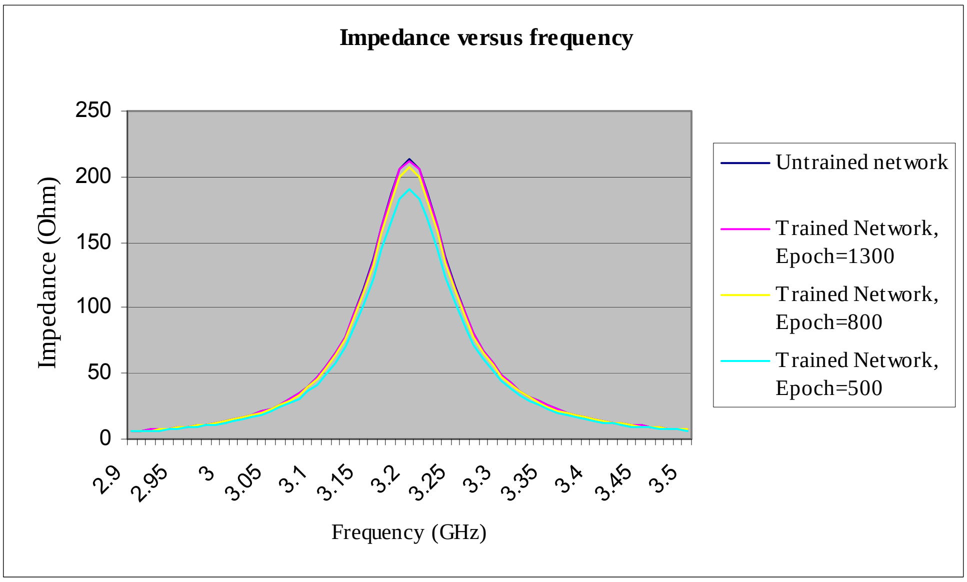

Figure5: Frequency versus Impedance

Figure5, shows the different plots of impedance for same frequency range incorporated by the annular ring microstrip antenna. That has been compared untrained network with trained network .The error is dispend on the number of epochs to achieve the goal; when epoch is 1300 then the error is 0.0532, epoch is 800 then error is 4.8307, and epoch is 500 then error is 72.2165.

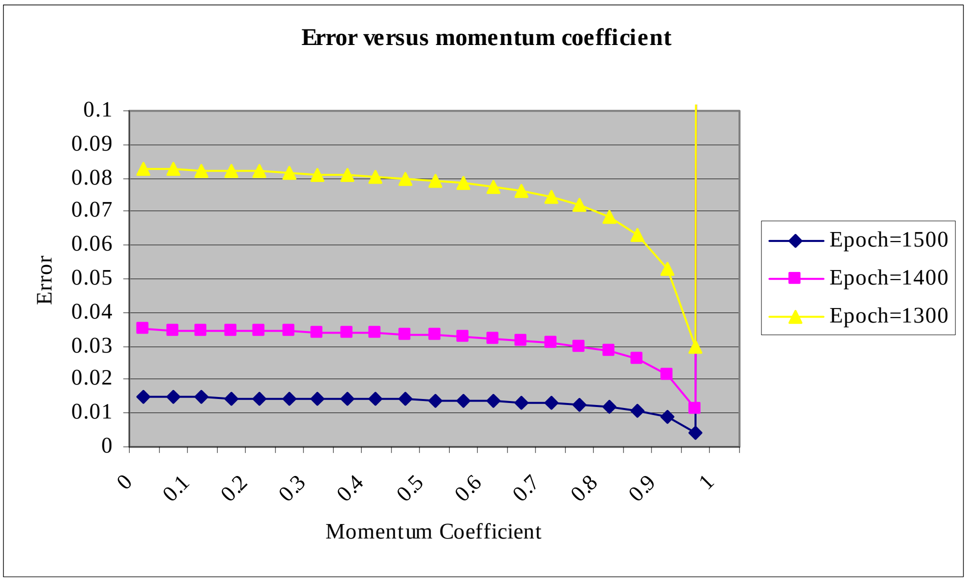

Figure6: Momentum coefficient versus Error

In figure6, the error obtained by the different epoch with variation of momentum coefficient, here it is seen that errer is low when epoch is 1500 in this plot momentum coefficient increases up to certain level the error is nearly constant but after a certain level of momentum coefficient error decreases exponentially . At momentum coefficient equal to one, the error becomes infinite. So it is clear that momentum coefficient can not become unity it is always less than unity.

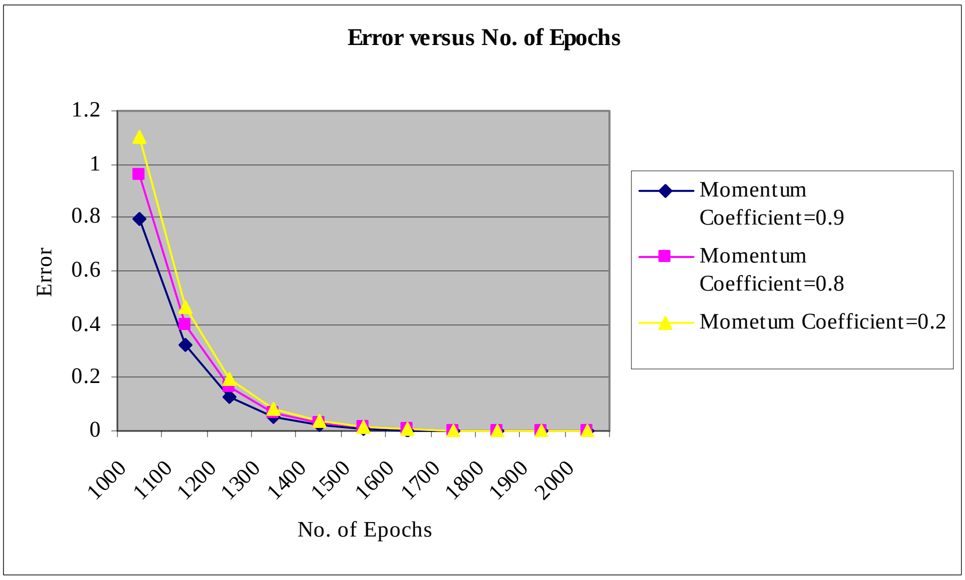

Figure7: Number of epoch versus Error

In figure7 shows that error is decreases when number of epochs increases at constant momentum coefficient. At epoch 1200, momentum coefficient 0.8 the error is 0.1312, momentum coefficient o.8 the error is 0.1655, and the momentum coefficient 0.2 the error is 0.1946.

V. Conclusion

In this paper structure of ARMSA is studied for the parameters and collected sets of datum for the parameters such as, the inner radius of the patch (a =) 3.0cm., the outer radius of the patch (b =) 6.0 cm., effective relative permittivity (ε_e = 2.2), width of the patch (W=) 3.0 cm., thickness of the patch conductor (t =) 0.0018 cm., and feed point (c_1=) 3.1 cm. The figure 5, 6, and 7 shows that after training the network the error is depends on the learning rate, Momentum, and number of epochs.from figure5, the number of epochs is higher the error is less; figure6, shows that momentum coefficient is always less than one but nearer to unity error is less and nearer to zero but not zero, error is higher. Figure7, shows that the epochs is higher then the error is less means until goal is not achieved by the network till loop is going on for achieving the goal.

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