A Heuristic Artificial Neural Network for Analyzing and synthesizing Rectangular Microstrip Antenna

M.Naser-Moghaddasi [1], Pouya Derakhshan Barjoei [2], Alireza Naghsh[3]
[1]Member of Central Commission for Scientific, Literacy & Art Societies Islamic Azad University Science and Research Branch

[2]Islamic Azad University Naein branch. Department of Electrical Engineering
[3]Islamic Azad University Najaf Abad branch. Department of Electrical Engineering

Summary
In this paper, both the synthesis and analysis of rectangular microstrip antenna models based on the artificial neural networks are presented to calculate accurately the resonant frequency of the rectangular microstrip antennas. Artificial neural networks are developed from neurophysiology by morphologically and computationally mimicking human brains The resonant frequency results obtained by using rectangular microstrip antenna characteristics and neural network models are very good agreement with the experimental results available in the literature. this paper presents a Multilayer Perceptron (MLP)modular neural network, training with the Resilient Back propagation algorithm which has been used for nonlinear device modeling in microwave band

Keywords:
Rectangular micostrip antenna, Neural network, Resonant frequency

1. Introduction

Microstrip antennas are also referred to as path antenna because of the radiating elements photo etched on the dielectric substrate. These patch antennas has some advantages such as small dimensions ,light weight, easy manufacturing, low cost, possibility of producing conformal antenna, high level of integration. However, it has also some drawbacks such as narrow bandwidth, generation of surface wave at the air-dielectric interface,and low overall efficiency due to dielectric losses. microstrip antenna elements can only operate effectively in the vicinity of resonant frequency. Printed circuit components and microstrip antennas have been increasingly used due to their widespread applications especially in wireless communication. Rectangular microstrip antennas are made of rectangular patch with dimensions width ,W, and length ,L, over a ground plane with a substrate thickness ,h, and dielectric constants ε_x , ε_y, as given in the figure1.

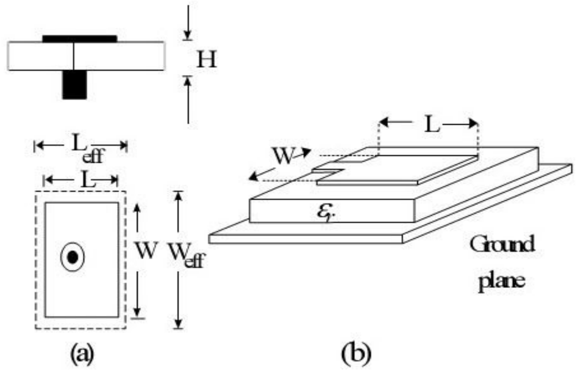

Figure1. Rectangular microstrip antenna, a)coax feed b)direct feed

Dielectric constants are usually used in the range between 2.2 and 12. However , the most desirable ones are the dielectric constants at the lower end of this range together with the thick substrates, because they provide better efficiency and larger bandwidth, but at the expense of larger element size. Microstrip is used extensively in both hybrid and monolithic microwave integrated circuits, and it is by far the most popular medium for the design of components with active devices, Figure(1) shows a cross-section of rectangular microstrip antenna. Although microstrip is physically extremely simple, it is the most complex of all the transmission lines .Pure TEM mode propagation is impossible because of the mixed dielectric, the medium is dispersive, a multitude of higher order modes can propagate along it and being an open structure, it can radiate energy as well as conduct it.Nevertheless,its popularity is a result of ease with which one can chip components. The relatively good thermal dissipation properties of the medium and, above all, the ability to make adjustments to microstrip circuits while operating at RF. [1][2][3][4].the effective dielectric constant or effective permitivity of substrate is:

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$$\varepsilon_{eff} = \frac{\varepsilon_g + 1}{2} + \frac{\varepsilon_g - 1}{2}[1 + 12\frac{h_e}{W}]^{-1/2} \quad (1)$$

$$\varepsilon_g = \sqrt{\varepsilon_r \varepsilon_y} \quad (2)$$

a practical width that leads to good radiation efficiencies is:

$$W = \frac{v_o}{2f_r}\sqrt{\frac{2}{\varepsilon_g + 1}} \quad (3)$$

The actual length of the rectangular microstrip antenna is:

$$L = \frac{1}{2f_r\sqrt{\varepsilon_{eff}}\sqrt{\mu_o \varepsilon_o}} - 2\Delta L \quad (4)$$

Where ΔL is extension of length and is given by[4][8]:

$$\frac{\Delta L}{h} = 0.412\frac{(\varepsilon_{eff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_{eff} - 0.258)\left(\frac{W}{h} + 0.8\right)} \quad (5)$$

2. Artifical Neural Network Analys and Synthes Characteristics

Artificial neural network have been very intensively explored from eighties, they have been used for adaptive controllers. Dealing with microwaves, artificial neural network appeared here at the beginning of nineties and they have been used for modeling active and passive components, design and optimization of microwave circuits, modeling microstrip antennas, reverse modeling of microwave devices, automatic impedance matching, etc.Using artificial neural networks, microwave engineers have tried to simplify a rather difficult and time consuming design of microwave systems. Artificial neural networks are electronic system of hardware or software nature, which are built according to the example of a human brain. a general multilayer feed forward artificial neural network is shown in figure(2),and a basic structure of each neuron element throughout the network is shown in figure(3).Therefore, artificial neural network consist of many simple non-linear functional blocks of a few types, which are called neurones,Neurones are organized into layers, which are connected by highly parallel synaptic weights, artificial neural network exhibit a learning ability, which means that synaptic weights can be strengthened or reduced so that artificial neural network can react on a given input pattern by a desired output one. This artificial neural network, exhibit a very high operational speed. The accurate evaluation of the resonant frequency in this paper is a key factor to determine its correct behaviors.[5][6][7].

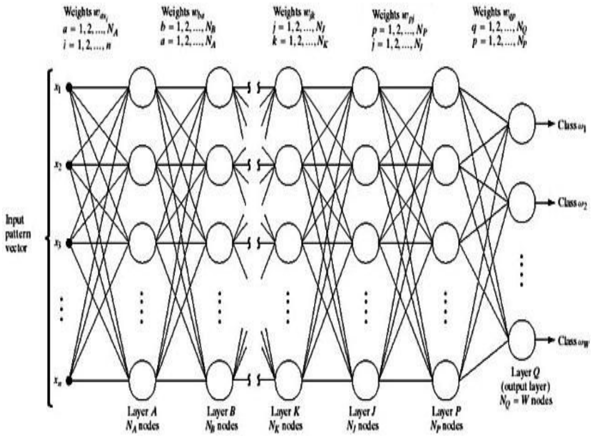

Figure 2. multilayer feed forward artificial neural network

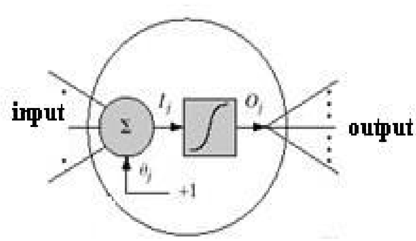

Figure 3.basic structure of neuron

For synthesis and analysis of our artificial neural network 715 datas gathered that all have been calculated from mathematical formula of microstrip antenna. We used 676 of them for training our artificial neural network analysis and synthesis parts, 40 datas remained for testing our analysis and synthesis artificial neural networks. Analyzing part of our artificial neural network is consist : four neurons in input layer, eleven neurons in hidden layers, and one neurons in output layer, for analyzing input parameters are width of the microstrip antenna, W,length of microstrip antenna ,L, height of microstrip antenna ,h , and effective permitivity of substance, ε_{eff} ,and in output layer resonant frequency has been obtained, the Mean square error in 2500 epochs of analysis is 10^{-5} ,that is reliable. in figure (4),frequency difference between formula and artificial neural network analysis is shown, it proofs good training of our analyzing network .In synthesis of artificial neural network of our paper ,our network consist :three neurons in input layer ,seven neurons in hidden layers and two neurons in output layer that parameters for synthesis here are permitivity of substrate ,ε_r, height of microstrip antenna ,h, and resonant frequency ,f_r , that all considered as inputs here. output of this synthesis are length of microstrip antenna ,L, and width of microstrip antenna ,W,. here the absolute mean square errors on 40 test datas are shown in figure (4) and (5) ,both are about 10^{-3} that are also reliable.

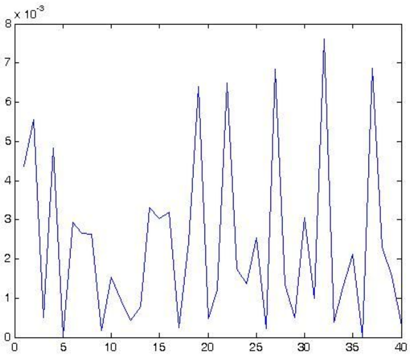

Figure4. error curve in synthesis of Length of microstrip antenna.(On 40 test datas).

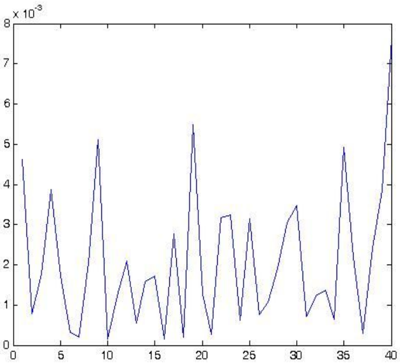

Figure5.error curve in synthesis of width of microstrip antenna.(On 40 test datas).

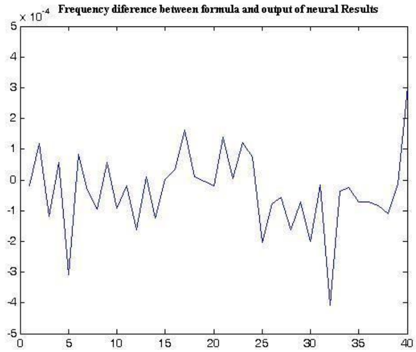

Figure6. frequency difference between Mathematical formula and Analyze of our artificial neural network.

3. Microstrip and Artificial Neural Network Method

In this work an artificial neural network model in introduced for the efficient calculation of Resonant frequency of rectangular microstrip antenna, The Multilayer perceptron network is selected due to its simplest and therefore most commonly used artificial neural network architectures have been updated for the calculation of the resonant frequency of rectangular microstrip antenna, in our paper the standard back propagation algorithm has been used for training, an multilayer perceptron consist three layers: an input layer, an output layer and an intermediate or hidden layer. Processing elements or neurons in the input layer only act as buffers for distributing the input signals x_i to processing elements in the hidden layer. Each neurons or processing element in the hidden layer sums up its input signals x_i after weighting them with the strengths of the respective connections w_{ji} from the input layer and computes its output y_j as a function f of the sum, namely[7][8][9].

$$Y_j = f(\mathbf{wji.xi}) \qquad (1)$$

Then f can be a simple threshold function, a sigmoidal or hyperbolic tangent function. The output of processing elements or neurons in the output layer is computed similarly. With training our artificial neural network consists of adjusting weights of artificial neural network with the use of the standard back propagation algorithm, the result of training that is our consequent resonant frequency of rectangular microstrip antenna , all the results that have been obtained from mathematical formula and our trained artificial neural network that is shown in figure(4),[2][3].

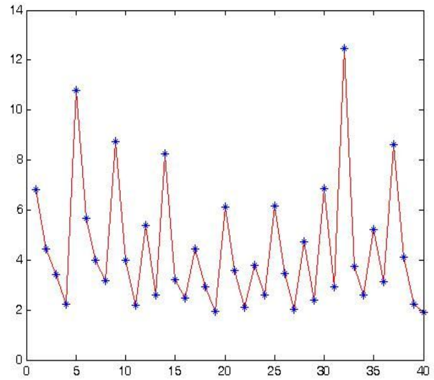

Figure 7. Mathematical results (shown by solid line), artificial neural network results (shown by asterisk)

The error reduction curve for algorithm considering training epochs is shown in figure(5).

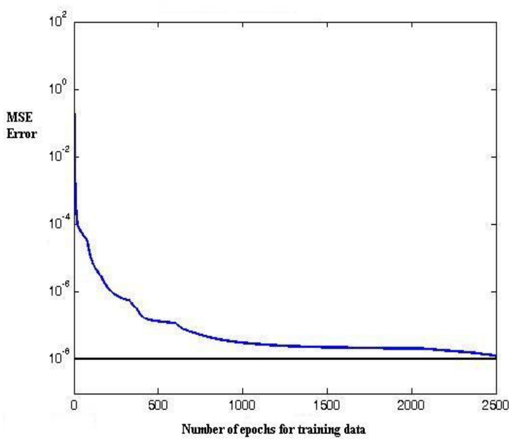

Figure 8. Error reduction curve versus epochs

4.Consequences

A method based on artificial neural network trained with the back propagation algorithm for calculating resonant frequency of rectangular microstrip antenna has been presented, in this paper our novel method of synthesis and analysis of artificial neural network have been described as can be seen from our simulation results and compare with mathematical and formula results some satisfactory consequence have been made by our learned artificial neural network ,however the error reduction curve is one proof of this result. The error that is shown in figure(5) is tolerable for most design applications, this method has been adapted for the computation of the resonant frequency of electrically thin and thick rectangular microstrip antennas, and also for engineering applications, the simple models are very usable. Thus The artificial neural network models given in this paper can also be used for many engineering and purposes because the results obtained using the models presented in this paper are very close to the experimental values presented in the literature.[10].

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Mohammad Naser Moghaddasi ,PhD,Member of Central Commission for Scientific, Literacy & Art Societies Islamic Azad University Science and Research Branch

Pouya Derakhshan Barjoei is a PhD student in Telecommunication Engineering at Islamic Azad University Science and Research branch, Tehran,IRAN,Faculty member of Electrical Engineering at Islamic Azad University Naein branch.

Alireza Naghsh is a PhD student in Telecommunication Engineering at Islamic Azad University Science and Research branch,Tehran,IRAN,Faculty member of Electrical Engineering at Islamic Azad University Najaf Abad branch.