ARTIFICIAL NEURAL NETWORK IN THE DESIGN OF RECTANGULAR MICROSTRIP ANTENNA

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ABSTRACT

A simple design to compute accurate resonant frequencies and the electric fields of rectangular microstrip antennas using artificial neural networks (ANN) is proposed. The ANN is developed to calculate the frequency and antenna's field. ANN is designed using multilayer perceptron networks (MLP). The results that were obtained accord the trained and tested data of ANN models. As a result, the ANN model is presented as a substitutional method to the detailed electromagnetic design of rectangular microstrip antenna.

KEYWORDS

Multilayer Perceptron Network, Rectangular Microstrip Antennas, Resonant Frequencies, Electric Fields.

1. INTRODUCTION

Nowadays, the systems of mobile communication need a movable wireless antenna size so as to meet the miniaturization needs of mobile units. One of the most appropriate antennas for mobile communication is a microstrip patch antenna owing to its attractive characteristics: low profile, light weight and easy fabrication. Currently, there are other governmental and commercial applications like radio and wireless communications which have identical specification. The use of microstrip antennas then can fulfil the previous requirements [1-2]. These antennas are low-profile with a compatibility with plane and non-plane surfaces. They are uncomplicated and do not cost much to build using the technology of modern printed circuit. Moreover, these antennas are mechanically strong when mounting on stiff surfaces and conformable with MMIC designs. In addition to that, they are very versatile in terms of resonant frequency, polarization, pattern, and impedance when selecting a specific patch shape and mode. Besides, the adjustment of adaptive elements with variable resonant frequency, impedance, polarization, and pattern can be realised by adding loads, like pins and diodes, between the patch and the ground plane [3]. Microstrip antennas are also called patch antennas due to the radiating elements (patches) photo engraved on the dielectric substrate. This radiating patch may take different shapes: square, circular, triangular, rectangular, elliptical or other shapes. This work is concerned with the rectangular ones under consideration “Figure 1”.

The increase demand of compactness of antenna size, bandwidth, reconfigurable antennas etc., has lead to the fast change in modern communication. As a consequence, the ongoing change of antenna parameter makes the design of antenna very difficult, cumbersome and time consuming since parameters must be calculated by the use of lengthy analysis and design cycles. According to papers’ reviews, the use of neural network have become very wide recently for wireless communication engineering. As a result, there is an elimination of complexity and time consumption of mathematical procedures of designing antennas such as method of moments

(MOM) [4]. The ANN model, artificial neural network, is designed to analyse microstrip antennas in different forms: circular, rectangular, and equilateral triangle patch antennas [5-6]. The emphasis here falls into two points: the resonant frequency and the electric field of antenna. Using ANN, an analysis is built to find out the resonant frequency and electric filed immediately for a given rectangular microstrip antenna system. These models are characterized by simplicity, easiness of application, and a very usefulness for antenna engineers.

2. RECTANGULAR MICROSTRIP ANTENNA

The rectangular microstrip antennas are constructed of a rectangular patch with dimensions, width, b, and length, a, over a ground plane with a substrate thickness h and dielectric constant (εr), as given in "Figure 1". Dielectric constant are usually used in the range of 1.2≤ εr ≤12. However, the most desirable ones are the dielectric constants in the lower end of this range together with the thick substrates, because they provide better efficiency, larger bandwidth, but at the expense of larger element size [7].

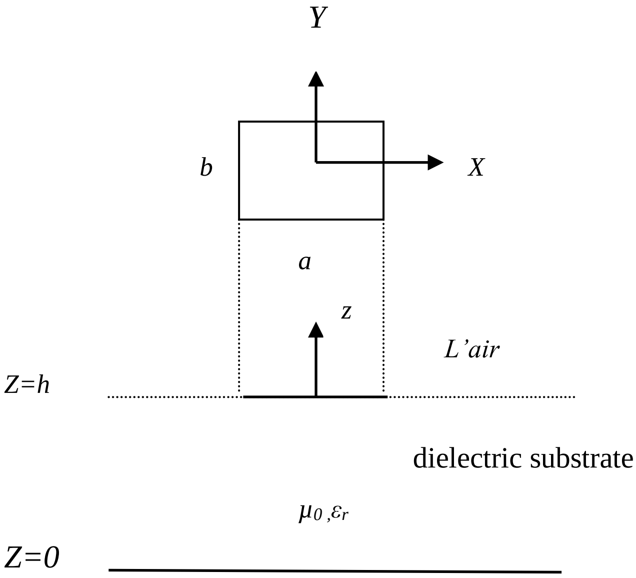

Figure 1. Rectangular microstrip antenna

3. RESONANT FREQUENCY AND ELECTRIC FILED OF RECTANGULAR MICROSTRIP ANTENNA

The formula for the resonant frequency of a rectangular microstrip antenna is obtained from the moments method (MOM). For the present paper, a simple formula was given as

$$E_x(x,y) = \frac{1}{4\pi^2}\iint_{-\infty-\infty}^{+\infty+\infty}\left[G_{xx}.\tilde{J}_x + G_{xy}.\tilde{J}_y\right]e^{i(K_x x+K_y y)}\,dK_x dK_y \quad (1)$$

$$E_y(x,y) = \frac{1}{4\pi^2}\iint_{-\infty-\infty}^{+\infty+\infty}\left[G_{yx}.\tilde{J}_x + G_{yy}.\tilde{J}_y\right]e^{i(K_x x+K_y y)}\,dK_x dK_y \quad (2)$$

To solve the equation moment method, we used Galerkin procedure

$$J_x(x,y) = \sum_{n=1}^{N} a_n J_{xn}(x,y) \quad (3)$$

$$J_y(x,y) = \sum_{m=1}^{N} b_m J_{xm}(x,y) \quad (4)$$

After some manipulation, we obtain this matrix:

$$\begin{bmatrix} (Z^1_{kn})_{NXN} & (Z^2_{km})_{NXM} \\ (Z^3_{ln})_{MXN} & (Z^4_{lm})_{MXM} \end{bmatrix} \begin{bmatrix} (a_n)_{NX1} \\ (b_m)_{MX1} \end{bmatrix} \tag{5}$$

Solving this system gives the resonance frequency

$$f = f_r + if_i \tag{6}$$

fi: the imaginary part of the resonance frequency .
fr: the real part of the resonant frequency.
The radiated electric field in the space is:

$$\tilde{\tilde{E}}(x,y,z) = \frac{1}{4\pi^2} \iint_{-\infty -\infty}^{+\infty +\infty} \tilde{\tilde{E}}_x(K_x, K_y, d).\, e^{-jk_{z0.}(z-d)} e^{j(K_x x + K_y y)}\, dK_x dK_y \tag{7}$$

By applying the stationary phase, we can calculate the field in remote area of the space:

$$\begin{bmatrix} E_\theta(r) \\ E_\emptyset(r) \end{bmatrix} = \begin{bmatrix} -\cos\emptyset & -\sin\emptyset \\ \cos\theta.\sin\emptyset & -\cos\theta.\cos\emptyset \end{bmatrix} \cdot \begin{bmatrix} E_x \\ E_y \end{bmatrix} \tag{8}$$

In the next section, a basic artificial neural network used in this article is described briefly and the application of neural networks to the calculation of the resonant frequency and electric filed of a microstrip antenna is then explained.

4. Design Problem for the Microstrip Antenna

In this work, we have developed two models. The resonance frequency of the microstrip antenna is obtained as a function of input variables, which are height of the dielectric material (h), dielectric constants of the substrate (εr), length (a) and width (b), using ANN techniques “Figure 2”. Similarly, the electric filed (E) of the antenna is obtained as a function of patch length (a), width (b), height of the dielectric substrate (h), the resonance frequency (fr) and dielectric constants of the material (εr) “Figure 3”. Therefore, the following subsections represent the first and the second step of ANN model which will be defined for the rectangular patch geometry.

4.1. The First Step of ANN Model

The input quantities to the ANN “Figure 2” can be ordered as:

- h: height of the dielectric substrate.
- a: length.
- b: width.
- εr: dielectric substrate.

The following quantities can be obtained from the output of the black-box as functions of the input variables:

- fr: the real part of the resonant frequency.
- fi: the imaginary part of the resonance frequency.

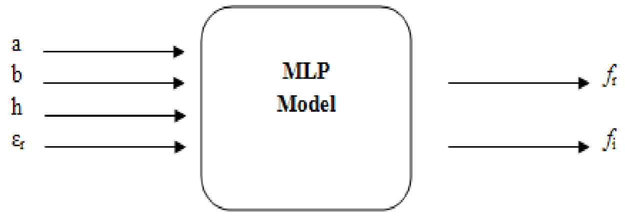

Figure 2. First step of ANN model

4.2. The Second Step of ANN Model

In the second step, we use a similar terminology of that in the first one. The electric filed (E) of the antenna is obtained from the output for a chosen dielectric substrate, height of the dielectric substrate, the real part of the resonant frequency, the length (a) and width (b) the input side as shown in "Figure 3".

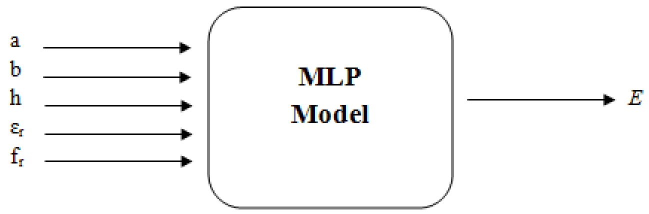

Figure 3. Second step of ANN model.

5. BUILDING NEURAL NETWORK FOR THE RECTANGULAR MICROSTRIP ANTENNA AND RESULTS

5.1. Multilayer Perceptron Networks

MLP are feedforward neural networks trained with the standard backpropagation algorithm. These networks are controlled, so they need a desired response to be trained. They are largely used for pattern classification and they are learning how to transform input data into a desired response. The networks can approximate virtually any input-output map with one or two hidden layers. The goal of presenting them is to approximate the performance of optimal statistical classifiers in hard problems. The majority of neural network applications include MLP. The basic MLP building unit is a simple model of artificial neuron. It calculates the weighted sum of the inputs plus the weight of the threshold and transmitting this sum through the activation function (usually sigmoid).

In a multilayer perception, the inputs to the next layer are formed by the outputs of the units in one layer. The compute of the network's weights is done by training the network using the back propagation algorithm [8].

5.2. MLP Modeling

We have obtained the training and test data of the ANN model from the method of moments (MOM) and the stationary phase. We have used 1000 examples for the training and 185 examples for the test. The data are in a matrix form. They consist of inputs and target values and arranged according to the problem's definitions. The MLP network that was used for the first step of the ANN model has a configuration of, 4 inputs, 12 and 8 neurons in two hidden layers and 2 outputs. In the second model, the MLP has a configuration of 5 inputs, 12 and 5 neurons in two hidden layers and 1 output. The sigmoid functions, linear are assigned respectively to the hidden and output layer. MLP trained with the standard back propagation algorithm.

5.3. Results

MLP network is the one which was given the best approximation to the target values in the first and the second step of the ANN model. Table 1 and 3 show the results of this model for an isotropic material and its comparison with the targets. The Comparison of measured, calculated frequencies [9-10-11] and our results is given in table 2. A good agreement with these frequencies can be noticed and the corresponding percentage error values are slight in the most cases.

Table 1: Results of the first step of ANN model and comparison with the targets

a (cm)	b (cm)	h (cm)	εr	fr-Target(GHz)	fr-MLP(GHz)	Errors	fi-Target(GHz)	fi-MLP(GHz)	Errors
4.00	2.75	0.15	3.00	4.8315	4.8789	0.04	0.0931	0.0940	0.0009
2.25	1.50	0.05	4.00	4.2415	4.1730	0.06	0.0790	0.0680	0.0100
3.50	2.75	0.35	3.25	5.1490	5.1169	0.03	0.0399	0.0388	0.0011
3.50	2.50	0.25	1.50	5.1430	5.1746	0.03	0.1148	0.1134	0.0014
3.25	2.25	0.35	3.50	5.2631	5.1639	0.09	0.0437	0.0596	0.0159

Table 2: Comparison of measured, calculated frequencies and our results

a (cm)	b (cm)	h (cm)	εr	Our Results (Ghz)	fr(Ghz) Mesured[9]	fr(Ghz) Calculated[10]	fr(Ghz) Calculated[11]
3.00	2.00	0.127	10.2	2.25	2.26	2.20	2.23
1.50	0.95	0.127	10.2	4.40	4.43	4.35	4.45
3.00	1.90	0.254	10.2	2.33	2.18	2.18	2.23
4.00	2.50	0.079	2.22	3.91	3.92	3.84	3.91
2.00	1.25	0.079	2.22	5.58	7.56	7.42	7.64

Table 3: Results of the second step of ANN model and comparison with the targets

a(cm)	b(cm)	h(cm)	εr	fr(GHz)	E-Target	E-MLP	Errors
2.50	2.00	0.25	2.50	4.2600	0.3248	0.3235	0.0013
4.50	3.00	0.05	3.00	2.8466	0.1153	0.1280	0.0127
3.75	3.00	0.15	3.25	2.6810	0.2726	0.2583	0.0143
3.00	2.25	0.25	2.50	3.8185	0.3918	0.3871	0.0047
3.00	2.50	0.25	2.70	3.4809	0.3959	0.3921	0.0038

6. CONCLUSIONS

The purpose of this study is to suggest a general design procedure for the microstrip antennas with the use of artificial neural networks. All this is shown through the use of the rectangular patch geometry. A multilayer perceptron based neural network model is presented in the aim of optimizing the design parameters of a microstrip antenna with better accuracy and less delay time. We can obtain the resonant frequency and the electric field with high accuracy.

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