Rectangular geometry antenna modeled on ferrite substrate

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Abstract: In this article, a general artificial neural network examination of a micro strip patch antenna is proposed using rectangular patch geometry modeled on ferrite substrate. The dimensions results, acquired by using ferrite as substrate for rectangular micro strip antenna and neural network models are very good unanimity with the experimental results available in the any printed material. Both deductive logic and examination of rectangular micro strip antenna models based on the artificial neural networks are presented to obtain patch dimensions of rectangular micro strip antennas (W, L) as the function of input variables, which are the height of the dielectric substrate (h), dielectric fixed value of the dielectric material $(\varepsilon x, \varepsilon y)$, and the reverberating frequency (f_r).
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1. Introduction

In recent years the application of magnetic materials increases as per the high frequency requirement. Ferrite is one of the important magnetic materials which are used as in both types single and polycrystalline. Some novel characteristics of polycrystalline ferrite over normal dielectric material make it very useful in microwave antenna applications. The use of ferrite due to its high dielectric constant make these antennas very low-profile, conformable to planar and non-planar surfaces, simple and inexpensive to manufacture using modern printed circuit technology [1-4].

Artificial neural network (ANN) have been very intensively explored from eighties, they have been used for adaptive controllers. Dealing with microwaves, ANN 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 micro strip antennas, reverse modeling of microwave devices, automatic impedance matching, etc. Using ANNs, microwave engineers have tried to simplify a rather difficult and time consuming design of microwave systems. ANNs are electronic system of hardware or software nature, which are built according to the example of a human brain. ANN consists of many simple non-linear functional blocks of a few types, which are called neurons. Neurons are organized into layers, which are connected by highly parallel synaptic weights, ANN exhibit a learning ability, which means that synaptic weights can be strengthened or reduced so that ANN can react on a given input pattern by a desired output one. This ANN, exhibit a very high operational speed.

In the any printed material, ANN models have been built usually for the examination of micro strip antennas in various forms such as rectangular, circular, and equilateral triangle patch antennas [5]. In these works, the examination problem can be defined as to obtain reverberating frequency for a given dielectric material and geometric structure.

However, in the present work, the corresponding deductive logic model is built to obtain dielectric fixed value of the dielectric material $(\varepsilon x, \varepsilon y)$ as the function of input variables, which are the height of the dielectric substrate (h), patch dimensions of rectangular micro strip antennas (W, L), and the reverberating frequency (f_r) (Fig.1). This deductive logic problem is solved using the electromagnetic formulae of the micro strip antennas. In this formulation, 2 points are especially emphasized: the reverberating frequency of the antenna and the condition for good radiation efficiency. Using reverse modeling, an examination is built to find out the patch dimensions of rectangular micro strip antennas (W, L) immediately for a given rectangular micro strip antenna system. The models are simple, easy to apply, and very useful for antenna engineers to predict both patch dimensions and reverberating frequency [6-7].

The rectangular micro strip antennas are made of a rectangular patch with dimensions width, W and length, L, over a ground plane with a substrate thickness h and dielectric fixed value $\varepsilon x, \varepsilon y$, as given in Fig.1. Dielectric fixed value are usually used in the range $2.2 \le \varepsilon_r \le 12$. However, the most desirable ones are the high dielectric constant for low profile, surface wave reduction etc.

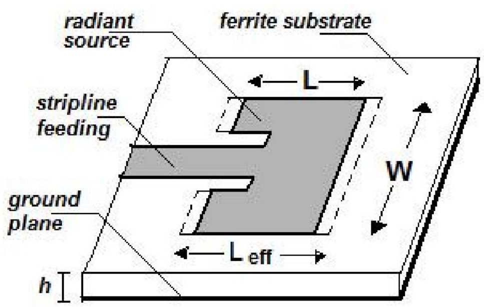

Figure 1. Geometry of single patch

In the any printed material, almost all works have been done by choosing the dielectric substrate to be in an isotropic structure. In this work, the model is capable of giving results for both isotropic and anisotropic structures of the dielectric substrate as well as ferrite substrate respectively. For an anisotropic ferrite substrate, the spacing parameter h is replaced by the effective spacing h_{eff}, and the geometric mean ε_m is used for the dielectric constant ε_r.

$$h_{eff} = h\sqrt{\frac{\varepsilon_r}{\varepsilon_m}}, \varepsilon_m = \sqrt{\varepsilon_x \varepsilon_y}$$

$$\varepsilon_{eff} = \frac{\varepsilon_m + 1}{2} + \frac{\varepsilon_m - 1}{2\sqrt{1 + 12\frac{h_{eff}}{W}}}$$

Width and Length

$$W = \frac{c}{2f_r}\sqrt{\frac{2}{\varepsilon_m + 1}}, L = \frac{c}{2f_r\sqrt{\varepsilon_{eff}}} - 2\Delta L$$

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

where ΔL is the extension of the length due to the fringing effects.

2. Neural Network Examination

The input/output quantities to the deductive logic and examination are shown in Figures 2. and 3. respectively. In the examination side of the problem, terminology similar to that in the deductive logic mechanism is used, but the dielectric constant of the antenna is acquired from the output for a chosen reverberating frequency and patch dimensions at the input side (Figure 3.).

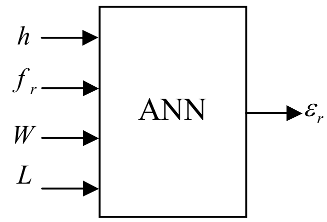

Figure 2. Forward side model

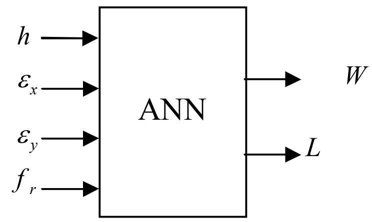

Figure 3. Reverse side model

Where, H, height of the dielectric substrate, $\varepsilon_x, \varepsilon_y$ permittivity in the x and y directions respectively of the ferrite material, f_r, reverberating frequency of the antenna, W, width of the patch, L, length of the patch.

Feed forward NNs with a single hidden layer that use radial basis activation functions for hidden neurons are called radial basis function networks. Feed forward NNs are applied for various microwave modeling purposes. A typical feed forward NN structure is given in Figure 4. The parameters c_{ij} and λ_{ij} are centers and standard deviations of radial basis activation functions. Commonly used radial basis activation functions are Gaussian and multi-quadratic. Given the inputs x, the total input to the i th hidden neuron is given by

$$\gamma_i = \sqrt{\sum_{j=1}^{n}\left(\frac{x_j - c_{ij}}{\lambda_{ij}}\right)^2}, i = 1, 2, 3, ..., N$$

where N is the number of hidden neurons.

The output value of the i th hidden neuron is $z_{ij} = \sigma(\gamma_i)$ where $\sigma(\gamma)$ is a radial basis function. Finally, the outputs of the feed forward NN are computed from hidden neurons as

$$y_k = \sum_{i=0}^{N} w_{ki} z_{ki}$$

In above equation w_{ki} is the weight of the link between the i th neuron of the hidden layer and the

k th neuron of the output layer. Training parameters w of the feed forward NN include w_{k0}, w_{ki}, c_{ij}, λ_{ij}, $k = 1, 2, \cdots, m$, $i = 1, 2, \cdots, N$, $j = 1, 2, \cdots, n$.

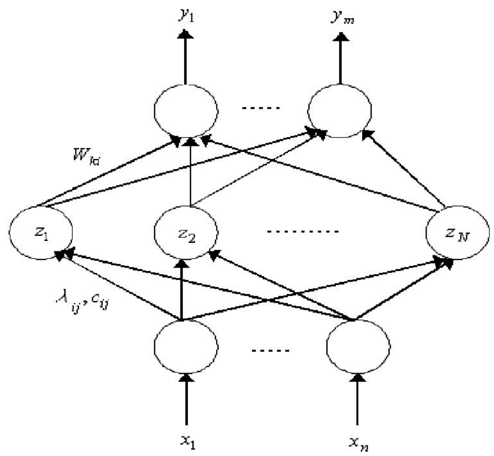

Figure 4. Feed forward neural NN structure

3. Experimental Results

As we can see from Table 1. for deductive logic and examination respectively, feed forward neural an isotropic material ($\varepsilon_x = \varepsilon_y$) and comparison with the targets giving the optimal accuracy.

Table 1. Results of the examination and comparison with target

h (cm)	ε_r	f_r (GHz)	W-target (cm)	W-FEED FORWARD NEURAL (cm)	L-target (cm)	L-FEED FORWARD ANN (cm)
0.165	17.5	10.23	0.6818	0.73338	0.35051	0.37731
0.165	17.5	9.93	0.7024	0.73338	0.3611	0.37731
0.165	17.5	9.83	0.7095	0.73339	0.36477	0.37731
0.165	17.5	8.5	0.8206	0.7347	0.42185	0.37776
0.165	17.5	8.3	0.8403	0.73669	0.43201	0.37845
0.165	17.5	6.23	1.1196	1.0653	0.57555	0.57555
0.165	17.5	6.23	1.1196	1.0653	0.57555	0.57555
0.165	17.5	10.23	0.6818	0.73338	0.35051	0.37731
0.254	17.5	10.73	0.6500	0.73338	0.33417	0.37731
0.265	17.5	9.28	0.7516	0.73338	0.38639	0.37731
0.156	16.55	9.23	0.7759	0.73338	0.39948	0.37731
0.156	16.55	11.03	0.6492	0.73338	0.33428	0.37731
0.2655	16.55	11.2	0.6394	0.73338	0.32921	0.37731
0.2655	16.55	7.93	0.9030	0.73338	0.46496	0.37731
0.1655	17.55	7.28	0.9568	1.0657	0.49184	0.49183

4. Discussions

In this paper, the examination is considered as a final stage of the design procedure, therefore the parameters of the examination network are settled by the data acquired altering the input-output data of the deductive logic network. Thus, reverberating frequency resulted from the combined separate elements antenna geometry is examined against the target in the examination network. Finally, in this work, a general design procedure for the micro strip antennas is suggested using ANNs and this is demonstrated using the rectangular patch geometry and the NN is employed as a tool in design of the micro strip antennas. Therefore, one can obtain the geometric dimensions with high accuracy, which is the length and the width of the patch in our geometry, at the output of the deductive logic network by inputting reverberating frequency, height and dielectric fixed value of the chosen substrate.

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