MODELING MICROSTRIP ANTENNAS BY NEURAL NETWORKS

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ABSTRACT

Microstrip antennas are more and more used in current radio communications. Hence, programs for their optimization and design are needed. In order to improve efficiency of such programs, artificial neural networks (ANN) are exploited. ANN can be used to approximate behavior of the designed structure. The paper describes the structure of ANN and their utilization for modeling microstrip patch antennas.

1 MICROSTRIP ANTENNAS

Microstrip antenna consists of three parts: a patch, a dielectric layer, and a ground plane. These antennas are thin and light, and hence, they are most used in aviation and mobile applications. Whereas they are not able to work with high power, they are used mainly in low-power transmitters and receiving applications.

2 NEURAL NETWORKS

Neural networks (NN) are electronic systems, which can be trained to remember the behavior of a modeled structure in given operational points, and which can be used to approximate behavior of the structure out of the training points.

Neural networks consist of layers of simple functional blocks - neurons. The model of the neuron is depicted in Fig. 1. The model of the neuron can be divided into three basic parts:

1. The group of synapsis and connecting lines; each of them is described by a weight.
2. The accumulator for summation of input signals.
3. An activation function for limiting the amplitude of the output of the neuron.

A neuron can be mathematically described by following two equations:

$$u_k = \sum_{j=1}^{p} w_{kj} x_j \tag{3.1}$$

$$y_k = \varphi\,(u_k - \theta_k) \tag{3.2}$$

where x_1, x_2, ..., x_p are input signals; w_{k1}, w_{k2}, ..., w_{kp} are synaptic weights of neuron k; u_k is the output of linear accumulator; θ_k is treshold; φ(.) is activation function and a y_k is the output signal.

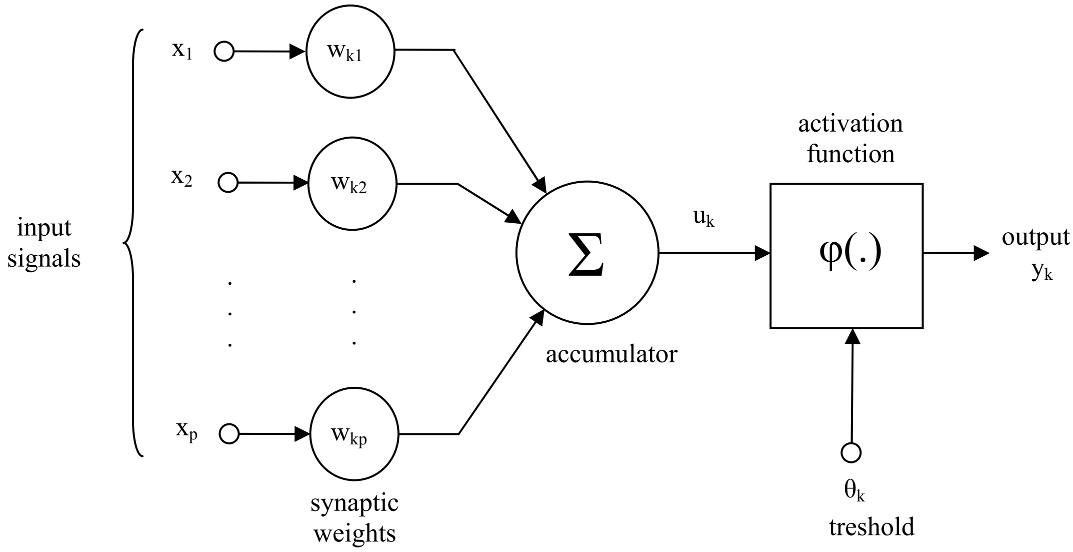

Fig. 1 *A nonlinear model of the neuron*

The way, which neurons are connected to whole network in, is described by the so-called network architecture. We distinguish between feed-forward networks and recurrent networks. A feed-forward network statically maps input patterns to output ones, a recurrent network maps input sequences to output ones. In case of modeling of our microstrip antenna, we use a feed-forward network.

Among the most interesting properties of neural networks, their ability to learn belongs. The set of well-defined rules for training the network is called the learning algorithm. In case of our networks for modeling microstrip antennas, we used so-called learning with teacher.

The availability of external teacher, whose knowledge is represented by set of input-output patterns, is the necessary condition for learning with teacher. The teacher is then able to provide the required response for the input pattern to the neural network. This response represents the optimal behavior of the neural network. The parameters of the network are then modified under the combined influence of the training vector and the error signal.

3 NEURON MODEL OF MICROSTRIP ANTENNA

For neural modeling, we have chosen the microstrip antenna with the rectangular patch. The antenna is modeled with the following parameters: the height of the substrate 1,27 mm, the relative dielectric constant of lossless substrate 4,5 (Arlon AR450); the patch is perfectly electrically conductive.

The width and the length of the patch antenna are the input parameters of the model. The results are resonant frequency and resonant antenna resistance.

For modeling of the antenna, we use *Neural Network Toolbox* of Matlab. The input patterns are elements of the 2-row matrix of different widths and lengths of the antenna patch, output patterns are corresponding resonant frequencies and resonant antenna resistances (for their calculation, we use MStrip program).

We use a multilayer feed-forward neural network for modeling. Neural network consists of one input node, two hidden layers with four and three neurons, and output layer with two neurons. Output neurons contain bipolar sigmoid as an activation function.

In the first step, we sample the input space of NN with a constant sampling step. We choose a relatively long step in order to obtain an initial notion of the behavior of the net with minimal effort. In the next step, we change the sampling to achieve a required accuracy.

Next, we choose the number of hidden neurons. Then, we train the net with a Bayessian training algorithm. By this, we find out the number of effective used parameters. Then, we change the number of hidden neurons to reach the number of effectively used parameters between 50% and 90%.

When the structure of NN is designed, we have to choose the proper training algorithm. The Matlab program offers several algorithms. In our case, moment adaptive algorithm worked as the fastest, but at the cost of the highest learning error. Levenberg-Marquardt algorithm appears as an optimal. Its speed is average, but achieved training error is the lowest. So we use Levenberg-Marquardt algorithm for training of our NN.

The behavior of NN out of training points is decribed by the cumulative error. The value of the relative error could be lower than 10%. In case of exceeding this value in some areas, we have to resample this areas with smaller sampling step and train the net again. It wasn't necessary in our case, because the error was under the limit in the whole range of input patterns.

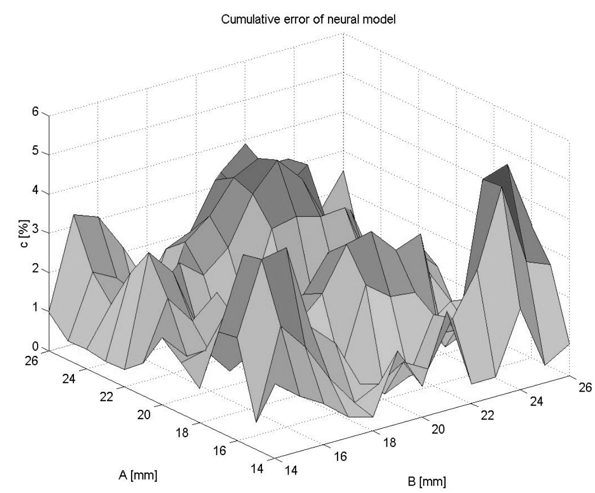

Fig.2 *The error of neural model*

4 CONCLUSION

We described the utilization of NN for modeling of microstrip antenna in this paper. We proposed principal procedure of creating neural model and we checked this procedure in practice.

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