PARAMETRIC TEST OF ANTENNAS USING THE NEURAL NETWORKS

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1. Introduction

The neural networks are currently very important part of the artificial intelligence. Some systems are very difficult to describe or their description is practically impossible due to their complexity. If the input data of such a system as well as the corresponding responses are known, it is possible to approximate the function of the system. The artificial neural networks are often used as universal approximators. Before using the neural network as an adaptive computing system, it is necessary to train the network to solve the problem.

Taking aforementioned into account, the neural networks have been considered to be very useful for electronic testing. Firstly, selected parameters or waveforms of a circuit under test (CUT) are measured and evaluated. Based on these parameters, the proper function of the CUT can be detected. In this way, one can create a training data set, which contains training objects representing the correct and incorrect circuit functions. After the training phase is finished and the neural network is satisfactory trained, the neural network can correctly classify 'unknown' tested circuits through evaluation of different parameters.

2. Experimental part

In our experiment, the feed-forward neural networks were employed to classify miniature antennas though the evaluation of several antennas parameters measured in the production test.

During the experiment, firstly, 6-wire miniature antennas with a ferrite core were tested. Dimensions of the ferrite core were 0.6 mm x 0.6 mm x 9mm. The antennas were designed to have a maximum of radiance at 12.5 MHz. Fig.1. shows the schematic diagram of the measurement circuit employing the H-bridge and the tested antenna. The circuit was controlled with two non-overlapping signals A and B, and their inverted signals A' and B'. Non-overlapping signals had a constant overlay of 4 ns. Waveforms of the non-overlapping signals A and B with frequency of 20 MHz are shown in Fig.2. The antennas were measured for frequencies in the range from 10 MHz to 20 MHz with a step of 0.1 MHz. Antenna measurements were made using a dedicated software called OntioLab that was developed at our department for this purpose, and contains controls for communication with measuring instruments, power sources, function generators and oscilloscopes. The program performs automated measurement, while the function generator sets the parameters of the non-overlapping signals for each frequency measurement point. Frequency measurement points were defined in a simple text file that was fed to the software. Each line contained a single frequency point, so the range and the step could be easily adjusted. For the tests described in this paper, frequency step of 100 kHz was used, except for the range from 12.2 MHz to 13 MHz, where the step was reduced to 10 kHz. Measurement settings in OntioLab allow the controll over the overlay of generated signals as well as the time step between two measurements. These values were set during the measurements to 4 ns and 0.3 s, respectively. Furthermore, the program reads the current consumption from the digital multimeter at each frequency. Then, the software reads the amplitude of the radiated field from the oscilloscope, which has been measured using a single loop detection antenna at a distance of 4 cm from the antenna under test. Last parameter measured was the DC resistance of the antennas using the four-wire method.

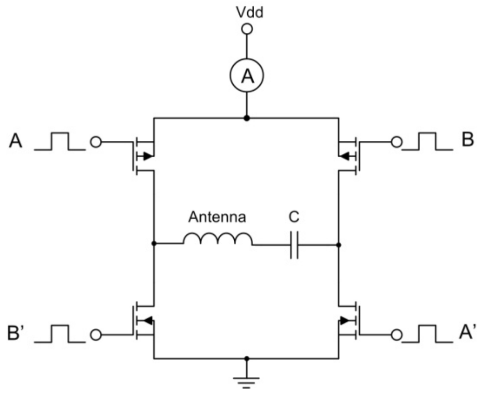


Fig.1. *Schematic diagram of the measurement circuit.*

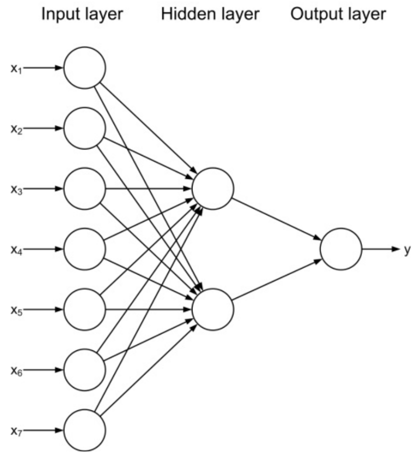
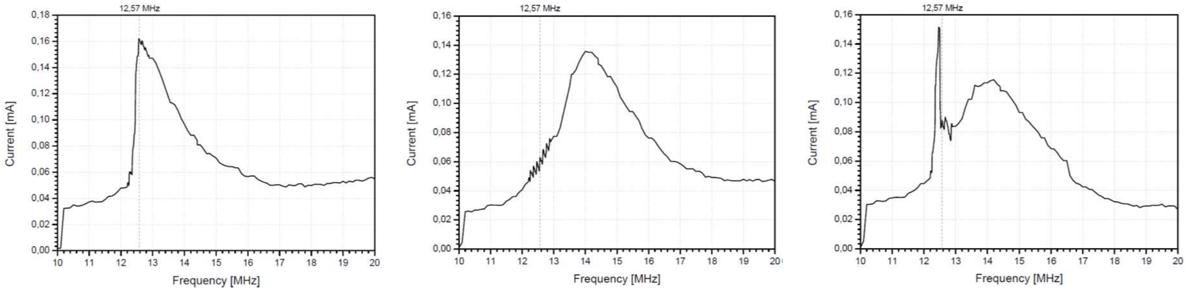


Fig.2. *Topology of a Feed-forward neural network*

In the next step, a feed-forward neural network was used for detecting the correct function of antennas, and the classification of tested antennas was performed. The developed software OntioLab includes a tool for creating and training a neural network, where the parameters of the neural network need to be set. These include the number of hidden layers, number of neurons in the hidden layers, the number of input and output neurons and learning parameters (learning coefficient λ, momentum μ, the maximum error E_{max} and the maximum number of iterations). The topology of the feed-forward neural network used for the antenna classification in this experiment is shown in Fig.2. The input layer contains 7 input neurons that represent inputs to the neural network, the hidden layer contains two neurons and the output layer consists of one neuron. The neural network output takes values in the range <0;1>. We chose two neurons in hidden layer because this neural network is able to correctly classify tested antennas. Basic principles of design topology of neural networks are referred in [1,2,3,4].

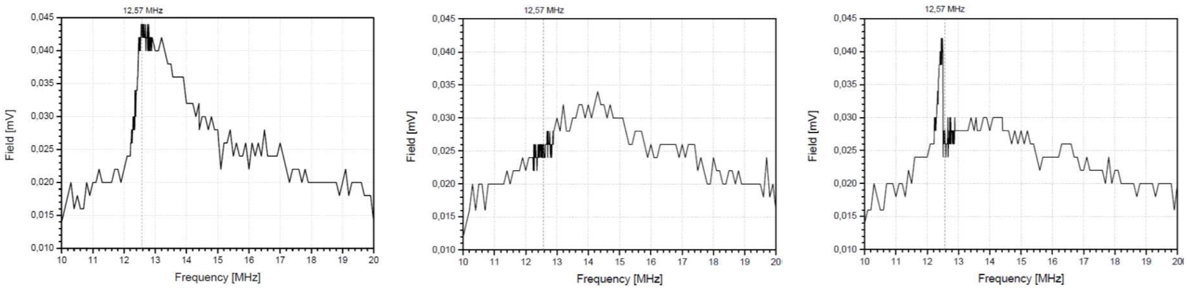
3. Results

Two waveforms were obtained during a particular antenna test. The first one is the current consumption dependence of the circuit in the assumed frequency range. Shape examples of the current consuption are shown in Fig.3. The second waveform represents dependence of the radiated field intensity on the generated frequency. Shape examples of the radiated field intensity are shown in Fig.4. The intesity of radiated field was measured at the distance of 4 cm from the antena under test by using a single loop detection antenna. Six parameters of these waveforms were investigated. First parameter was the maximum current consumption frequency f_{Imax}. Other parameters were the maximum intensity of radiated field U_{max}, intensity at frequencies 13.56 MHz ($U_{13.56}$) and 14.4075~MHz ($U_{14.4075}$), and the minimum value of the first derivative for both waveforms (d_{1I} and d_{1U}). These 6 parameters together with the DC resistance were applied to the neural network as the input data. Based on this data processing, the proper function of the antennas could be identified by the neural network.



(a) *Normal current consumption behavior.* (b) *Faulty behavior with a shifted maximum.* (c) *Faulty behavior with a sharp peak.*

Fig.3. *Exmaples of the current consumption as a function of frequency.*



(a) *Radiated field intensity of a good antenna.* (b) *Faulty behavior with a shifted maximum.* (c) *Faulty behavior with a sharp peak.*

Fig.4. *Examples of the radiated field intensity as a function of frequency.*

Current consumption and the radiated field intensity dependency measured on antennas with corect parameters are shown in Fig.3a. and Fig.4b, respectively. The maximum is located approximately at frequency of 12.57 MHz in both waveforms. The potentionally increased value of the DC resistance will not necessarily be reflected in these waveforms. Such an increase could be caused by a bonding contact between the antenna wires and contact pads of the antenna. Examples of waveforms obtained by the measurement of a defective antenna are shown in Fig.3b. and Fig.4b.

These errors are easy to detect since the maximum current frequency is significantly shifted, and also there are increased values of the current cunsumption at frequencies of 13.56MHz and 14.4075 MHz. On the other hand, poorly detectable errors are shown in Fig.3c. and Fig.4c. Typical characteristic observed for these waveforms is one or more sharp peaks. In these cases, the maximum current frequency as well as the maximum intensity of the radiated field might still be the same as for a good antenna. For such cases, the minimum value of the first derivative of both waveforms by frequency was used. This minimum value of first derivative represents the steepest descent in the current consumption or the radiated field intensity as a function of frequency. Such a descent is small for correct waveforms without sharp peaks (Figures 3a, 3b, 4a and 4b). In contrast to that, the very step descent was observed in waveforms with sharp peaks. Sharp peak errors are sometimes detectable from the current consumption values at frequencies 13.56 MHz and 14.4075 MHz.

In our experiment, a feed-forward neural network was used for the classification of antenna parameters. The neural network architecture was composed of the input layer with 7 neurons, one hidden layer with two neurons and the output layer with one neuron. The training data set was created by data obtained from the measurement of 100 tested antennas, and such a set consisted of a uniform distribution of good and faulty antenna parameters. Required output of the neural network was set to 1 for antennas with correct parameters, otherwise it was set to 0. Learning process of the neural network took approximately 40000 iterations. Learning of the neural network runs until the maximum output error is not greater than $E_{max} = 0.1$. Antenna with the output of neural network in the range $<1 - E_{max}, 1>$ was classified as correct. The output of the neural network in the range $<0; E_{max}>$ indicated a faulty antenna. In other cases, the anenna was classified as unclassified. Proper functionality of the neural network classification has been verified on 600 tested antennas, which were previously evaluated. The neural network recognized 100% of faulty antennas, while 12 antennas were unclassified. Unclassified result occurred in cases where the parameters were slightly worse than the correct antennas parameters. As the next step, other 1000 antennas were evaluated using the neural network and the results were verified. In all cases, the neural network was able correctly classify the tested antennas.

4. Conclusion

Antennas with ferrite cores were tested in our experiment. The serial resistance, current consuption and the intensity of radiated field as a function of frequency were evaluated. Frequency was changed in the range from 10 MHz to 20 MHz with various step. From the measured dependencies, the frequency related to the maximum current consumption and the maximum intensity of radiated field, and the intesity at frequencies 13.56 MHz and 14.4075 MHz were obtained. The minimal value of the first derivative of both waveforms was used to detect sharp peaks. The feed-forward neural network wass used to clasify the tested antennas. The neural network consisted of three layers, where the input layer contained 7 neurons, the hidden layer was composed of two neurons and the output layer consisted of one neuron. Training data set was created by 100 measured antennas, which consisted of a uniform number of good and faulty antenna parameters. The correct classification of the neural network has been verified on 1600 tested antennas. The neural network has detected all defective antennas and recognized the antenna with slightly worse parameters.

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