Neural Network Based Software for Modeling Printed Pentagonal Dipole

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Abstract- **This paper presents software for modelling printed pentagonal dipole. The software is based on neural model that calculates dipole resonant frequency versus dipole dimension and substrate dielectric constant. The neural model training and test set consist of results get by WIPL-D software package. WIPL-D uses Method of Moments enabling high accuracy of results, but also causing a long simulation time. Unlike this software, artificial neural network can achieve both great simulation speed and the satisfactory accuracy.**

Keywords – **printed antenna, pentagonal dipole, neural network**

I. INTRODUCTION

Printed antennas, including microstrip and printed antennas, have several well known advantages over other antenna structures, including their low profile, light weight, low cost of production and compatibility with microwave monolithic integrated circuits (MMICs) and optoelectronic integrated circuits (OEICs) technologies [1]. Because of these merits, forms of the printed antenna have been utilized in many applications such as in mobile communication base stations, spaceborne satellite communication systems and even mobile communication handset terminals. Also, it was ease of fabrication and development.

For this reason, design techniques for printed antennas have attracted much attention from antennas researches [2]. The most known method used for modeling printed antennas is the electromagnetic simulation. Although it is very correct process, it has some disadvantages which can not satisfy requirements of communication systems designing under some circumstances. Its basic disadvantage is that electromagnetic simulation has high demands concerning the hardware resources necessary for its software implementation. The software implementation itself might be very complicated and faced with many difficulties. Also the time needed for numerical calculation by electromagnetic simulation could be unacceptably long. The method of moments (MoM) is a very popular algorithm of computer electromagnetic calculations. It is widely used for antenna simulations and electromagnetic wave scattering analysis due to its good accuracy. The MoM is based on transformation of field equations into a system of linear equations [3]. The mathematical basis for the MoM has been known for a long time however, the method was used for solving particular electromagnetic-field problems, such as the analysis of linear antennas in the early 1950s. The main disadvantages of the MoM is demand to solve a large number of time-consuming complex electromagnetic equations.

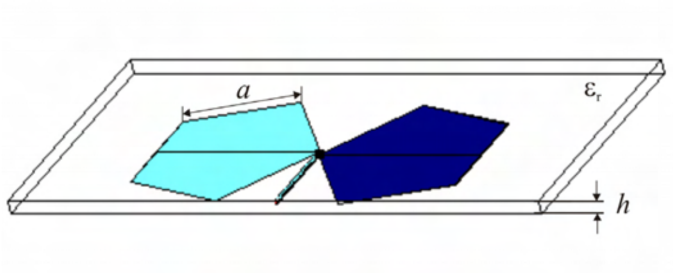

Fig.1. Printed pentagonal dipole

The previous researching, concerning the modeling of slotted patch antennas have showed that the neural network models can have satisfactory accuracy similar as MoM but also can have higher simulation speed then EM simulations [4-7]. In this researching, it is shown that neural network could be very successfully for slotted patch antenna modeling carried out in the field of signal and noise modeling of these devices. Recent research [8] point out that neural network can be good tool for modelling printed pentagonal dipole resonant frequency versus its dimension. This paper suggests neural model of pentagonal dipole that calculates resonant frequency versus dipole dimension and substrate dielectric constant. It is incorporate in the software enabling great simulation speed, same accuracy as MoM accuracy and user friendly work.

II. PRINTED PENTAGONAL DIPOLE

The printed pentagonal dipole is presented on Fig.1. It consists of two regular pentagons of dimension *a* that are situated on substrate with dielectric constant e_r and heigh *h.* One half of pentagon is in on side of dielectric and other half is on opposite side of dielectric. The dipole is fed by symmetrical microstrip lines of input impedance of 100 Ω. The corner reflector is consists of two metal plates which is situated at an angle of 45°. Proposed dipole is used as element of printed arrays enabling side (SLS) lobe suppression better than 34 dB in E-plane [9]. Such impressive SLSs are hardly achievable with conventional microstrip antenna arrays (with patches). In microstrip antenna arrays presented in literature, side lobe levels are suppressed 25 dB (related to main lobe) at best. For this reason, the tools for modelling printed pentagonal dipole are research in this paper.

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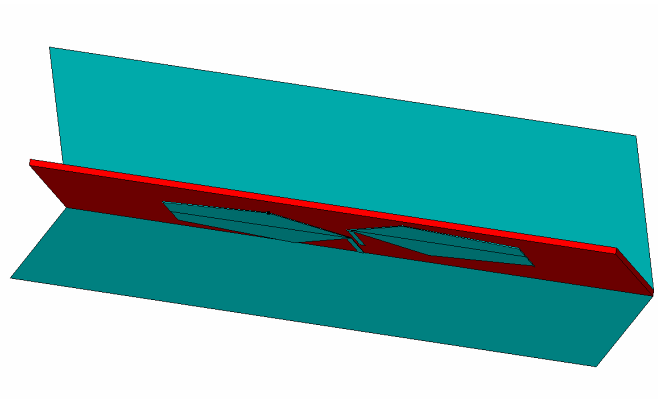

Fig. 2. Model of printed pentagonal dipole in WIPL-D software

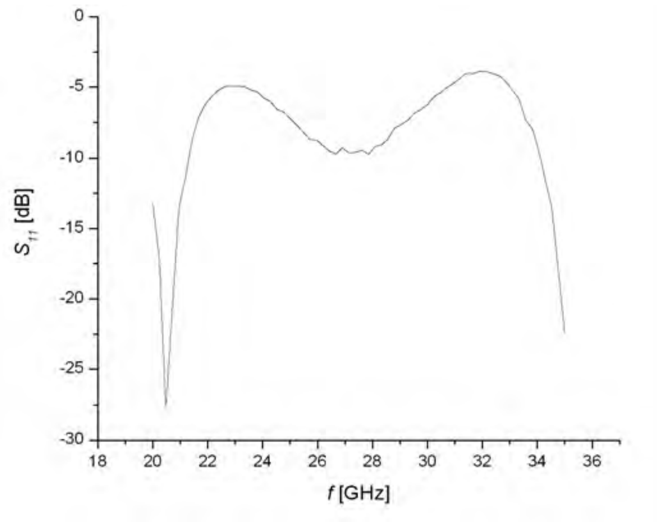

Fig. 3. Simulated S_{11} paremetrs for pentagonal dipole side a= 5mm obtained by software WIPL-D

III. Modeling Printed Pentagonal Dipole Using WIPL-D Software

WIPL-D is a commercial software for high frequency electromagnetic modeling and simulation. For over a decade, it has been a useful and reliable assistant to experts both in industry and academia. This software is specially tailored for research and design of antennas and microwave circuits as well as for analysis of scatterers and EMC problems [10]. It enables modeling of arbitrary metallic and dielectric 3D structures with wires, plates and parametric objects. Also, it uses higher order basis functions and the Method of Moments (MoM) to provide highly efficient analysis. For electrically large structures, special techniques such as multilevel fast multipole method and smart reduction of expansion order boost the performance even further.

The model of printed pentagonal dipole in WIPL-D software is presented in Fig. 2. WIPL-D software enables the simulation of Y-parameters, Z-parameters, S-parameters (Fig. 3.), radiation pattern, etc. The main disadvantage of WIPL-D software is long simulation time, especially when the process of modelling antennas must be done in some period of time.

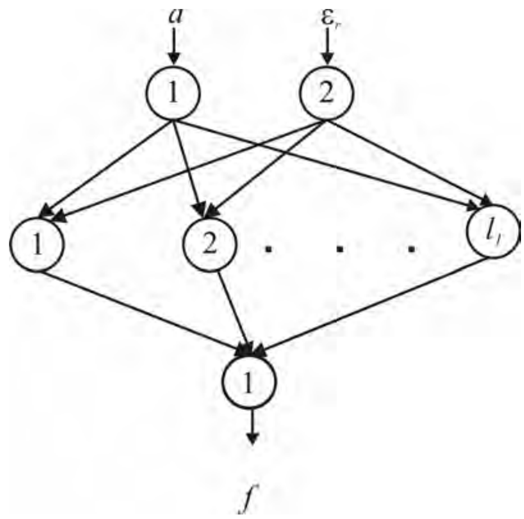

Fig. 4. Neural model of printed pentagonal dipole

IV. Modeling Printed Pentagonal Dipole Using Neural Networks

An Artificial Neural Network is very sophisticated modeling techniques capable of modeling extremely complex functions. Indeed, anywhere that there are problems of prediction, classification or control, neural networks can be introduced [11,12].

The neural network is inspired by the way biological nervous systems, such as the brain, process information. It is composed of a large number of highly interconnected processing elements - neurons working in unison to solve specific problems. Typically, a number of neurons are organized in layers. The input layer is not really neural at all: these neurons simply serve to introduce the values of the input variables. The latest layer of neural network is output layer and its neurons give output of neural network. Other neurons, which are not connected with input or output links, are hidden neurons. The hidden and output layer neurons are each connected to all of the neurons in the preceding layer. These neurons receive a number of inputs, either from original data or from the output of other neurons in the neural network. Each input comes via a connection that has a strength or weight. Each neuron also has a single threshold value. The weighted sum of the inputs is formed, and the threshold subtracted, to compose the activation of the neuron. The activation signal is passed through an activation function (transfer function) to produce the output of the neuron. In this way, signals flow from inputs, forwards through any hidden neurons, eventually reaching the output neurons and forming feedforward neural network.

Neural networks learn by example. The neural network user gathers representative data, and then invokes training algorithms to automatically learn the structure of the data. Neural networks are applicable in virtually every situation in which a relationship between the predictor variables-inputs and predicted variables - outputs exists, even when that relationship is very complex and not easy to articulate. The key feature of neural networks is that they learn the input/output relationship through training. In supervised learning, the network user assembles a set of training data. The training data contains examples of inputs together with the corresponding outputs, and the network learns to infer the relationship between the two.

MLP neural network for modeling printed pentagonal dipole consists of input, one hidden and output layers (Fig.4.). The number of input layer neuron is equal to number of dipole parameters that determine modeling. In this application, there are two input parameters: dipole dimension a and substrate dielectric constant ε_r. The number of hidden layer neurons is variable during training process and output layer has one neuron that gives resonant frequency f_r. The MLP network models the function:

$$[f_r] = f\ (a, \varepsilon_r) \tag{1}$$

The activation functions of the hidden layers are sigmoid, while the neurons of the output layers have linear activation functions. The neural networks were trained using Levenberg-Marquardt method with 10^{-4} performance goal. The notation of MLP models is MLPn-l_1-l_2-…-l_{n-2} where n represents layer number and l_1-l_2-…-l_{n-2} are the numbers of neurons of its each hidden layer.

The values of resonant frequency fr necessary for the training and the test MLP neural networks, were obtained by WIPL-D software. This software uses method of moments to calculate S_{11} parameter for certain frequency f of pentagonal dipole with specific dimension. Training and test sets consist of only resonant frequency f_r defined by minimum value of S_{11} parameters for specific dipole.

Pentagonal dipole, modeled in this paper, has a substrate with height h=0.254 mm. The width of fed line w depends on substrate dielectric constant ε_r and its range is [0.23 mm, 0.198 mm][13]. The other dipole parameters are changeable. In the training set with 33 samples two input parameters have following range: 3 mm≤a≤7 mm and 2.1≤ε_r≤2.5.

V. Simulation Results

The test set contained 10 samples that have not been used in training process. Test results of successfully trained MLP networks are presented in the Table I together with the average test error (*ATE*), the worst case error (*WCE*) and the Pearson Product-Moment correlation coefficient (r^{PPM}). The minimum of average test error and the maximum value of r^{PPM} coefficient represent the basic criterion for selection the best MLP network. Selected neural model is MLP3-4.

At first, generalization level of MLP3-4 model should be checked. First, dependence of resonant frequency f_r on pentagonal dipole dimension a for different dielectric constant ε_r obtained by MLP3-4 compared with WIPL-D simulation is shown in Fig. 5. This figure shows the satisfying accuracy of neural model compared with MoM simulation results. The similar conclusion can be done in Fig. 6. that shows how resonant frequency f_r depends on dielectric constant ε_r for different values of pentagonal dipole dimension a.

TABLE I
TEST RESULTS

MLP model	*WCE* [%]	*ACE* [%]	r^{ppm}
MLP3-4	3.8106	1.3908	0.9992
MLP3-3	3.1403	1.6080	0.9990
MLP3-2	3.9077	1.4751	0.9990
MLP3-5	3.6858	1.5806	0.9988
MLP3-6	4.8766	1.6835	0.9983
MLP3-7	3.3281	1.6863	0.9983
MLP3-12	4.7610	1.9812	0.9977
MLP3-13	9.6557	4.6384	0.9891

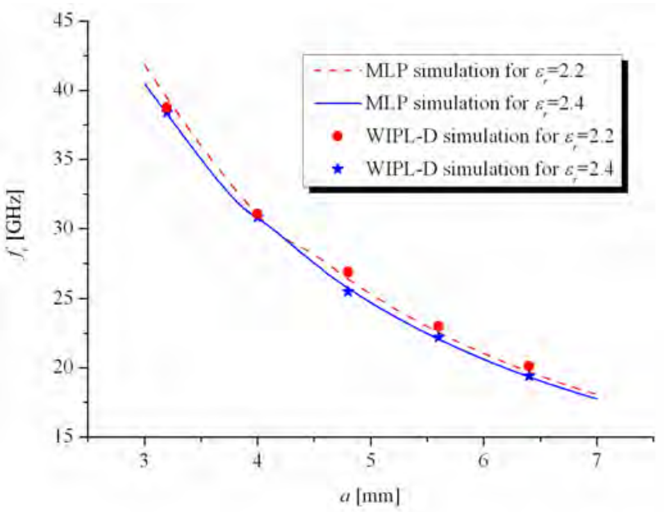

Fig. 5 Resonant frequency f_r versus pentagonal dipole dimension a for ε_r=2.2 and ε_r=2.4

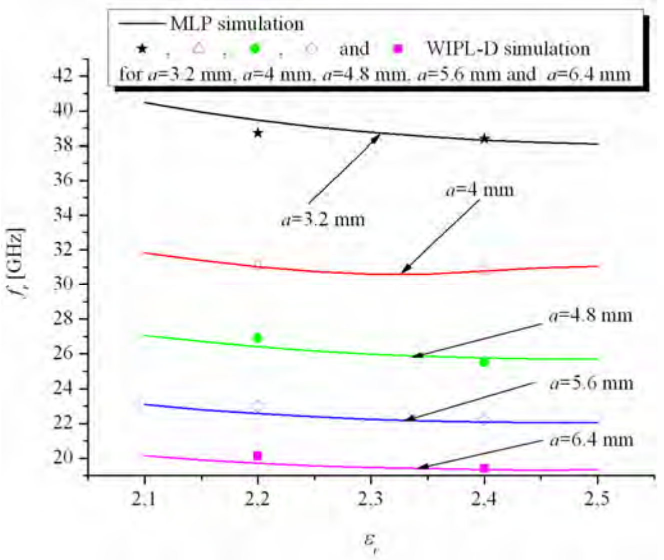

Fig. 6 Resonant frequency f_r versus dielectric constant ε_r for different pentagonal dipole dimension a

Further, proposed neural model improves pentagonal dipole modeling with great speed of work. Fig. 7. shows the dependence resonant frequency f_r on dipole dimension a and dielectric constant ε_r. This dependence is presented using 729

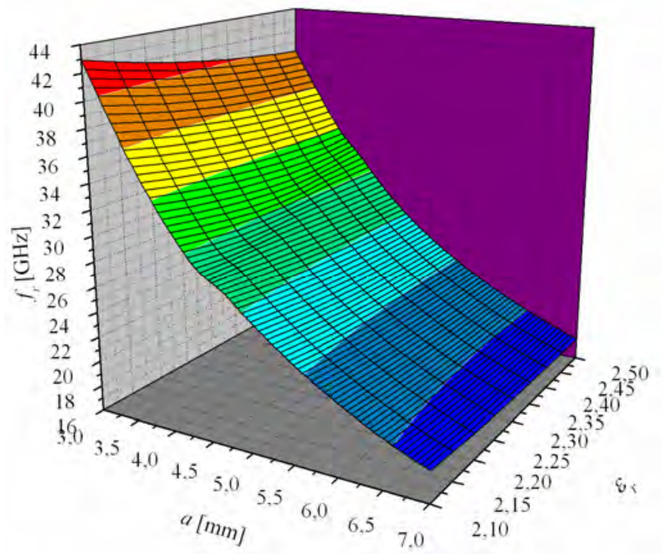

Fig.7 Resonant frequency f_r versus dielectric constant ε_r and pentagonal dipole dimension *a*

values of f_r obtained by MLP simulation for 2 seconds. If we use MoM simulation in WIPL-D software to obtain the same number of fr values, we will do it for a few days. For these reasons, MLP simulation is better alternative in applications where simulation has to be finished in certain period of time.

VI. Software "Pentagonal Dipole"

Software module "Pentagonal Dipole" (Fig. 8.), whose code is written in Visual C++ programming language, uses MLP3-4 model for calculate resonant frequency of printed pentagonal dipole. Range of input parameters is limited by the range of parameters from training process. When user inputs parameters, the values of resonant frequency f_r is calculated for the pentagonal dipole with these dimensions. Also, it offers the possibility of optimization. It means that user do not have to input both dipole parameters. The user can input one or no one parameters and this software module can calculate the dimension of dipole that has requested resonant frequency f_r.

VII. Conclusion

This paper presents the neural model of pentagonal dipole as an alternative to time-consuming detailed EM models. The proposed neural model is incorporated in software module "Pentagonal Dipole" that has a user friendly interface keeping similar accuracy as EM methods and surpassing EM methods with greater simulation speed.

Acknowledgements

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Fig.8 Software "Pentagonal Dipole"

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