International Conference on Antenna Theory and Techniques, 6-9 October, 2009, Lviv, Ukraine pp. 351-353

ANALYSIS OF FIELDS REFLECTED FROM MODEL OF HUMAN BODY SURFACE USING ARTIFICIAL NEURAL NETWORK IN TIME DOMAIN

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Abstract

The problem of determination of thickness a layer of layered medium by impulse irradiation is considered. The impulse fields reflected from the model of human body surface are analyzed by artificial neural network in time domain directly. The normal incidence of plane wave with Gaussian time form on the layered medium with losses is considered. The reflected electromagnetic field is obtained by FDTD method. Initial data for neural network analysis are the values of amplitude of electrical component of reflected field. As an example, the network is trained to determine the thickness of one of the layers of the medium. The stability of the determination in presence of interferences, experimental errors and instabilities of medium parameters is investigated by numerical simulation.

Keywords: time domain, FDTD, artificial neural network, impulse fields, layered medium .

1. INTRODUCTION

One of the the most important directions of utilization of impulse signals is finding of parameters and characteristics of different media with losses by impulse irradiation. Owing to the significant width of frequency spectrum ultra wide band signals can penetrate into the depths of the media because of low frequency part of the signal spectrum and provide the good precision of position determination because of high frequency part of the spectrum [1]. But the analysis in time domain of the pulse signal reflected from the media to determine their characteristics becomes enough complicated when the spatial duration of used signal in medium is comparable or bigger than typical sizes of layers of studied structure. Nonlinear dependence of amplitude of reflected field on electrical parameters and other characteristics of medium but definite and appropriate change of pulse form naturally permit to use the artificial neural network for the analysis of such a system. Although the change of frequency spectrum of the reflected signal can provide necessary information about layered structure, it is estimated to use only time parameters, i.e. the amplitude of signal, for the analysis. The assumption, that the analysis is possible, is based on the well-known structure and principles of work of artificial neural network [2]. So, it is surmised that a neural network can find a method and provide necessary time and frequency analysis of the signals owing to training on known results [3]. It was shown that the analysis by means of neural network provides stability in case of variations of electrical parameters of media and good noise immunity [4].

In the presented report the normal incidence of impulse plane wave on layered medium with losses is considered, but the presented approach is applicable for a number of variations of the problem due to universality of the principles of work of artificial neural networks. For example, the training on pure experimental data is used in [5], but to investigate almost similar layered structure in ten times higher frequency than in our work [4] was used. It is affirmed in the work [5] that the approach has some advantages in comparison with correlation method.

The purpose of the report is to study the possibility of determination of sizes of layered medium with known electrical parameters by means of artificial neural network and to investigate the stability of the determination in presence of interferences, experimental errors and instabilities of the medium parameters.

2. STATEMENT OF THE PROBLEM

The plane electromagnetic wave with time dependence in the form of Gaussian pulse with duration 0.5 ns falling normally into layered medium shown in Fig. 1. The layered structure is consisted of three layers with different electric permittivity and conductivity. The structure is a model of human body surface. So the first layer has electrical parameters of skin; the second one has parameters of adipose tissue; the third one has parameters of muscular tissue. The initial thicknesses of the layers are 2, 20, 30 mm correspondingly.

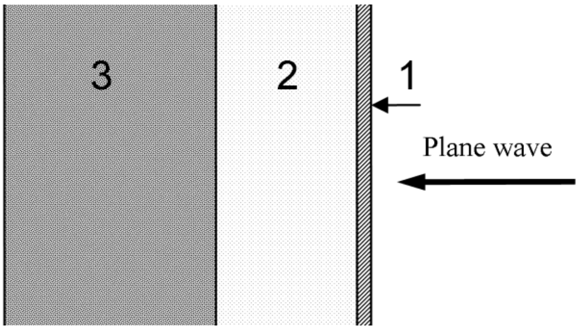

Fig. 1. Investigated structure (1-skin, 2- adipose tissue, 3- muscular tissue)

Initial data for neural network are the set of values of amplitude of electrical field near layered medium with constant time step. The data for training and verification of the network are received by direct numerical simulation with the use of FDTD method. All energy of wave that passes through the last layer is absorbed. Due to significant losses and thickness of last layer the absorbing cannot influence on the time form of reflected field too much. Data for training are the time dependences of amplitude of electric component of field reflected from the structure in the remote point where the reflected field cannot superimpose on incident one. The second layer thickness is changed from 10 to 30 mm with step 2 mm in the numerical simulation.

3. THE SOLUTION OF THE PROBLEM

The numerical simulation by means of FDTD method gives the set of data for the training of the neural network. The examples of the simulation are depicted on the Fig. 2.

The first impulse on the Fig. 2 represents time dependence of incident field. As for the rest part of the graph it is seen that they have no noticeable differences and, moreover, we can't define the thickness d_2 from the curves easily but can try to entrust with the task to our neural network. The case is interesting because the peaks of signal reflected from different layers are not resolved. It is affirmed in [6] that analytical Newton-Kantorovich method does not work in this case because of strong dependence on position of reflected impulses but better Gel'fand-Levitan method, in sense of nonresolved peaks, cannot provide good results in the case of low-contrast media.

Starting from the moment of time when the curves become different to the moment when they tend to zero we extract the values of amplitude with time step 15 ps. So, there is a set of 200 values of amplitude for each electrodynamic problem. There are 11 problems for training with step 2 mm for thickness of second layer d_2. Other parameters of the problems are the same.

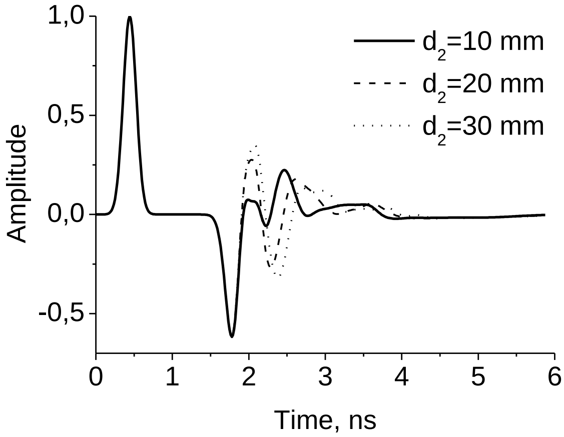

Fig. 2. Time dependence of the amplitude of electrical field under the layered structure for different thicknesses of the second layer d_2.

Hence our neural network must identify the thickness d_2 with step 2 mm precisely under ideal conditions. The artificial neural network is realized on the base of network with one hidden layer and sigmoid excitation functions.

Initial data for network x_i are normalized amplitude of electrical component of incident plane wave (see Fig. 2). Sought weight coefficients W are found from Widrow-Hoff learning rule ($W^{(2)}$) and backpropagation learning rule ($W^{(1)}$). Each output function y_i takes on values from range 0.99-1 for corresponding value of thickness of second layer d_i but for other values of d_i it takes on values from range 0-0.01. The network contains 200 elements in input layer (N=200), 20 neurons in hidden layer (K=20) and 11 neurons in output layer (M=11). Algorithm of training is realized on C++. The process of training lasts no more than several minutes.

4. NUMERICAL SIMULATION

After the determination of weight coefficients W one should check the network on new initial data. The reaction of network on data for intermediate values of d_2 is represented by approximately mean output value y_i between two values y_i for the closest values d_2 because of interpolating properties of the neural [3]. The network was unstable concerning influence of first layer thickness d_1 that provides big errors in identification of second layer thickness. The explanation of this from electrodynamics can be found in huge dielectric permittivity of the medium in layer 1. The drawback was corrected by subsidiary training on the parameter d_1. As a result we obtained the stable distinguishing of thickness of second layer not only in presence of variation of d_1, which is provided by corresponding learning, but in presence of variation of real part of dielectric permittivity and conductivity of medium of first layer [4].

The stability of results concerning the change of the same parameters of second layer is increased. But more interesting results relative to the immunity to noise are obtained. The neural network determines the thickness of second layer precisely in presence of white noise when the ratio of corresponding mean powers P_{signal} / P_{noise} equals to 1 (0 dB), where P_{signal} is averaged on time interval analysed by neural network. But the increasing of noise level gives the small absolute error of determination (2 mm) that does not increase up to signal-to-noise ratio (SNR) -30 dB. The time forms of the signals are presented in Fig. 3.

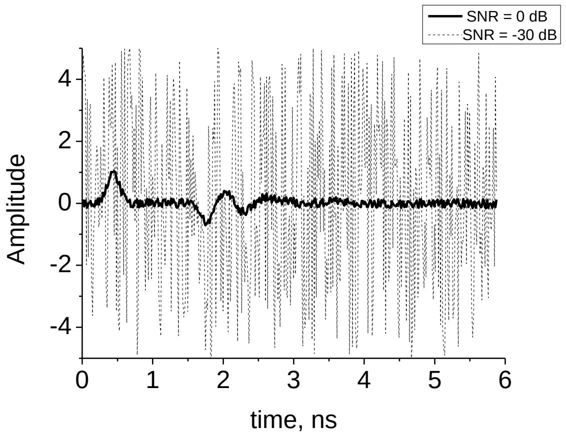

Fig. 3. Time dependences of the amplitude of electrical field under the layered structure in presence of white noise for different SNR

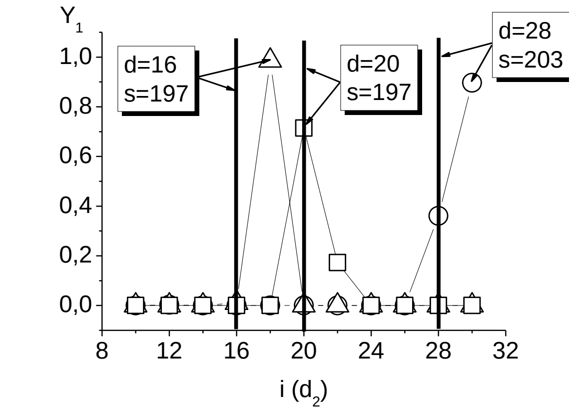

Fig. 4. Output values of network for the case of simulation of experimental errors for distance to observation point *s*=200 mm

Also the stability of results is investigated for the errors in distance to observation point *s*=200 mm (Fig. 4) and time of observation (Fig. 5). It is seen that the neural network determines the thickness in that cases sometimes precisely, sometimes with errors but the value and sign of errors do not correspond to value of time or distance shift. So, it means that the thickness d_2 isn't obtained by moment arrival of electromagnetic wave, but some special characteristics of impulse.

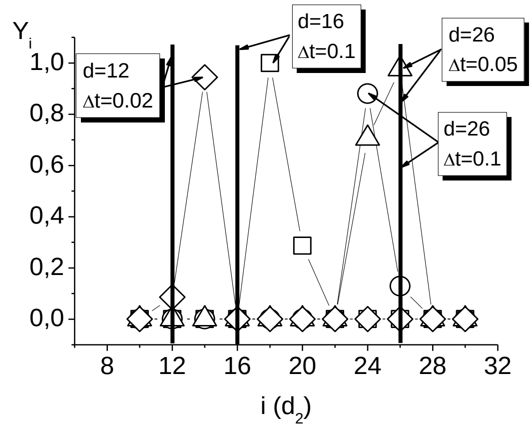

Fig. 5. Output values of network for the case of simulation of experimental errors for observation time (ns)

5. CONCLUSION

The possibility of determination of parameters of layered medium from reflected impulse electromagnetic field in time domain by artificial neural network has been shown. The stability of the determination in presence of different experimental errors and intense noise has been investigated.

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