Modeling of the Propagation Curves from ITU-R P.370-7 Recommendation using Neural Approach

Bratislav Milovanović, Zoran Stanković and Nebojša Vasić[1]

Abstract – **In this paper modeling of the propagation curves from ITU-R P.370-7 recommendation will be done using neural model based on multilayer perceptron network. In order to increase accuracy and generalization ability of neural models a special two-phase training process procedure has been developed and applied. This way enables fast and accurate computing the field strength level at reception points for any given effective antenna height from 37.5 m to 1200 m and range from 10 km to 650 km.**

Keywords – **ITU-R P.370-7 recommendation, neural network, neural model, electromagnetic field strength.**

I. Introduction

Design of any telecommunication system requires efficiently prediction of the electromagnetic field strength level. Great number of global and local parameters such as: configuration of the nearby terrain, obstacles and their attributes, climate zone, refraction index, multipath etc. affect the propagation of the electromagnetic waves. Therefore, it is almost impossible to develop a universal algorithm, meaning the reasonably short computing time, which will be able to solve the problem for the macro cell, micro cell and indoor propagation. To produce optimized algorithm almost every method omits one or more of the mentioned parameters.

A propagation model is a set of mathematical expressions, diagrams and algorithms by which signal strength level or path loss can be adequately represented or calculated. Generally, the propagation models can be either statistic (also called empirical), or deterministic, or a combination of these two, also known as a pseudo-deterministic.

Empirical models are derived from the extensive terrain measurements and statistic data analysis. The diagrams and tables of corrections that are result of the previous statistic analyze then give the correlation between terrain parameters and signal strength level. ITU-R method is typical statistic method. This method is based on reading the field strength level on the given diagrams in ITU-R P.370-7 recommendation [1,2]. Diagrams show field strength level in dBμV/m as a function of distance and effective height (Fig. 1).

The main problem is the inaccuracy of the reading due to visual errors and the existence of the only six discrete effective height curves. So the interpolation procedure must be the part of the immoderate algorithm, described in [2]. In practice it needs to calculate the field strength level in numerous

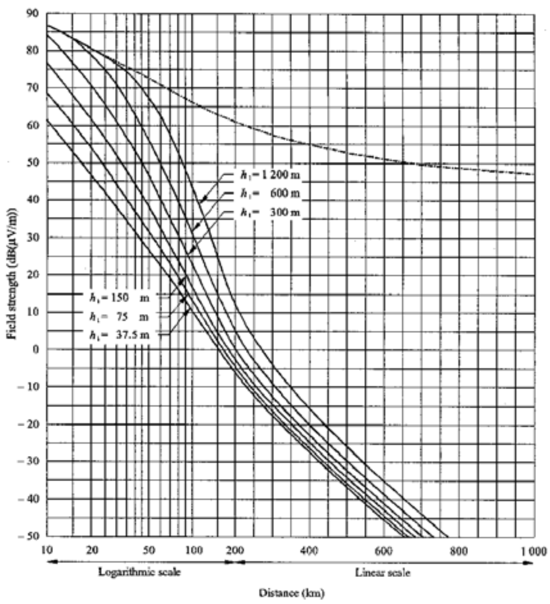

Fig. 1. Field strength (dB(μV/m)) for half wave dipole, which radiates 1 kW e.r.p. [1], land, 50% of the time, 50% of locations, frequency 450-1000 MHz.

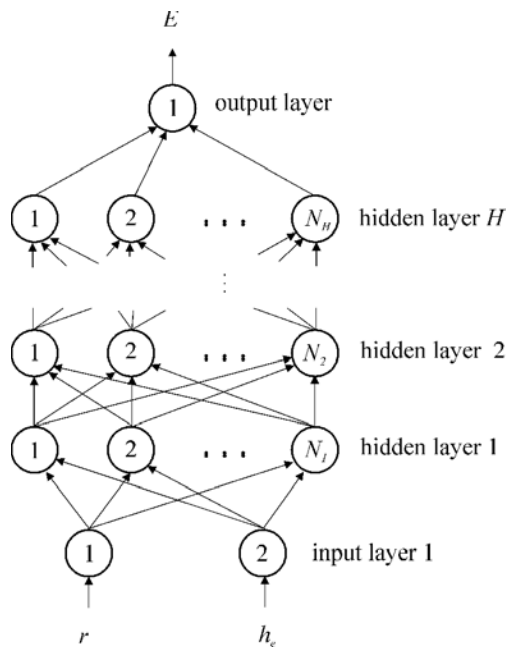

Fig. 2. Neural model architecture used for prediction of the electric field level E as a function of effective height h_e and distance between receivers r.

[1]Bratislav Milovanović, Zoran Stanković and Nebojša Vasić are with Faculty of Electronic Enginnering, Beogradska 14, 18 000 Nis, Serbia and Montenegro, E-mail: [bata, zoran, nvasic]@elfak.ni.ac.yu

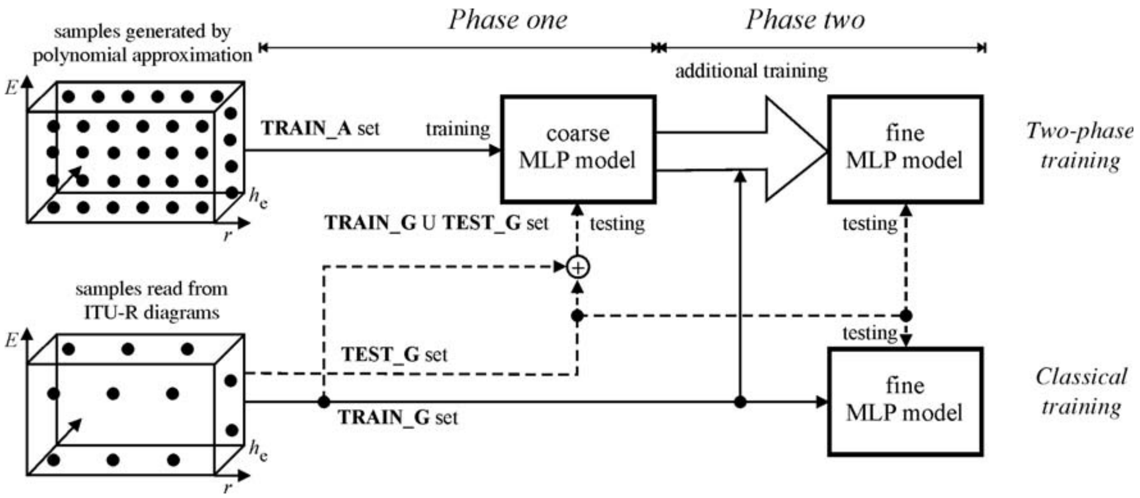

Fig. 3. Two-phase and classical training of the propagation curve's MLP neural models.

points for each azimuth in the sector of interest so the method becomes thorough job.

As one of the alternatives to the visual reading is modeling of the propagation curves by neural networks. First neural models for this purpose are based on the multilayer perceptron network (MLP-Multi Layer Perceptron) [3-8] and has been introduced in [7,8] showing good accuracy and fast computation. Further accuracy improvement and generalization abilities of the MLP neural models of the propagation curves, especially in ranges slightly out of the defined input parameters range, can be achieved using two phase training procedure that will be presented in this paper.

II. Neural Model of the Propagation Curves from ITU-R P.370-7 Recommendation

The statement of the problem is as follows: find the field strength level function as a function of distance and effective transmitter's height

$$E = f(h_e, r) \tag{1}$$

According to the above MLP neural model will have two neurons in the input layer and one neuron in the output layer (Fig. 2). Number of hidden layers is great than one but the results obtained in [7,8] showed that the optimum is two hidden layers. This conclusion was decisive which model to choose and thus we will deal only with models with two hidden layers. Activation functions in the hidden layers are of tang-hyperbolic type, but at the output neuron they are linear. In an agreement with this notation for MLP model is M$n - l_1 - l_2 - ... - l_n$ where n is the total number of neural layers in the given model and a $l_1, l_2, ..., l_n$ are the numbers of neuron in the hidden layers, respectively.

The method applied in training procedure of the MLP neural models of the propagation curves consists of two phases (Fig 3): "coarse" training using the large set of the input variables and "fine" training using the smaller set of input variables defined by ITU-R P.370-7 recommendation. Coarse training phase was conducted in the large set of inputs - 10000 samples generated by approximation function from

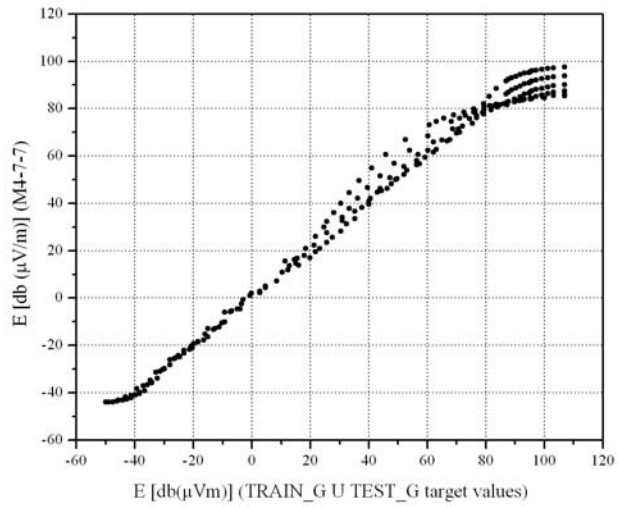

Fig. 4. M4-7-7 correlation diagrams after first training phase.

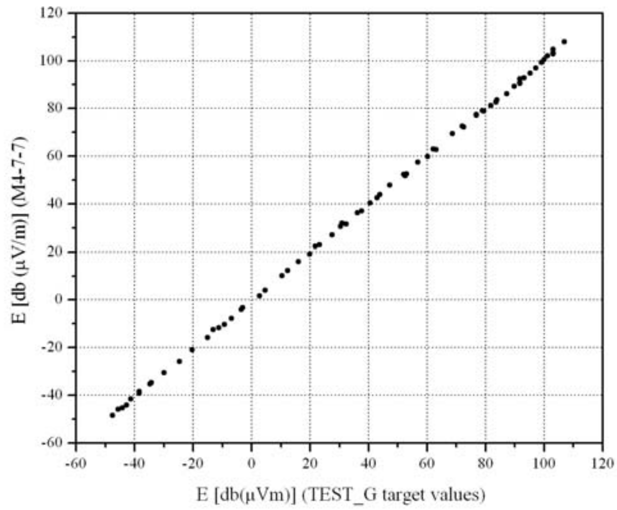

Fig. 5. M4-7-7 correlation diagrams after second training phase.

Table 1. Testing results of the propagation curve's MLP neural models

MLP model	Two-phase training (phase one) (TRAIN_G U TEST_G set)		Two-phase training (phase two) (TEST_G set)		Classic training (TEST_G set)	
	WCE [%]	ATE [%]	WCE [%]	ATE [%]	WCE [%]	ATE [%]
M4-5-5	18.50	2.85	1.65	0.45	39.21	1.51
M4-6-6	17.35	2.70	1.97	0.48	3.70	0.57
M4-7-7	14.95	2.48	1.60	0.45	9.82	3.69
M4-8-2	16.94	2.75	2.74	0.61	18.93	2.29
M4-8-5	19.25	2.58	3.21	0.84	5.62	1.03
M4-8-8	18.29	2.62	12.94	0.77	4.25	0.92
M4-9-5	18.19	2.30	4.13	1.14	18.56	5.57
M4-9-8	17.91	2.39	3.34	1.03	7.60	2.08
M4-9-9	17.83	2.57	2.41	0.57	8.68	1.10
M4-10-4	14.83	2.22	1.93	0.55	3.68	1.04
M4-10-9	16.06	2.48	2.17	0.57	5.90	1.05
M4-10-10	17.30	2.31	3.46	0.91	3.99	1.21

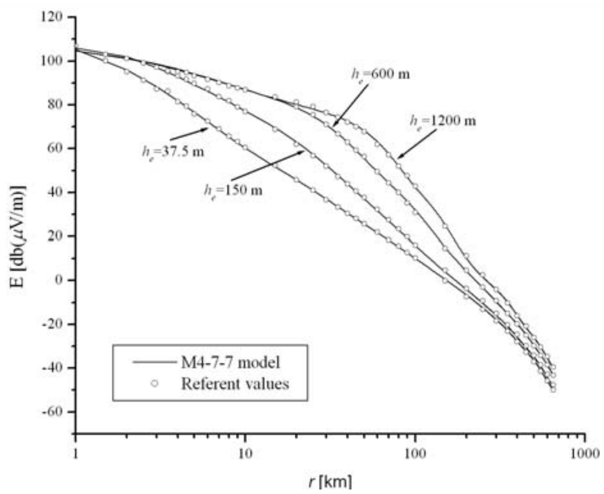

Fig. 6. Comparison of the M4-7-7 output curves to referent values that haven't been included in training set (two-phase training).

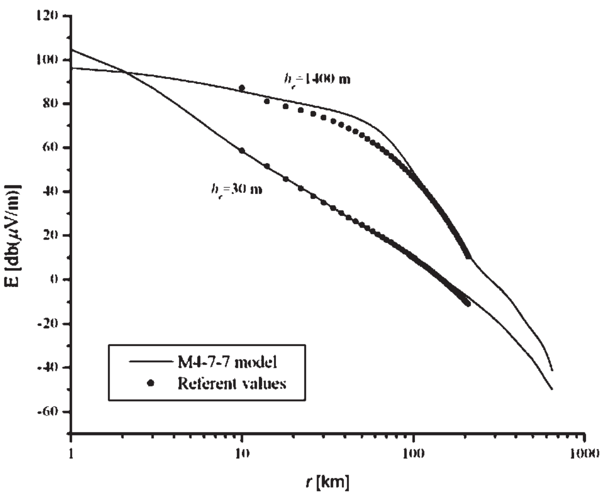

Fig. 7. Comparison of the M4-7-7 output curves to values obtained by polynomial approximation application for the cases of h_e=30 m and h_e=1400 m that are not belonging to a range of training neural models (two-phase training).

[2] in the range of 30 m<h<1400 m and 1 km<r<650 km. In this phase we applied Quasi-Newton training method with required maximum absolute error of 10^{-3}. Despite the lower efficiency of Quasi-Newton method compared to the Levenberg-Marquardt method it was optimal solution thanks to its applicability on large sets of inputs. Neural models that showed the best results in testing procedure were picked up for the second phase. This way the chosen models from the first phase have the a priori knowledge and increase the accuracy in the second phase. In order to test MLP model at the first training phase (cycle) we used set of 228 samples directly read from the ITU-R diagrams (TRAIN_G ∪ TEST_G). This set was split then in two subsets: one for training in the second cycle (155 samples - TRAIN_G) and the other for testing (73 samples - TEST_G). Training set was quite smaller compared to the previous set. In this phase Levenberg-Marquardt training method was applied showing the well known efficiency when dealing with the smaller set of training samples.

Simultaneously using the same set of input values form the second phase (cycle) training was done directly on classic way for the purpose of comparing with the new herein described training approach (Fig. 3). Testing of both models (new two cycle phase approach) and classic (direct) was caried on the same set of 73 samples and the results are shown in Table 1. Average absolute error (ATE) and maximum absolute error (WCE) present mean values of the three best trainings of the same MLP model. Analyzing the results shown in the Table 1 one can observe the advantages of the two phase training method: decrease of the maximum test error and consequently decrease of the average test error. Test correlation diagrams for M4-7-7 model which have the smallest errors are shown in Fig. 4 and Fig. 5 (after first and second phase respectively)

III. Simulation Results

Neural model based on two phase training method, which has shown the minimum error during testing, was used then for simulation of the field strength level as a function of effective antenna height and distance from transmitter's point. Fig. 6 shows the propagation curves for effective antenna height values of 37.5, 150, 600, and 1200 m obtained by M4-7-7 model with respect to the reference values read from the dia-

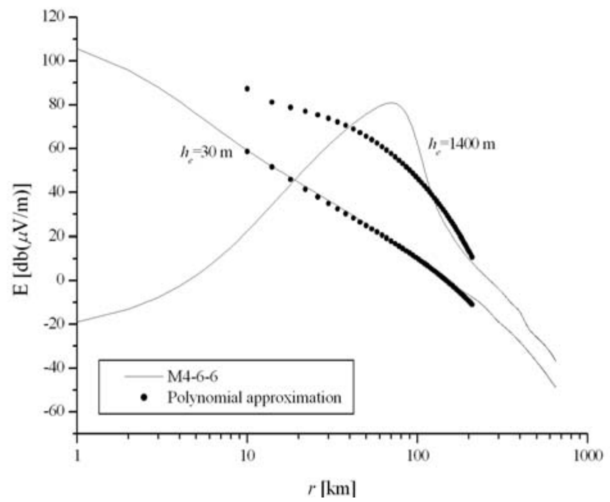

Fig. 8. Comparison of the M4-6-6 output curves to values obtained by polynomial approximation application for the cases of h_e=30 m and h_e=1400 m that are not belonging to a range of training neural models (classical training).

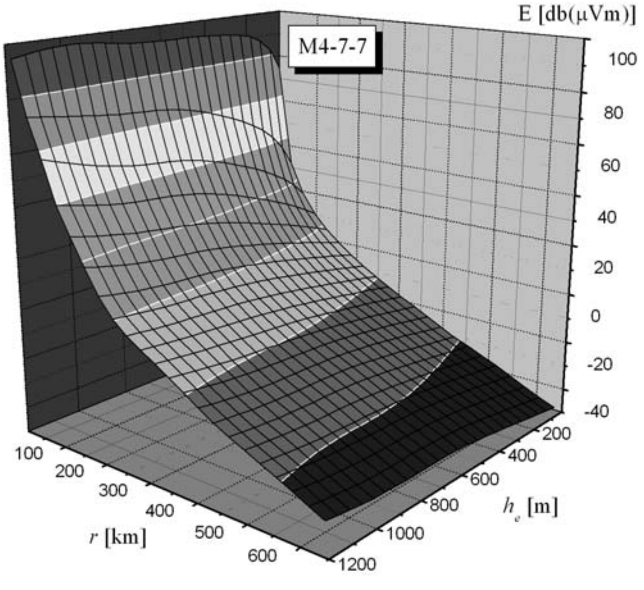

Fig. 9. Three dimensional presentation of the field strength level as a function of effective antenna height and distance, generated by M4-7-7 model.

gram. We can see the excellent fitting of the values obtained by M4-7-7 model in the reference values. This signifies the high accuracy of the two phase model.

Furthermore in order to explore the extrapolation the same neural model was used to generate the propagation curves for h_e=30 m and h_e=1400 m (Fig. 7). Due to inability to get the values from the diagram these curves were then compared to the approximate values. For the same effective heights (30 m and 1400 m) propagation curves were generated using M4-6-6 model that has been passed the standard (direct) training procedure and showed minimum error (Fig 8). It can be seen that M4-7-7 model is better than M4-6-6 especially in area where extrapolation is a must.

M4-7-7 model was used to generate complete three dimensional presentation of the field strength level as a function of effective antenna height and distance. Also, simulation was done in 15640 points producing the three dimensional pattern on Fig. 7. To do that it took only 5 seconds on PIII 450 MHz hardware platform with 128 MB RAM.

IV. Conclusion

Probably the most reliable statistic method for field strength prediction in radio and TV systems is ITU-R method. Reading the diagrams often makes this method effortful, so the adequate neural model has great practical utility. The results presented in this paper prove that neural model based on MLP network is accurate alternative to the classic reading the diagrams. Excellent agreement between referent values (the diagram's values) and values obtained using MLP neural model so as fast computation time (only 5 seconds last computation in 15000 points) are the main advantages of the MLP models developed with two phase training method. In addition two phase method requires less training samples than direct method to get the same target accuracy thanks to knowledge gained in the first training phase. This implies that pre-knowledge improves the accuracy and fast learning at the second training phase. The greatest accuracy increase is in the extrapolating area - slightly out of the range of input effective height values, which is very useful in practice. Finally, thanks to its features MLP model can be embedded in software for prediction of the field strength level.

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