Modeling of the ITU-R P.370-7 Propagation Curves by Neural Network

Zoran Stanković, Bratislav Milovanović, Jelena Jovković, Jelena Antonijević

Abstract – **ITU-R is basically graphic method. The main problem with ITU-R method is the extrapolation of the curves with the calculated h_e that differs from the values shown on the diagrams in Rec. ITU-R P.370-7. We provided the MLP neural model of the propagation curves which would solve the problems mentioned above.**
Keywords - **Propagation curves, neural network model, Recommendation ITU-R P.370-7.**

I. Introduction

The development of telecommunications as a global initiative took a step forward when the European Telecommunications Standards Institute (ETSI) and the Radiocommunication Sector of the International Telecommunication Union (ITU-R) signed an Agreement to increase the exchange of information and strengthen co-operation between the two bodies. Prediction of the electro-magnetic field strength has an important role in the design of telecommunication systems. Due to many parameters, such as nature of immediate surroundings, climate zone, type of the path, refraction index etc., which take an influence to a level of the electro-magnetic field, it is very difficult to develop general algorithm which would be both, numerically stable and economic for hardware. Developed methods could be divided into two groups: statistic methods and deterministic methods. Each of them has advantages but neither can completely solve the problem.

After many twists and turns, the International Telecommunication Union is on the verge of settling the matter of radio transmission specifications for third-generation (3G) wireless services. Probably the most popular method for prediction of the electro-magnetic field at a receiver's point is ITU-R method (former CCIR method), revised and described in the recommendation ITU-R P.370-7. Because of its complexity we are going to introduce only the basics of ITU-R method [1,2].

The ITU-R Sector plays a vital role in the management of the radio-frequency spectrum and satellite orbits, finite natural resources which are increasingly in demand from a large number of services such as fixed, mobile, broadcasting, amateur, space research, meteorology, global positioning systems, environmental monitoring and last but not least, those communications services that ensure safety of life at sea and in the skies.

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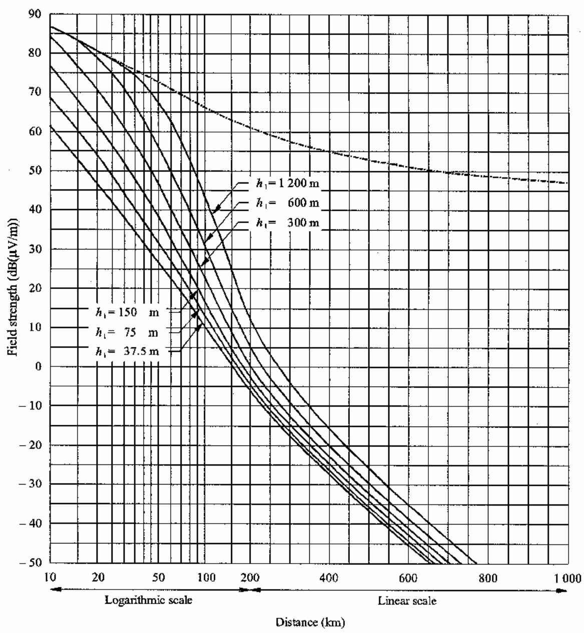


Fig. 1. Field strength (dB(μV/m)) for half wave dipole, which radiates 1 kW e.r.p. [1], land, 50% of the time, 50% of locations, frequency 450-1000 MHz

The ITU-R method is statistic and is based on measurements of the field strength conducted on a terrain with the *effective height of the transmitting antenna* as a parameter [1] and adjusted for half-wave dipole antenna, which radiates 1 kW e.r.p. The obtained results are then statistically treated, and for the statistic-calculated values it's been drown patterns of the field strength (dBμV/m) versus distance (km) with effective antenna height as a parameter ($h_e = 37.5$m, 75 m, 150 m, 300 m, 600 m and 1200 m). *The effective height of the transmitting antenna* is defined as its height over the average level of the ground between distances of 3 and 15 km from the transmitter in the direction of the receiver. Curves on the diagrams (figures) are given for effective antenna heights between 37.5 m and 1200 m, each given value of the "effective height" being twice that of the previous one. For the "effective height" between 0 m and 37.5 m there is an algorithm described in [1], Annex 1 (1.3.1). There are diagrams (figures) for VHF band (30-250 MHz) and UHF band (450-1000 MHz). Each diagram corresponds to the field strength values exceeded at 50% of the locations (within the area of approximately 200 m by 200 m) for different percentages of time.

Various corrections are developed for achieving better accuracy that take into account spatial variations, for example the degree of terrain irregularity of the nearby terrain (terrain factor – parameter Δh), the clearance angle correction and the height gain factor that takes into account type of zone (urban, suburban and rural) and frequency range for its calculating (see Table 1 in [1]). This method with the corrections mentioned above (terrain factor, clearance angle etc.) can give quite precise estimation of the field strength at a receiver's point but it still remains not accurate enough for some fields of implementation.

Propagation curves should provide high signal intensity, full coverage, and satisfying quality in short time for concurrent telecommunication system. The disadvantage of this method is the fact that computed effective heights differs from the discrete values shown on the Figure 1, so it requires the interpolation of the effective heights between the nearby curves. Also, the distance scale between 10 km and 200 km is logarithmic, which leads to smaller reading resolution. Accuracy of the method, therefore, gradually decreases, especially for the distances between 20 km and 100 km.
Propagation plays an essential part in design and planning of a system, both for achieving the wanted signal quality and also to see whether sharing is feasible with other systems.

The purpose of this work is to develop an appropriate neural model for the field strength propagation curves that would overcome disadvantages of the graphic reading (shown on diagrams from reference [1]) which remained not precise and suitable enough because not all the necessary points are presented on the graphic lines and calculations of corrections are found to be difficult. Thus, the goal is to find easier method for modeling propagation curves that couldn't be read from the graphics. Approximation interpolation method [2] already provided some useful solutions, but we will prove that our presented method provide results of high precision and that the method itself is easy-to-built, it's simulation speed is relatively high and has much greater possibility of generalization.

II. NEURAL MODEL OF ITU-R P.370-7 PROPAGATION CURVES

The analyzed problem is presented through model of the electric field level E function depending on two variables, effective height h_e and distance between receivers r using following equation:

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

In order to develop proper neural model we investigated MLP neural network [3-6] with two hidden layers. Neural model consists of two neurons in input layer corresponding to input network parameters h_e i r, hidden layers are constructed of sigmoidal neurons and output layer is presented with one neuron that corresponds to the output of the network E (Fig. 2.). Common representation for neural network is MLP4-*m*-*n* model where remark m stands for number of neurons in the first hidden layer and n represents number of neurons in the second one.

Training of the neural model with different number of neurons in hidden layers is developed by training set consisting 190 samples. Sample values are found from the curves that describe relation (1) for different values of $h_e \in \{35.7, 75, 300, 600, 1200\}$. 38 points are sampled at each curve. Levenberg-Marquardt training method is used with 10^{-4} as given accuracy (mean-squared error metric). Input parameter ranges that MLP models are trained into are shown in Table I.

TABLE I
INPUT PARAMETER RANGES OF MLP MODELS

Input parameter	h_e [m]	r [km]
Range	35.7-1200	1-650

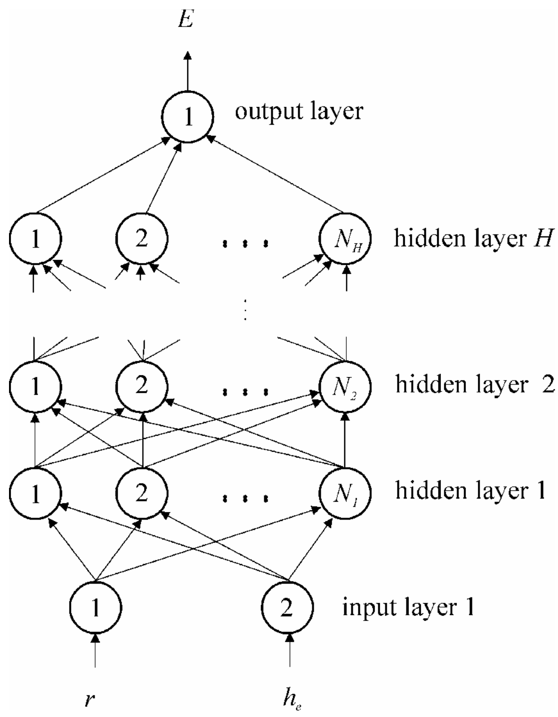


Fig. 2. Neural model architecture used for prediction of the electric field level E as a function of effective height h_e and distance between receivers r

III. TESTING RESULTS

In order to test trained MLP models we used three different test sets: TEST_A, TEST_B and TEST_C. The first set, named TEST_A, consists of samples that were used for model training (it is equal to training set). The second one, TEST_B, (38 samples) is formed from graphically ordered points from the curve h_e = 150 that wasn't used for reading test samples. The third set, TEST_C (255 samples), consists of values determinated for E applying polynomial approximative formulas at points that are belonging to training curves from the graphics $h_e \in \{35.7, 75, 300, 600, 1200\}$, but having r different from points that form training set.

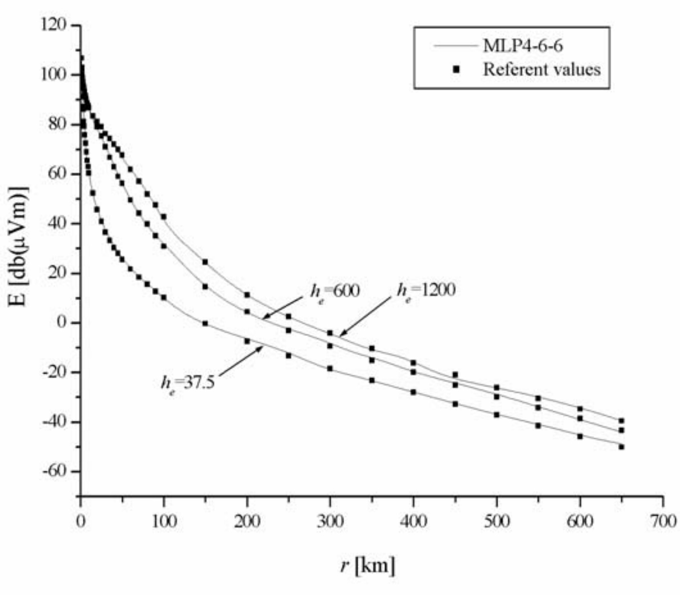
TABLE II
TESTING RESULTS ON VARIOUS TEST SETS

Test set	TEST A		TEST B		TEST C	
Model	MRG [%]	PRG [%]	MRG [%]	PRG [%]	MRG [%]	PRG [%]
MLP4-5-5	1.98	0.37	3.03	0.98	3.17	0.72
MLP4-6-6	1.32	0.39	1.16	0.41	3.03	0.71
MLP4-7-7	2.25	0.39	1.82	0.71	2.44	0.57
MLP4-8-8	1.96	0.37	1.49	0.42	3.21	0.60
MLP4-9-9	2.28	0.32	2.42	0.63	2.86	0.70
MLP4-10-9	2.36	0.34	2.08	0.60	2.84	0.50
MLP4-10-10	2.11	0.35	3.10	1.12	1.73	0.51

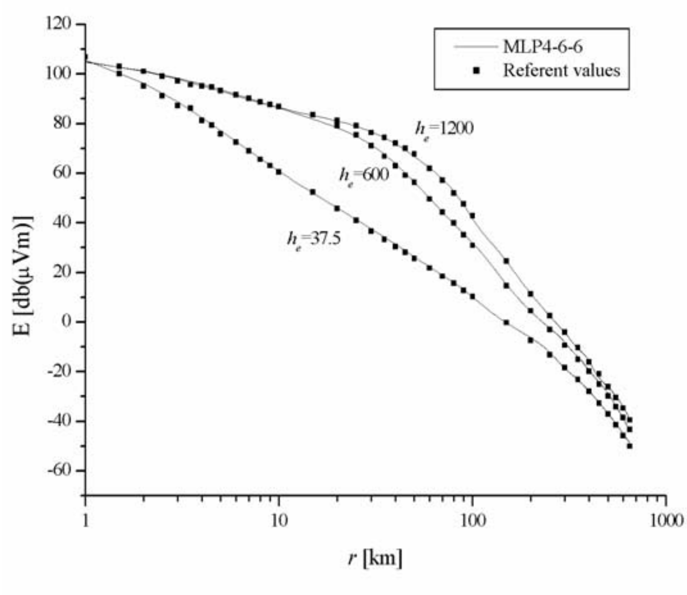
IV. SIMULATION RESULTS

To generate curves characterized by (1) we chose MLP4-6-6 model which have best testing results on TEST_B set. First, these curves are compared to referent values included in training set (Fig. 3.). Further, these curves are compared to referent to referent values that haven't been used in training set (h_e=150 case) (Fig. 3.). Finally, output curves of MLP model are compared to values obtained by polynomial approximation method for h_e values that haven't been used in training set.

In order to examine generalization capability of the neural model it was used for generation of output curves even for the values of h_e that are not belonging to a range in which neural model was trained. These out-of-range values are examined for h_e=30 and h_e=1400 (Fig. 5.). Presented model has shown that for h_e=30 output curves are much closer to the referent values generated by approximate method than for the extremely high case of h_e=1400. Also, we examined and showed that all remained neural models didn't provide good simulation results for the same values of h_e that are out of a training range.

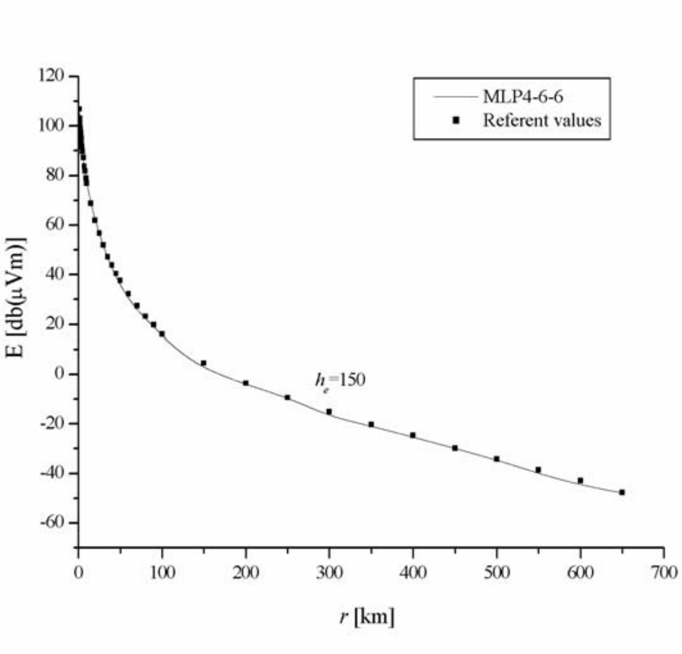


a.) linear *r* scale

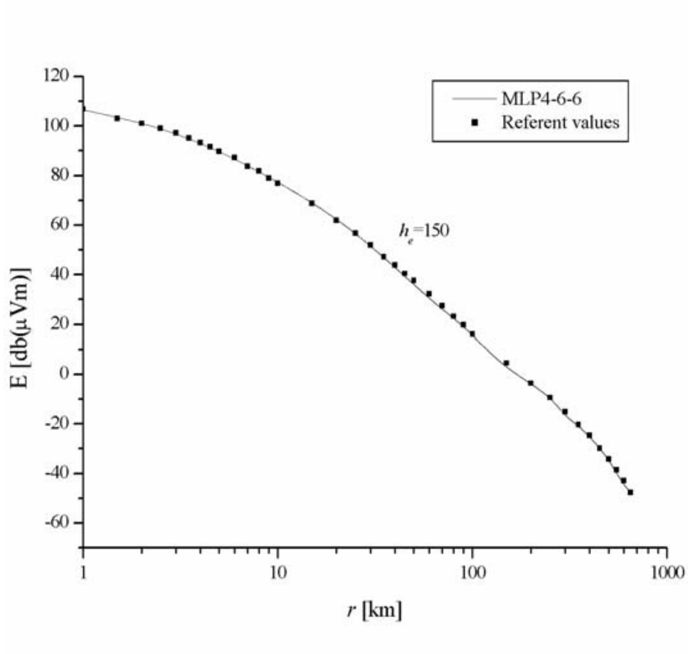


b.) logarithmic *r* scale

Fig. 3. Comparison of the MLP output curves to referent values included in training set



a.) linear r scale



b.) logarithmic r scale

Fig. 4. Comparison of the MLP output curve for the h_e=150 case, that hasn't been used in training set, to referent values

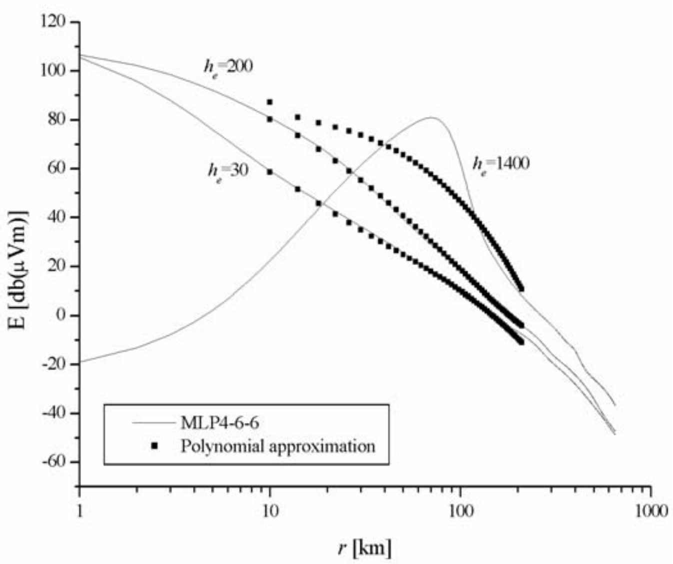


Fig.5. Comparing output curves of MLP model to values obtained by polynomial approximation application for the cases of h_e=30 m and h_e=1400 m that are not belonging to a range of training neural models.

V. CONCLUSION

In this paper a neural network model for propagation curves of the electric field strength is proposed. Presented method provides solutions that can achieve pretty elegant and fast solutions for rather difficult electro-magnetic Maxwell equations for the electric field that are commonly used in mathematics. It is proved that recommended model provides optimal method, faster and more accurate than others, more precise than graphic utilization or polynomial interpolation. Network itself can easily be trained; it is rally flexible and performs great possibility of generalization. The results show that the proposed model can give improved characteristics over conventional methods.

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