Joanna MICHAŁOWSKA

The Institute of Technical Sciences and Aviation
ORCID: 0000-0002-2353-6305

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Prediction and Assessment of Exposure to Electromagnetic Field During a Helicopter Flight

Abstract*. The paper present the research concerning the value of the electric component of the electromagnetic (EM) energy determined by NHT3DL meter by Microrad with the 01E measuring probe during flight of Robinson R44 Raven helicopter. The point of reference for the recorded measurement was the normative limits of the electromagnetic field (EMF), which can influence a pilot in the course of a flight. Selected studies of the maximum value recorded by the meter was E = 7.68 V/m when landing at an airfield equipped with the VHF (Very High Frequency) omnidirectional radio range (VOR) approach system. The developed model of neural networks is used to predict the value of electric field exposure in the context of flight safety analysis*

Streszczenie. *W artykule przedstawiono badania dotyczące wartości składowej elektrycznej energii elektromagnetycznej (EM) wyznaczonej miernikiem NHT3DL firmy Microrad z sondą pomiarową 01E podczas lotu śmigłowca Robinson R44 Raven. Punktem odniesienia dla zarejestrowanego pomiaru były granice normatywne pola elektromagnetycznego (PEM), które może oddziaływać na pilota w trakcie lotu. W wybranych pomiarach maksymalna wartość zarejestrowana przez miernik wynosiła E = 7.68 V/m podczas lądowania na lotnisku wyposażonym w system podejścia dookólnego VHF (Very High Frequency) -VOR. Opracowany model sieci neuronowych służy do przewidywania wartości ekspozycji pola elektrycznego w kontekście analizy bezpieczenstwa lotów. (****Przewidywanie i ocena ekspozycji na pole elektromagnetyczne podczas lotu helikopterem****)*

Keywords: electromagnetic field, aircraft, exposure, air navigation devices, artificial neural network
Słowa kluczowe: pole elektromagnetyczne, samoloty, narażenie, urządzenia radionawigacyjne, sztuczna sieć neuronowa.

Introduction

Monitoring of the electromagnetic field at workplaces is an extremely important aspect of research, especially when there is a factor in the loss of not only health but also life. Special attention in this context should be given to helicopter pilots. In helicopters, apart from simple electronic systems, there are advanced avionics devices emitting an electromagnetic field. In addition to the electromagnetic field from on-board devices to which pilots and passengers are exposed, there are also devices for guidance and communication with the airport emitting an electromagnetic field. These include systems such as: VHF omnidirectional radio range (VOR), VHF Communication, Instrument Landing Systems (ILS) Glideslope, ILS Localizer. Detailed characteristics of the radio navigation devices is described in [1-5].

The developed model of neural networks proposed in the work allows to predict the value of the measured field based on the analytical model without taking time-consuming measurements. The forecast model was built on the basis of time series. It allows to predict the value of the electric field and its parameters, which in turn will allow the pilot to take protective measures and enable preventive control activities and minimize the negative impact of the field on the environment [6-11].

Method and Materials

The measurements of the electromagnetic field were carried out in a Robinson R44 Raven helicopter at the Aviation Training Center of the State School of Higher Education in Chełm. The aviation center is an organizational unit of the State School of Higher Education in Chełm, where as part of engineering studies training courses for the commercial helicopter pilot license are conducted. The Robinson R44 Raven is a single-engine piston-driven helicopter, which can carry 3 passengers plus 1 pilot. During such trainings, the crew performs the so-called airfield traffic pattern or route flights. The electromagnetic field tests for the electric component were carried out using the NHT3DL meter by Microrad with the E01 measuring probe operating in the frequency range from 100 kHz to 6.5 GHz (Fig. 1). The detailed characteristics of the meter has been presented in paper [1].

In order to analyze the results, the so-called background measurement when the helicopter was on the apron without any devices working was performed. Measurements were made successively from the moment the crew started air taxiing until the rotor stopped after landing. A model for analysis with the use of neural networks was developed, in which the measurement data of the electromagnetic field intensity values recorded by the NHT3DL meter were implemented.

Fig.1 Reference drawing of electric field measurement with a meter with 01E measuring probe in Robinson R44 Raven helicopter.

The developed model of the neural network consists of 7 layers, such as: one-dimensional plexus, 2 layers of long-short-term memory and 3 layers of densely connected neurons. The network model is presented in Figure 2. The network predicts a single successive value based on the previous 60 measurements. The network was trained on data that was divided into 3 sets: for learning, for testing while learning and validation. The model metric was the mean square error (MSE) function and the Huber loss function was used. The selection was made due to the fact that it is a combination of mean squared error and the absolute value function, thanks to which it is less sensitive to outliers. The loss function and metrics in the developed model have been optimized in terms of minimum values [12-17].

In order to present the regularities, a statistical analysis was also developed. The values of the analyzed parameters were measured on a normal scale, characterized by a number and percentage, and measured on a quotient scale using the mean, medians, standard deviation (SD) and the range of variation. A 5% inference error and the related significance level p <0.05 were assumed.

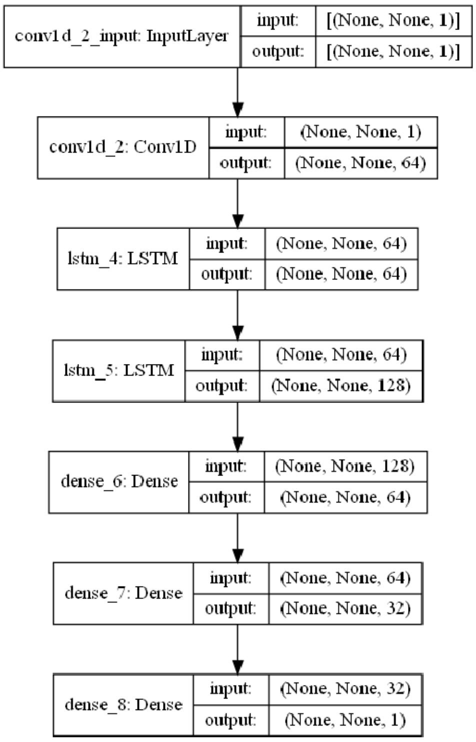

Fig.2 The Structure of the data used for network development

Result and discussion

The flights presented in the article were made during the flight on the route: 1, 2. Depułtycze Królewskie - Lublin, 3. Radawiec-Chełm-Zamość, 4,-circles above the Depułtycze Królewskie airfield traffic pattern, 5- Lublin airport traffic pattern. Figure 6a shows the background measurement results. Figure 6b shows the selected flight marked as No. 2. The highest RMS values for the electrical component E = 6 V/m were achieved at the measurement point where the R44 helicopter was on the landing approach path according to the instrumental landing system (ILS) performed at the Lublin airport.

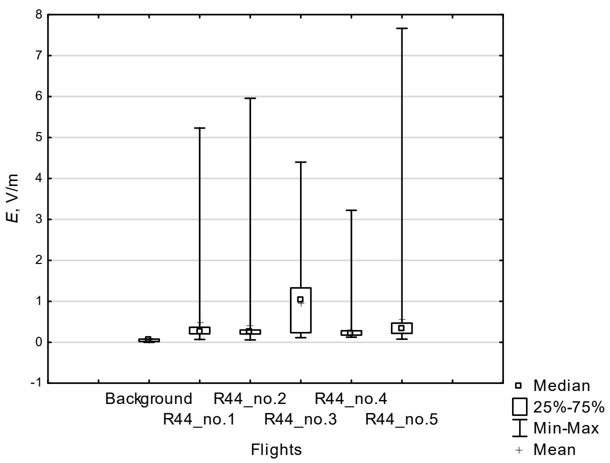

Fig.3 Box plots of measurement of electric component of electromagnetic fields

The developed statistical model is used to observe the regularities that result between the tested flights. It can be noticed that the values of the electric field during flights are several times higher compared to the recorded measurements of the so-called background. The values of the electric component of the electromagnetic field during the flight marked as No. 4 are lower. These differences are due to the fact that on the route No. 1, 2 and 5, the helicopter made landing approaches at Lublin airport. The airport is equipped with VOR, ILS navigation systems that emit an electric field (Fig. 4).

The model of the neuronal network presented in the paper allows for a short-term forecast of the electric field without carrying out time-consuming and difficult research trials. Figures 5 and 6 show the function of changing the values per epoch.

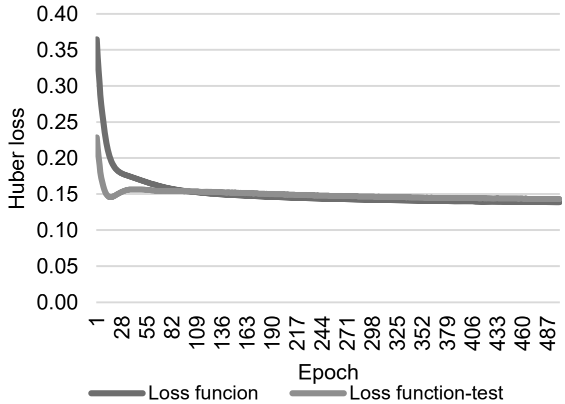

Fig.4. Converting model accuracy to epoch

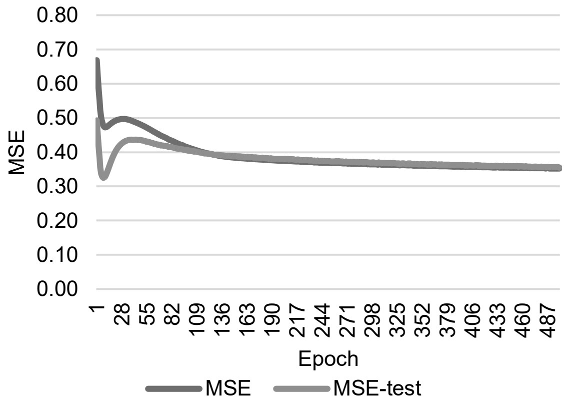

Fig.5. Change of model loss function value per epoch

During study, the accuracy, measured as the mean absolute error, for the study data was 0.3522, and for the test set was 0.3556. In the case of the loss function, the values were 0.1386 for the set intended for study and 0.1432 for the test set.

The values predicted by the network and the data set which the network was compared with are shown in Figure 6

The main characteristics of the graph variability, based on single past values, are predictable, however, in the case of peaks significantly deviating from the waveform, their occurrence depends on other parameters than the signal waveform itself

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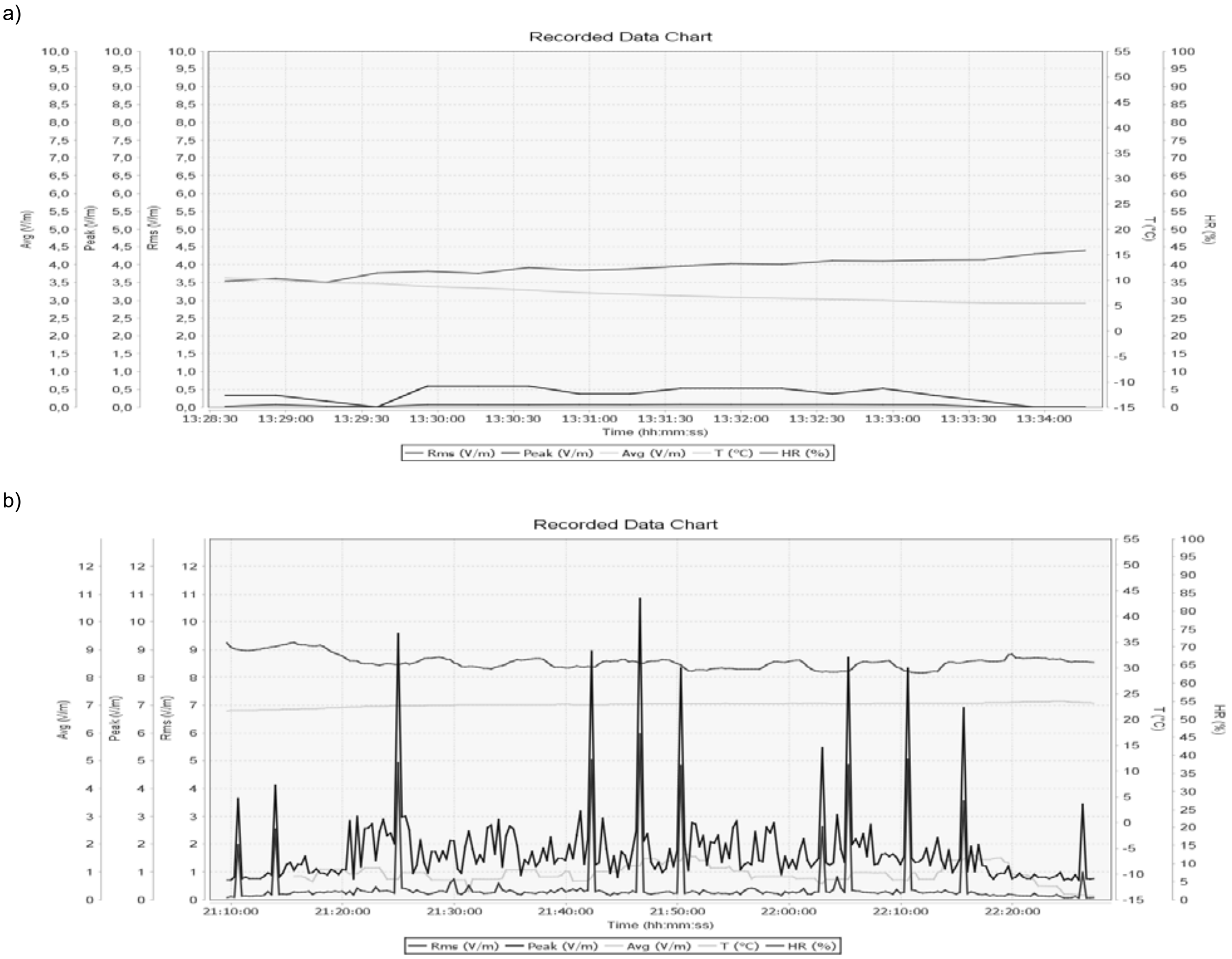

Fig.6. Distribution of the intensity of the electromagnetic field: a) background b) Robinson R44 nr 2 flight

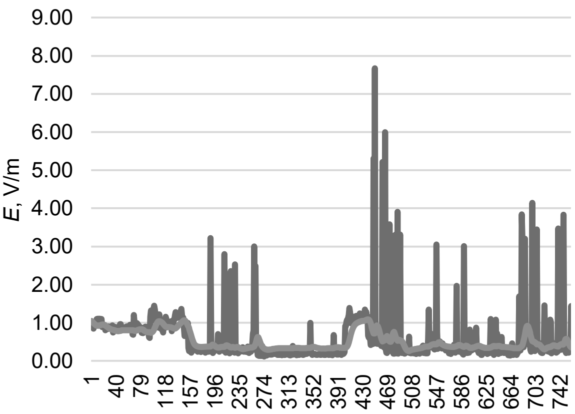

Fig.7. Graph of the values predicted by the network of the electric component of the electromagnetic field

Conclusion

. The developed algorithm using neural networks is used to analyze flight safety in the context of the electromagnetic field. Based on the analysis, it can be seen that the measurement values obtained during the flight in the Robinson R44 helicopter are several times higher compared to the values measured without the airport operation (background). The highest RMS values of the electric field are in the range of RMS *E* = 3.2 - 7.8 V/m,.
while the PEAK values, *E* = 8.5 - 10.8 V/m. Measurements of the intensity of the electromagnetic field constantly monitor the values of the intensity of the electromagnetic field which people are exposed to. By acting through the directed electromagnetic energy, irreversible actions are carried out destroying the equipment, which leads to a reduction in safety and a negative impact on human health and, consequently, can lead to a catastrophe. The development of the model of neuronal networks allowed to determine the characteristic course. It can be concluded that the neural network model predicts the theoretical value of the electrical component in the case when there are no additional external factors that significantly differ from the obtained results. The overall network error and overall prediction accuracy would be much better if an additional parameter was added to the network input that would be associated with the presence of these significant outliers. The creation of such a model will be the subject of further research and analysis.

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***Authors**: Dr inż. Joanna Michałowska, The Institute of Technical Sciences and Aviation, The State School of Higher Education in Chełm, Pocztowa 54, 22-100 Chełm, e-mail: jmichalowska@pwsz.chelm.pl,.*

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