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MEASURING EXPOSURE TO HIGH-FREQUENCY ELECTROMAGNETIC FIELDS EXPERIENCED BY A HELICOPTER CREW DURING FLIGHT

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Abstract
High-frequency electromagnetic fields (EMF) can have a negative effect on both the human body and electronic devices. Monitoring and measurement of the electromagnetic field generated by devices is important from the point of view of environmental protection, the human body and electromagnetic compatibility. In this study, we tested the value of the electromagnetic field strength determined by the NHT3DL by Microrad with measurement probes during flights in the Robinson R44 helicopter. The reference point for the results obtained were the normative limits of the electromagnetic field permitted to affect the crew and passengers during flight. The maximum RMS values recorded during the measurements were E = 4.399 V/m in the 100 kHz–6.5 GHz frequency band and for the magnetic component H = 2.829 A/m in the 300 kHz–30 MHz frequency band. These results were passed to the Statistica 13.3 software for a detailed stochastic analysis of the values tested.

Keywords: electromagnetic, helicopter, exposure, high-frequency
Type of the work: research article

INTRODUCTION

The development of civil aviation around the world has driven a constant movement towards increasing the level of safety. The European Aviation Safety Agency (EASA) recommends undertaking extensive activities related to the monitoring of critical elements of the flight safety system [1]. Aircraft crew may demonstrate a noticeable impairment of cognitive performance, spatial cognitive disorientation, or crew task saturation syndrome, incorrect prioritization. Even weak fields such as those of natural origin (Earth) have an effect on psychomotor changes and unconscious behavior. According to the Pentagon research agency DARPA, these factors may have played a role in class A accidents as well as deaths. A hypothesis has been put forward that such reduction of cognitive abilities could be linked to interaction with high-frequency fields from an extensive electronic avionics system as well as fields propagated from external sources [2-3]. The influence of the electromagnetic field on health and various areas of human activity is studied in many research centers around the world. Despite wide interest from researchers, however, there is as yet no clear assessment of the influence of the electromagnetic field [4-5]. To improve reliability in general aviation and to adapt to the proposed requirements, aviation training centers are obliged to introduce systems for monitoring and analyzing flight parameters.

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The current literature only describes numerical analyses and simulations of the field phenomena that occur on the surface and inside aircraft, specifying near and far specified. Such analyses are very often based on CAD models and the finite difference time domain method (FDTD). Electromagnetic compatibility studies related to equipment certification and approval occur at the test stage only during equipment design [6-7].

In this study, we tested the value of the electromagnetic field strength experienced by crew during flights in the Robinson R44 helicopter. The intensity of the electromagnetic field for aviation maintenance workers was related to the guidelines of Directive 2013/35/EU in which reference levels for time averaged exposures of workers of ≥6 min. [8] Moreover, the legal regulations for Reference levels for time averaged general public exposures of ≥6 min to electromagnetic (EM) fields have been compared with the normative values presented by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) [9].

MATERIALS AND METHODS

The measurements of the electromagnetic field were carried out on a Robinson R44 Raven II rotorcraft, in a certified Aviation Training Center of the State School of Higher Education in Chełm. This is an organizational unit of the State School of Higher Education in Chełm, where, as part of engineering studies specializing in helicopter training in the field of Mechanics and Machine Construction, training courses for the commercial helicopter pilot license are conducted.

As part of their certificates, aviation training centers are obliged to increase the level of aviation safety, identify potential threats, and disseminate awareness among the aviation community of any threats so identified which may reduce the level of aviation safety. Despite the fact that the Robinson R44 helicopter, compared to other helicopters, is equipped with relatively modest electrical and navigational equipment, it contains devices emitting electromagnetic fields. The sources of radiation in which a significant increase in the value of the electromagnetic field intensity was observed during the conducted measurements include: Garmin G3X avionics devices, transponder, radio communication antenna, Magnetic compass, VHF Omni-directional Range (VOR) antenna, Instrument Landing System antenna (ILS) and numerous converter power supplies.

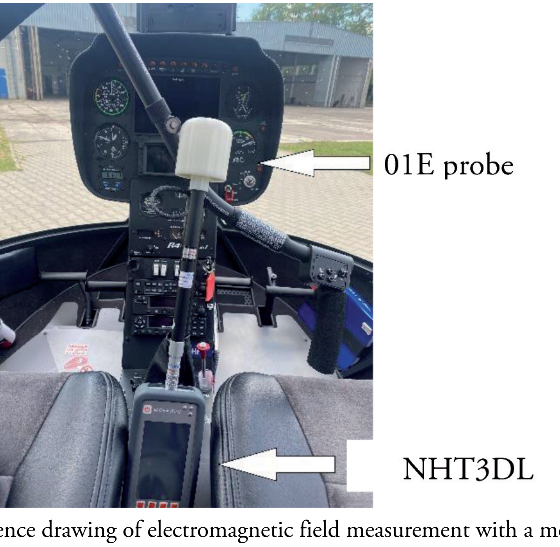

Figure 1. Reference drawing of electromagnetic field measurement with a meter with 01E measuring probe in a Robinson R44 Raven helicopter.

The measurements were carried out in accordance with the PN-T-06580-3: 2002 standard, which defines the methods of measuring and assessing EMF at workstations with frequencies from 0 Hz to 300 GHz. The exposure tests were performed using a Microrad NHT3DL meter (Figure 1) with measurement probes (Table 1). This device is used to measure and test electromagnetic fields in a wide range of frequencies present in the general environment as well as in the working environment in accordance with the international standards described in [10]. Due to the broadband measurements resulting from the greater availability of measuring devices, the results obtained were compared with the lowest normative values in a given frequency band range.

Table. 1. Basic technical data of the probes used for the study [11].

Technical specification	01E	04E	02H
Frequency range	100 kHz–6.5 GHz	3 MHz–40 GHz	300 kHz–30 MHz
Measurement range	0.2–360 V/m	0.5–350 V/m (cw)	0.016–16 A/m
Dynamic range	65 dB	56 dB	60 dB
Sensor type	Diode dipoles	Diode dipoles	Coils
Directivity	Isotropic	Isotropic	Isotropic
Frequency response	± 1.5 dB (1 MHz–3 GHz) ± 2.5 dB (3 GHz–6.5 GHz)	± 2 dB (10 MHz–7 GHz) ± 6 dB (7 GHz–40 GHz)	± 1.5 dB (0.5 MHz–30 Hz)
Linearity	± 0.5 dB (2–200 V/m)	± 0.5 dB (2–350 V/m)	± 0.5 dB (0.032–16 A/m)
Operating temperature	0°C–50 °C	0°C–50°C	0°C–50°C
Size	327 x 60 Ø(mm)	327 x 60 Ø(mm)	365 x 120 Ø(mm)
Weight	120 g	120g	180g

The measurement of the electric and magnetic components of the electromagnetic field takes place in three directions X.Y.Z for the peak value of the pulse (PEAK) and the effective value (RMS), which determines the maximum value in time. In the high-frequency range, the effective value (RMS) is most often adopted in standards and legal acts [12]. EM field measurements were carried out from the moment the crew started taxiing until the helicopter stopped after landing. Measurements were made with a sampling time of 1 s. In order to analyze the results, a background measurement when the helicopter was not operating was carried out. The flights presented in the study were made on the route: Radawiec-Chełm-Zamość-Radawiec.

In order to observe the correct patterns, a statistical analysis was performed. This consisted of entering the values of the electromagnetic field intensity recorded by the NHT3DL meter into the Statistica 13.3 program. The values of the analyzed parameters measured on the normal scale were characterized by number and percentage, while those measured on the quotient scale by mean, medians, standard deviation (SD) and the range of variation. A 5% inference error and the related significance level $p < 0.05$ were taken.

RESULTS AND DISCUSSION

This section presents selected results of electromagnetic field measurements with the NHT3DL meter with 01 E, 04 E, 02 H measuring probes. The obtained RMS and Peak values, to which the regulations refer, were analyzed. Figures 2-4 show the results of the measurements of the electromagnetic field in the Robinson R44 rotorcraft.

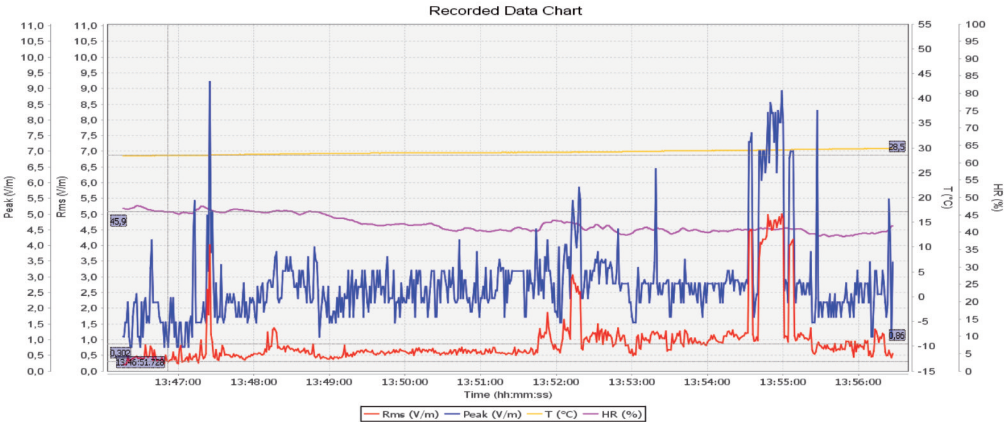

Figure 2. The intensity of the electric component of the electromagnetic field during the flight of the Robinson R44 with the 01E measuring probe.

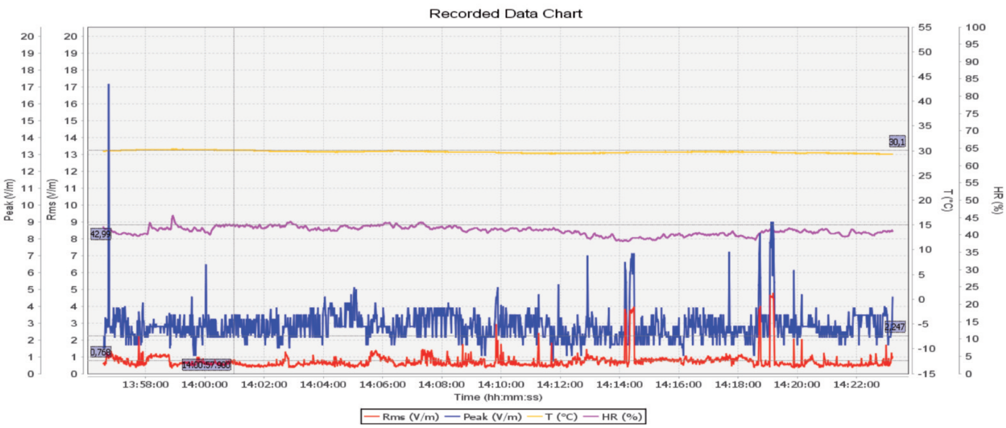

Figure 3. The intensity of the electric component of the electromagnetic field during the flight of the Robinson R44 with the 04E probe.

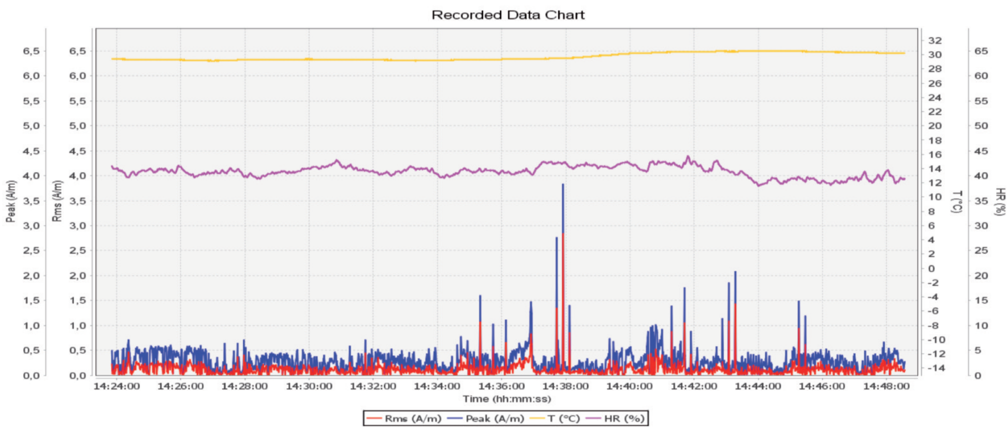

Figure 4. The intensity of the magnetic component of the electromagnetic field during the flight of Robinson R44 with the 02 H probe.

The observed values in the range 3.0–4.0 V/m were obtained during correspondence with the airport. In order to observe the regularities in the studied phenomena of the electromagnetic field, resulting from the large number of samples obtained during the measurements, a statistical analysis was performed (Table 2).

Table 2. Characteristic of the intensity of the electromagnetic field *E*, V/m, *H*, A/m for testing airplanes.

Variable	Mean	Median	Minimum	Maximum	SD	Standard error
background 04E (RMS)	0.0961	0.0900	0.0050	0.3260	0.0664	0.0034
background 04E (Peak)	0.9680	0.7730	0.0000	5.2450	0.7195	0.0375
background 02H (RMS)	0.0038	0.0036	0.0002	0.0251	0.0019	0.0000
background 02H (Peak)	0.0043	0.0000	0.0000	0.0430	0.0063	0.0002
background 01E (RMS)	0.1179	0.1140	0.0930	0.8280	0.0435	0.0020
background 01E (Peak)	0.4836	0.4670	0.1650	1.7860	0.1140	0.0053
04E (RMS)	0.6761	0.5990	0.3610	2.8780	0.2476	0.0078
04E (Peak)	2.8299	2.7880	0.7730	17.1400	0.8321	0.0263
02H (RMS)	0.1165	0.0928	0.0060	2.8291	0.1329	0.0042
02H (Peak)	0.2705	0.2492	0.0098	3.8228	0.2339	0.0073
01E (RMS)	0.9480	1.1735	0.1090	4.3990	0.8360	0.0264
01E (Peak)	2.4044	2.8070	0.3300	10.2500	1.4853	0.0469

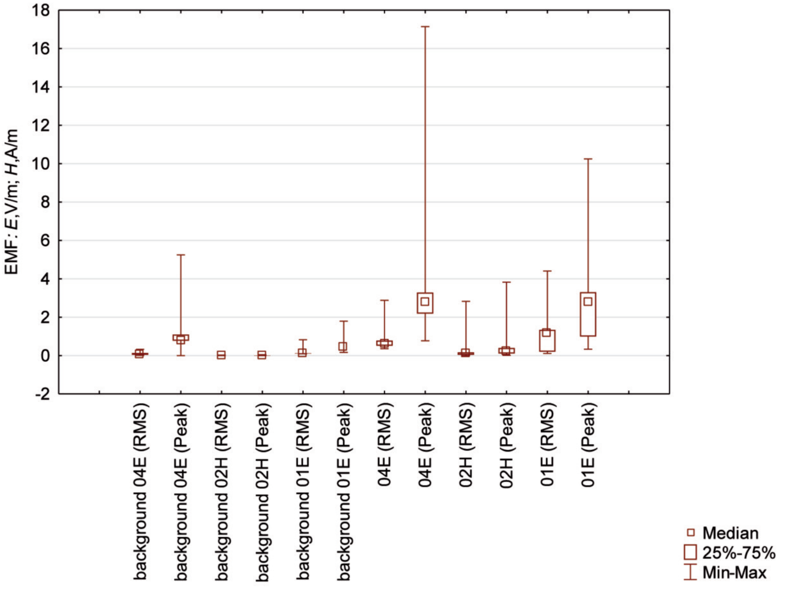

Figure 5. Range of quality and median of EMF during helicopter flight.

The average value of the electromagnetic fields for the analyzed flight varies for the electrical component from 0.096 to 2.82 V/m, and for the magnetic component from 0.003 to 0.27 A/m. The quality parameters tested are very high, in the range for the electrical component E = 0–17.14 V/m and for the magnetic component H from 0 to 3.82 A / m. In order to verify this hypothesis, the differences between the tests obtained with the NHT3DL meter are presented in Figure 5.

Figure 5 shows the differences between the measurement of the so-called Backgrounds without helicopter operation when compared to electromagnetic field measurements during flight.

CONCLUSIONS

The highest values of the electromagnetic field were observed in the Robinson R44 helicopter for RMS values: E = 4.399 V/m in the frequency band 100 kHz–6.5 GHz, E = 2.878 V/m in the frequency band 3 MHz–40 GHz and for the magnetic component H = 2.829 A / m in the frequency band 300 kHz–30 MHz. The maximum values obtained originate in radio communications. Long-term exposure to an electromagnetic field may have various negative consequences for both humans and devices responsible for flight safety. The values of the electromagnetic field distribution obtained during the measurements performed in the rotorcraft did not exceed the normative limit values for the electric component, but for the magnetic component they were exceeded (0.16 A / m according to 2013/35 / EU directive and 0.163 A / m according to ICNIPR). The measured instantaneous Peak values were several times higher than the RMS value. Although they occur temporarily, they may also affect the electronic devices in the rotorcraft, which in turn affects flight safety.

Monitoring the impact of the electromagnetic field on the environment is important, as somatic symptoms usually appear after some time, including effects on the reproductive system (asthenozoospermia, oligozoospermia, necrozoospermia), disturbances in memory processes, sleep disorders and their complicated forms, endocrinological disorders and severe psychosomatic medical conditions and the effects of exposure are often irreversible. The negative effects of the electromagnetic field affecting the reproductive system have been described in papers [13-14]. There are no reports in the literature regarding the limitation of the negative effects of the electromagnetic field on the crew of an aircraft, apart from shielding devices in aircraft. Therefore, a representative group of instructor pilots should be tested to identify trends. This will be the subject of our team's future research work.

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