DOI: 10.35784/IAPGOS.27

THE CONCEPT OF A FLYING ELECTROMAGNETIC FIELD MEASURING PLATFORM

Sławomir Szymaniec, Sławomir Szymocha, Łukasz Miszuda
Opole University of Technology, Faculty of Electrical Engineering, Automatic Control and Informatics Institute of Computer Science, Opole, Poland

Abstract. *Nowadays, humans are surrounded by more and more devices that artificially generate an electromagnetic field. According to law, supervision of the level of the electromagnetic field requires specific measurements. Measurement performed by traditional methods have several limitations, which come from the infrastructure and time taken to perform the measurement. New methods of measurement are being developed in order to execute the research relatively quickly and repeatedly without any limitations. One of the methods is to use a flying mobile measurement platform.*

Keywords: electromagnetic field, flaying platform, measuring

KONCEPCJA LATAJĄCEJ PLATFORMY POMIAROWEJ POLA ELEKTROMAGNETYCZNEGO

Streszczenie. *Człowieka obecnie otacza coraz więcej urządzeń, które sztucznie generują pole elektromagnetyczne. Zgodnie z prawem nadzór nad poziomem natężenia pola elektromagnetycznego wymaga pomiarów. Pomiar wykonywany metodami tradycyjnymi ma kilka ograniczeń dotyczących infrastruktury i czasu wykonywania pomiaru. Opracowuje się coraz to nowe metody pomiaru aby można było go wykonać w miarę szybko i powtarzalnie bez ograniczeń infrastrukturą. Jedną z metod jest wykorzystanie do pomiarów platform latających.*

Słowa kluczowe: pole elektromagnetyczne, platforma latająca, pomiar

Introduction

Direct influence of the electromagnetic field on a human being may cause numerous threats to health or safety. A person within the electromagnetic field is exposed to the presence of a magnetic field and induced electric fields caused by electrical currents flowing through the body.

Human beings are not usually able to feel the direct effect of the electromagnetic field on their organisms. According to studies [6–8, 11], the effects of the electromagnetic field may have other consequences that can be revealed with a time delay, especially during strong exposures, and they include:

- nervous system disorders,
- cardiovascular disorders,
- disorders of the immune system,
- neoplastic processes,
- subjective complaints, such as: headaches, fatigue, memory problems.

The influence of the electromagnetic field can also have an indirect impact on people, interpreted as contact currents that flow through the human body touching a metal object that has a different electrical potential due to the electromagnetic field impact on it [7].

The effects of the indirect impact of the electromagnetic field can also include:

- interference with electronic devices, including medical equipment, electronic implants (such as cardiac pacemakers) and medical devices worn permanently on the body (such as infusion pumps)
- a threat to the functioning of passive metal implants
- damage to magnetic storage media [6].

In our environment, the problem of measuring the electromagnetic field without restrictions coming from the infrastructure and various external conditions has not yet been solved. The generality of infrastructure is now a very big problem when performing an electromagnetic field measurement, because it is not possible to take measurements very close to the source of the electromagnetic field. The main sources of the electromagnetic fields include, for instance: high voltage lines, which during transmission create around themselves an artificial EM field, transformer stations, mobile phone stations, RTV transmitters [6].

1. Measurement of the electromagnetic field

Nowadays, it is difficult to imagine life without electricity anymore. In the early years no one was thinking about the influence of the electromagnetic field and radio waves on living organisms. With time, however, an increasing number of people began to pay attention to the levels of electromagnetic radiation produced by human beings, which surrounds ours communities to an ever growing extent [2]. According to the national Act of 27 April 2001 – Environmental Protection Law (unified text Journal of Laws 2013, 1232 with subsequent amendments), electromagnetic fields are defined as electric, magnetic and electromagnetic fields with frequencies ranging from 0 Hz up to 300 GHz. The evaluation of electromagnetic field levels in the environment is carried out as part of the State Environmental Monitoring. The Voivodship Inspector for Environmental Protection conducts periodic studies of the levels of electromagnetic fields in the environment. The number of measuring stations, the type of areas on which measurements are carried out and their frequency in Poland is specified in the Regulation of the Minister of Environment of November 12, 2007 on the range and manner of conducting periodic tests of electromagnetic fields in the environment (Journal of Laws No. 221, item 1645).

As of 1st July 2016, all members of the European Union are bound by the Directive 2013/35/EU of the European Parliament and of the Council dated 26 June 2013 on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (electromagnetic fields) (20th individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC) and repealing Directive 2004/40/EC [12].

The above Directive was followed by the national Regulation of the Minister of Family, Labour and Social Policy dated 29th June 2016 on the occupational health and safety of workers likely to be exposed to electromagnetic fields.

The Regulation defines the electromagnetic threats as harmful for health and describes hazardous and severe effects of direct or indirect impact of electromagnetic fields (EM fields) in the work space due to, inter alia, direct biophysical effects of EM fields upon the human organism, including:

- thermal effects – heating of the tissue through the EM energy absorbed,
- non-thermal effects, that is: agitation of muscles, nerves or sense organs which are likely to exert deleterious effect upon

the mental and physical health; agitation of sense organs may lead to transient symptoms, such as vertigo or phosphenes that provoke transient afflictions or affect cognitive functions or other brain or muscle functions and as a consequence, are likely to influence the capability to safely perform one's work.

2. Regulations regulating electromagnetic measurement

The regulation defines three basic categories of sites on which EMF monitoring should be carried out:

1) Central districts of settlements or cities with a population of over 50,000.
2) Other (smaller) cities.
3) Rural areas.

For each of the above mentioned area categories there are selected 45 measuring points – a total of 135 points. Measurements at the selected points are repeated after each full, 3-year measurement cycle. Within one year, measurements are made in 45 points (15 per area category). The range of conducted tests of electromagnetic field levels in the environment will include measurement of the intensity of the electrical component of the electromagnetic field in the frequency range of at least 3 MHz up to 3000 MHz. Measurements at each point are performed once a year.

The norm defines the principles of selecting the measurement area. The measurements are conducted with the aid of the so called measurement points: the basic measurement points (corresponding to the actual location of the workers) and the auxiliary measurement points (whose purpose is to obtain the information on the spatial distribution of the fields). The measurements are conducted to the maximum height of 2 m from the ground on which the worker is located. The working conditions of field sources should be selected in a manner allowing for the designation of the maximum value of field intensity in areas where workers are currently stationed or consider the possibility of greater field intensity, compared with the measurements, when assessing the exposure level [10].

Detailed values of permissible intensity of radiation fields have been specified in the ordinance of the Minister of the Environment dated October 30, 2003 on the permissible levels of electromagnetic fields in the environment and ways to check compliance with these levels (Journal of Laws No. 192, item 1883). According to that Regulation, acceptable levels of electromagnetic fields have been designated for "sites dedicated for development" and "places accessible to the public" and refer to different ranges of field frequencies from 0 Hz up to 300 GHz.

From the point of view of environmental monitoring the most important aspect is the frequency range, which might be from 3MHz to 3000MHz. The permissible electromagnetic field intensity for a given range is $E = 7$ V/m for the electrical component and $S = 0.1$ W/m^2 for the power density. They are many times more stringent than the WHO recommendations and ICNIRP limits adopted by the EU (from 28 V/m to 61 V/m, depending on the frequency) [14].

The magnitude of measured values of electromagnetic field (EMF) intensities is the resultant of the number of sources and their power.

The norms for maximum levels of electromagnetic fields in most countries around the world are in order with the recommendations of the International Commission on Non-Ionizing Radiation Protection (ICNIRP). The level indicated in the ICNIRP recommendation results from the assessment of a possible thermal effect, the value being several times smaller (by applying an additional margin of safety) in relation to the level of the field considered safe.

Based on the data gathered from five largest operators of overhead high voltage lines, the high voltage network is 32859 km of the HV line. There are 1437 WN/SN stations operating in this network, in which 2630 transformers are installed. In addition, the Polish Office of Electronic Communications has prepared a list of permits for the construction of base stations of mobile network operators. Their total number was 45456 at the beginning of this year. The list includes GSM network stations operating in the 900 and 1800 MHz as well as WCDMA 2100 MHz. Taking the above data into account and the aforementioned number of measurements carried out by the voivodship environmental inspectorate, it can be concluded that this is a relatively small number. Performed measurements are carried out on the basis of legal regulations [12].

3. Mobile measurement of electromagnetic field

Currently, in times of rapid development of automation and its interference in various areas of our lifes, also measurements of the electromagnetic field are carried out using it to a greater or lesser extent. The use of sensors placed on cars affects the availability of measurements. The sensor placed on the roof of a car is limited by environmental and technical conditions where the car can reach. Measurement can be performed relatively quickly and systematically, moving a given vehicle according to predetermined roads. The data transmitted by the sensor also have such parameters as the GPS network data so that the measurement results can be placed on the map and compared with measurements made at another time, in the same place. The levels of measured signals can be shown on the map in different colors.

The next step towards a greater automation of the measurements of the electromagnetic field is the use of a flying platform, under which the sensor were mounted. Currently manufactured sensors, from a technical point of view, can be placed on flying platforms. Performing measurements using a flying platform is the solution to one of the currently unresolved problems, which is the lack of barriers related to the availability of the area. The flying platform has unquestionable freedom of movement in the field. Unpaved roads or places which cannot be reached by a car are no longer a problem. The flight route can be planned in advance and performed without the direct presence of the person supervising the flight. As a result, the "pilot" is not exposed to the fields being measurement. Measurements can theoretically be performed without time limits 24 h/365 days. The flights will be carried out using a previously saved trajectory in autopilot mode with operator supervision. The only limitation are the weather conditions. The sensor moving on the platform has one more advantage, it has the ability to catalog a large area within a relatively short time. Due to this, the measurement performed in a dozen of defined points for each area can be extended to a much larger number of measuring points, thus increasing the quality of the measurement.

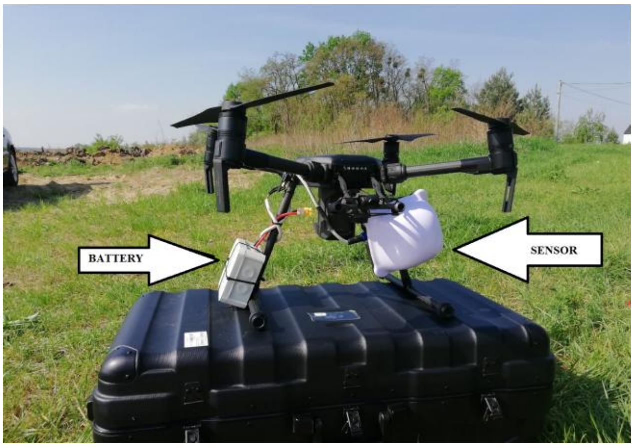

Fig. 1. Mobile platform with sensor and battery

The platform presented in figure 1 has been used to conduct test measurements in order to verify the measurement correctness as well as to control the influence of the mobile platform itself upon the measurement conducted.

The platform is it Quadrocopter equipped with TB50 LiPo battery, 4280 mAh, 22.8V LiPo 6S. Can fly 27 minutes. Control: 2.4 GHz: 4.3 miles (7 km, FCC); 2.2 miles (3.5 km, CE); 2.5

miles (4 km, SRRC) 5.8 GHz: 4.3 miles (7 km, FCC); 1.2 miles (2 km, CE); 3.1 miles (5 km, SRRC). Equipped with on-board systems: TimeSync system, accelerometers, gyroscopes, compasses, barometers, ultrasonic sensors, cameras and satellite positioning systems, gyroscopic flight stabilization systems. The measuring sensor used is cMonitEM from Wavecontrol [21] the measurement is isotropic.

The measurements of the intensity of the electromagnetic field plays an important role in relation to the conducted research on the implantation of the electromagnetic network and phone transmitters in close proximity to residential buildings and the influence of the intensity of the electromagnetic field on living organisms.

According to the concept of mobile network systems, the entire field handled by a given network is divided into areas ("cells") presented on propagation maps with the use of hexagons including base transceiver stations (BTS) located in the center. The communication between a moving cell phone user in the most popular GSM 900 network and the base station takes place in the 890–915 MHz bandwidth and between the base station and phone – in the 935–960 MHz bandwidth. Individual "cells" may possess a diameter from a few hundred meters in office centers up to more than a dozen kilometers in areas of a low population density. This means that in large urban agglomerations in order for a network to work properly it requires the functioning of 30–50 base stations which, taking into consideration the presence of three providers on the market (plusGSM, EraGSM, and Idea Centertel), results in a quite vast number of radiation sources.

The configuration of a base station depends on its purpose and location. In cities, sector antennas are usually installed in such a manner so that the main radiation beams are directed in three or four directions, thus ensuring an almost even cover of the entire cell in terms of the radio signal. In terms of base stations located in rural areas as well as near the main road and railroad trails, sector antennas are installed on lattice or concrete-steel towers, and directed at one or two azimuths. It also sometimes happens that some stations include omni-directional radiation antennas.

The radio frequency power (microwave range) provided for each antenna depends on the station's function within the network, and the receivers installed in base stations are selected from a type series offered by a given producer (Nokia, Siemens, Ericsson). For base stations located in cities the typical power provided for each sending-receiving antenna is: 25 W for single system stations and 50 W for dual system stations (GSM/DCS). In stations located outside of cities the power provided for each antenna is slightly lower.

Apart from sector antennas ensuring communication with cell phones, base stations include also radio lines necessary to execute direct communication between individual base stations. Depending on the function within the system, radio line systems include installed parabolic antennas with different diameters (from 0.3 m to 3.0 m) working in the following frequency bandwidths: 7, 15, 23, 38 GHz. Apart from the so called Radio Line Stations which include only radio line antennas (sometimes more than 15) this type of antenna is present in almost all base stations, although the number of radio line antennas usually does not exceed 10. The power provided for radio line antennas is very low and usually does not exceed 1 W.

The power of a base station is oscillatory and this is connected to the fact that the power of the transmitter adjusts to the number of users logged to the station and the technology in which the units operate. This concerns digital systems such as UMTS and LTE meaning that it changes in time [16].

In order to conduct tests, a mobile telephony mast (height 50 m), located in an area characterized by a small density of buildings and other objects, has been selected. The choice was due to the fact that the probability of disrupting the work of the platform in case it flew in excessive proximity to the mast, was too high (likely to provoke the disruption of the signal controlling the platform and, in the worst case, the disintegration of the platform upon the fall from a great height). In order to eliminate the disruptions to the platform, one may replace the radio control with the laser control, whereas the disruptions in the transmission of data from the sensor might be eliminated by way of transmitting the data through the optical fiber [5]. In many countries and army, wired drones are used [17, 20]. The platform's flight has been supervised by a person with proper qualifications. The measurements have been recorded on a memory card placed in the sensor. The frequency of recording equaled every 1 second. The sensor's producer has also enabled its users to transmit the measurements directly upon the dedicated server. The test results are currently being developed. Performing the measurements concerning the influence of the mobile platform upon the proper measurement of the electromagnetic field is yet another vital test to be considered.

Fig. 2. Flying platform during test testing

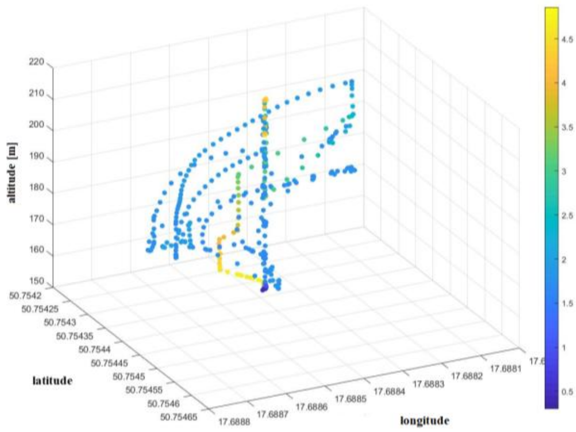

Fig. 3. Developed results of test measurements

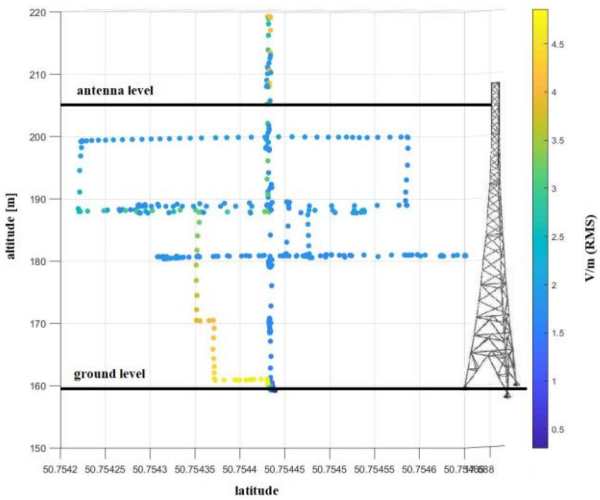

Fig. 4. Developed results of test measurements in relation to the mast height

Figures 3 and 4 present the developed results of test measurements conducted in close proximity to the mobile telephony mast. The levels of electromagnetic fields (based on the electrical component) recorded by the sensors have been presented on the basis of the GPS points assigned to a given field being measured. The flight route of the platform has been selected by way of experiment since it constituted a test measurement. Figure 3 depicts the measurement results in relation to length, latitude and height, whereas figure 4 depicts the same measurement results in relation to latitude and height. The levels of electromagnetic fields measured were assigned to appropriate colors.
A comparative analysis with a meter placed on the ground and an analysis of disturbances in the impact of electronics will take place in the next experiment and its results will be presented in the magazine.

4. Summary

The use of flying platforms to perform measurements of the electromagnetic field is a very good alternative to traditional methods. Thanks to UAV (unmanned aerial vehicle*)*, it is possible to carry out measurements on a larger area in a much shorter period of time. The measurement is not limited by infrastructural barriers, therefore the measurement can be made close to the source of the electromagnetic field. The measurement route, once planned, can be repeated several times in different periods to make the analysis more transparent. This function depends on the software. DJI provides a tool to download aircraft data. Machining is done manually. Then the whole is applied to the IGIS map or connected to the 2D map by means of GPS trajectory.

The first test measurements of electromagnetic field generated by the mobile telephony station, are being followed by preparations to perform other measurements of electromagnetic field generated by radio-tv masts and high voltage lines. Taking the measurements can be accompanied by transmitting them in a real-time to the server where they are displayed after being properly processed. The only hazard observed was the disruption of the mobile platform by the strong sources of electromagnetic field.

By applying colors to the measurement results you can quickly determine how the intensity of the electromagnetic field changes at a given point. The basic advantage of the measurement based on the autonomous unit is the ability to perform measurement of the fields distribution for the magnetic and electrical components. Thanks to the point measurement of the area, it is possible to generate a spatial grid of the fields distribution, which has been difficult so far.

The flying unit is able to study points that were previously unattainable. It would be advisable to use many UAV units controlled by the "Boids" algorithm, which would allow to make measurements with a high density of measurement points [1;2].

At present, quick and efficient measurement of electromagnetic field becomes a necessity in a world where technological development affects every possible field, in particular the field of wireless technologies. Unmanned aerial vehicles might turn out of considerable importance in this respect.

References

[1] Beni G., Wang J.: Swarm Intelligence. Proceedings of the Seventh Annual Meeting of the Robotic Society of Japan, 425–428, 1989.
[2] Butlewski R., Kasprzyk R.: Pole elektromagnetyczne jako czynnik szkodliwy w przemysle elektroenergetycznym. Zeszyty Naukowe Politechniki Poznańskiej. Organizacja i Zarządzanie 59, 19–23, 2013.
[3] Dyrektywa Parlamentu Europejskiego i Rady Europy 2013/35/UE z dnia 26 czerwca 2013 r. (available: 20.06.2019).
[4] Eberhart R., Kennedy J.: Particle swarm optimization. Proceedings of the International Conference on Neural Network, 1942–1948, 1995.
[5] Fritzel T., Strauß R., Steiner H., Eisner C., Eibert T.: Introduction into an UAV-based near-field system for in-situ and large-scale antenna measurements. 2016 IEEE Conference on Antenna Measurements & Applications (CAMA), 2016, 1–3, [DOI: 10.1109/CAMA.2016.7815762].
[6] Gruber J., Jóźwiak I., Kowalczyk D.: Metody odzyskiwania i kasowania danych z nośników magnetycznych i nośników pamięci flash. Zeszyty Naukowe Politechniki Śląskiej. Organizacja i Zarządzanie 74, 2014, 35–44.
[7] Gryz K., Karpowicz J.: Zasady oceny zagrożeń elektromagnetycznych związanych z występowaniem prądów indukowanych i kontaktowych. Podstawy i Metody Oceny Środowiska Pracy 4(58), 2008, 137–171.
[8] Lewicka M. Dziedziczak-Buczyńska M. Buczyński A.: Electromagnetic radiation influence on living organisms. Polish Hyperbaric Research 4(25), 2008, 33–41.
[9] Tomczykowski J.: Sieci energetyczne pięciu największych operatorów. Energia Elektryczna 5/2015, 23–25.
[10] Norma Ochrona pracy w polach i promieniowaniu elektromagnetycznym o częstotliwości od 0 Hz do 300 GHz: PN-T-06580:2002
[11] http://archiwum.ciop.pl/26003.html (available: 3.03.2018).
[12] http://www.opole.pios.gov.pl/wms/Pliki/2017/Ocena_wynikow_pomiarow_monitoringowych_PEM_za_rok_2016.pdf (available: 21.02.2018).
[13] http://www.wavecontrol.com/rfsafety/en/ (available: 16.05.2018).
[14] http://www.who.int/mediacentre/factsheets/fs193/en/ (available: 10.04.2018).
[15] http://www.wios.lodz.pl/Monitoring_promieniowania_elektromagnetycznego_PEM,38 (available: 20.04.2018).
[16] https://pem.itl.waw.pl/artyku%C5%82y/pomiary-pem-w-otoczeniu-stacji-bazowych-telefonii-kom%C3%B3rkowej-sbtk-oraz-punkt%C3%B3w-dost%C4%99pu-lokalnych-sieci-dost%C4%99pu-bezprzewodowego-rlan/ (available: 1.07.2018).
[17] https://tech.nikkeibp.co.jp/dm/atclen/news_en/15mk/010401054/?ST=msbe&P=3 (available: 20.06.2019).
[18] https://www.aspen-electronics.com/wcrange.html(available: 10.04.2018).
[19] https://www.piit.org.pl/wazne/pem (available: 10.05.2018).
[20] https://www.riseabove.com.au/powerline-power-tether-system-for-drones (available: 20.06.2019).
[21] https://www.wavecontrol.com/rfsafety/images/datasheets/en/cMonitEM_Datasheet_EN.pdf (available: 20.06.2019).

Prof. Sławomir Szymaniec
e-mail: s.szymaniec@po.opole.pl

Prof. dr. Eng. (born 1949, Opole) A: electronics engineer, expert diagnostician, appraiser electric machines; Head of the Department, author of 2 monographs; co-author 2 monograph; author of 236 articles; co-author of 6 patents, 2010 winner of the 15th edition of the competition for the research prize Siemens company for outstanding achievements in technology and research, 1st place winner; he is the creator of the Opole School known in Poland and abroad Diagnostics of Electrical Machines and Drives, organized a research team academy industrial dealing in the operation and diagnostics of machines electric and manages His work; at department in the implementation of 42 scientific works research implemented in industry; author or co-author of 41 expert opinions for industry; managed 2 research projects implemented in industry; co-author of about 1,400 technical works for industry.

ORCID ID: 0000-0002-7642-1456

M.Sc. Sławomir Szymocha
e-mail: slawomir.szymocha@doktorant.po.edu.pl

Born 1989, Lubliniec – M.Sc., Opole University of Technology, two-time winner of the second place in the diploma dissertation competition organized at the Faculty of Electrical Engineering of Automatics and Informatics: Ing 2014, Master. 2015, co-author of two European utility models, Ph.D. student at the Opole University of Technology from 2016, involved in the implementation of projects related to renewable energy and implementation of innovation. Currently employed as a designer of control cabinets.

ORCID ID:0000-0001-6548-9896

M.Sc. Łukasz Miszuda
e-mail: lukaszmiszuda@wp.pl

Born 1991, Prudnik – M.Sc., Opole University of Technology, Ph.D. student at the Opole University of Technology from 2017. He carries out international projects related to control. Currently employed as an industrial automation programmer.

ORCID ID:0000-0003-0289-053X

otrzymano/received: 02.08.2019 *przyjęto do druku/accepted: 06.12.2019*