Safety Engineering

UDC: 537.811
DOI: 10.7562/SE2019.9.02.03
Original article

DRAGAN KLJAJIĆ[1,1]
NIKOLA ĐURIĆ[2]
KAROLINA KASAŠ-LAŽETIĆ[3]

[1,2,3]University of Novi Sad,
Faculty of Technical Sciences,
Trg Dositeja Obradovica 6,
21000 Novi Sad, Serbia,

[1]*dkljajic@uns.ac.rs*
[2]*ndjuric@uns.ac.rs*
[3]*kkasas@uns.ac.rs*

THE HIGH-FREQUENCY EMF INVESTIGATION OVER THE CAMPUS AREA OF THE UNIVERSITY OF NOVI SAD

Abstract: *An issue of electromagnetic field (EMF) pollution in the environment has become particularly important due to a continuous increase in the number of artificial EMF sources. Consequently, appropriate measurements and control of EMF level have been performed in different indoor and outdoor environments. This paper presents details about the broadband EMF monitoring campaign over the University of Novi Sad campus. Outdoor measurements of the high-frequency electric field were carried out in spatial and temporal domain, at frequently visited campus' locations. Exposure assessment was performed in compliance with national legislation, showing that acquired results are far below prescribed reference levels, thus distinguishing the campus as a low exposed area.*

Keywords: electromagnetic field, monitoring, radiation exposure.

INTRODUCTION

The number of artificial electromagnetic field (EMF) sources in human surroundings continuously grows, as a consequence of the rapid technological progress of the society. Those sources are an inevitable part of the living and working environment and their constant presence trigger doubt and worry of the general population, regarding possible harmful EMF effects on health [1].

In line with that, the area of EMF investigation has become particularly significant regarding the prevention and protection of the general population EMF exposure. Thus, a great number of EMF surveys and measurement campaigns on an international scale have been conducted. The measurements were being performed in various indoor/outdoor environments, at different periods, using various measuring techniques and equipment [2]-[4].

Regarding places of EMF investigation, particular attention has been paid to sensitive zones such as schools, residential areas, shopping centers, as well as other public spots [5]-[9]. The university campus areas are also classified as highly sensitive. Thus, some scientific studies deal with EMF investigation in those areas [10], [11].

Besides the fact that measurements have to be done in accordance with relevant EMF standards and recommendations [12]-[14], the recent trends suggest continuous monitoring of EMF levels on a long-term basis [15]. Following this approach, the campaign of broadband EMF monitoring was carried out over the University of Novi Sad campus during 2018. This campaign was based on the outdoor long-term monitoring of the high-frequency electric field.

This paper brings an analysis of the monitoring campaign's results. In the following sections, basic details about the campus area and applied measuring procedure are given, together with an appropriate discussion of the results for the electric field strength measurements and performed exposure assessment.

MONITORING CAMPAIGN'S ACTIVITIES

The University of Novi Sad is the second-largest university in the Republic of Serbia. Its campus occupies an area of 256,807 m^2 and is located in the southwestern part of the city of Novi Sad. The sketch of the campus area is presented in Fig. 1.

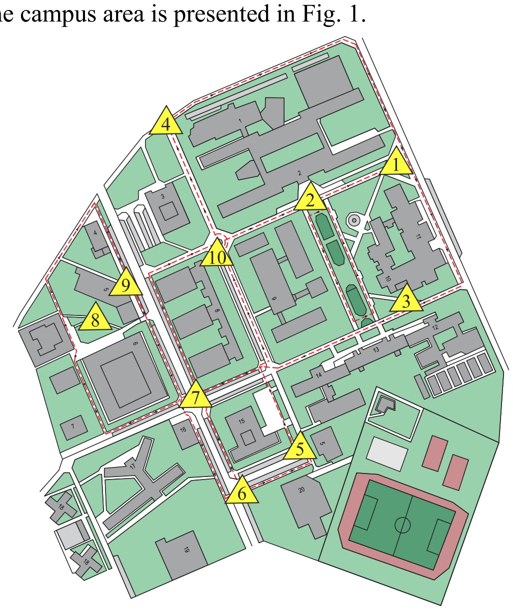

Figure 1. *Campus area of the University of Novi Sad*

[1] Paper is presented in 14th International Conference on Applied Electromagnetics PES 2019, Nis, Serbia

A headquarters of the university is located in the campus, as well as seven out of thirteen faculties that belong to the university. Within this campus, there are four main traffic streets and several pedestrian zones. Additionally, this area is surrounded by residential buildings and a few high frequent traffic streets.

According to its position, it is clear that the constant presence of people distinguishes the campus area as highly sensitive. Moreover, people's daily activities impose necessities for the use of different wireless communication technologies. Therefore, the presence of the high-frequency electric fields originated from a number of EMF sources, is expected in the campus area.

Those facts initiated the idea for the long-term broadband monitoring of the high-frequency electric field at campus' locations most frequently visited by students and university staff, marked with yellow triangles in Fig. 1. The intention was to obtain information about the temporal fluctuation of the field.

Additionally, in order to achieve an insight into the spatial fluctuation of the field, monitoring campaign included the initial short-term measurements in a spatial domain. Those measurements were carried out along the campus most important pedestrian paths, labeled with red lines in Fig. 1.

A) Preliminary field scanning

The intention of a preliminary field scan over the campus was to determine the spatial changes of the electric field strength at places with large fluctuation of people. Measurements were taken in 1005 measurement points, evenly distributed at the distance of 2 m along the selected pedestrian paths.

During measurements, the instrument's field probe was positioned at a height of 1.1 m above the ground level, according to the standard SRPS EN 50492:2010 [13].

Measurements were carried out using Narda NBM-550 handheld broadband field meter [16], equipped with the electric field probe EF 0691 [17]. The main parameters of this probe are provided in Table 1 [17].

Table 1. *Electric Field Probe EF 0691 [17]*

Parameter	Value
Frequency range	100 kHz to 6 GHz
Measurement range	0.35 V/m to 650 V/m
Linearity	±0.5 dB (2 to 400 V/m)
Frequency sensitivity	±1.5 dB (1 MHz to 4 GHz)

The frequency range of the applied electric field probe covers the operating frequencies of almost all known sources of the high-frequency electric field. Therefore, information on the overall and cumulative electric field strength presented at a particular location has been provided.

B) Broadband continuous monitoring

The continuous and long-term monitoring of the electric field at ten measurement locations was performed at the most frequently visited places in the campus. Those places are in front of faculty buildings, students' cafeterias, students' dormitories and at the most frequent pedestrian paths.

This phase of the campaign was done applying the protocol developed in the SEMONT (*Serbian Electromagnetic Field Monitoring Network*) system [18]. It consisted of two parts:

- **Preliminary electric field spatial scanning, over the grid of 25 measurement points** – with the aim to determine the spatial distribution of the field strength at a particular location [12] and to find the point with the field strength maximum (so-called hot spot) [13].
- **Four-hours monitoring of the field strength in the hot spot** – setting up the instrument's field probe at a height of 1.7 m [18]. The pedestrian access was forbidden during the monitoring, with the aim to achieve measurement conditions as in the so-called unperturbed field area.

Lastly, the exposure assessment was performed, applying the SEMONT's boundary exposure assessment method [20], calculating the exposure boundaries according to the following expressions:

$$GER_{low} = \left(\frac{E_m}{E_{ref\,\max}}\right)^2 \; and \; GER_{up} = \left(\frac{E_m}{E_{ref\,\min}}\right)^2, \quad (1)$$

and obtaining the range where the real exposure is located.

In this equation, E_m is the broadband measured value of the electric field strength, while $E_{ref\,min}$ and $E_{ref\,max}$ are minimal and maximal reference levels, prescribed by the legislation [19], for the frequency range of the applied field probe.

MEASUREMENT RESULTS

A short statistical analysis of the results of a preliminary electric field scan along the most important pedestrian paths in the campus is provided in Table 2.

Table 2. *Actual field strength values along campus pedestrian paths*

E_{min} [V/m]	E_{avg} [V/m]	E_{max} [V/m]	$E_{st.\ dev.}$ [V/m]
0	0.477	2.547	40.261

These results show that the acquired values of the electric field strength are at least four times lower than the minimal reference level of $E_{ref\ min}$ = 11 V/m, prescribed by the national legislation [19]. Consequently, the campus area can be considered as a zone with a low spatial distribution of the high-frequency electric field.

A) Monitoring results

Broadband monitoring of the field was carried out from 9 A.M. until 1 P.M., which is a rush period at the university, with the high frequency of students and university staff.

A short statistical analysis of the obtained average field strength values is given in Table 3.

Table 3. *Average field strength values during the four-hour monitoring*

E_{avg} [V/m]				
Location	***Min***	***Avg***	***Max***	***Std.* [%]**
1	0.119	0.178	0.242	3.047
2	0.237	0.296	0.353	3.193
3	0.486	0.551	0.612	3.406
4	0.131	0.183	0.245	3.177
5	0.616	0.709	0.756	2.808
6	**1.012**	**1.120**	**1.271**	**5.844**
7	0.618	0.727	0.894	5.475
8	0.466	0.515	0.576	3.030
9	0.139	0.216	0.454	5.022
10	0.521	0.644	0.748	5.780

Additionally, a short statistical analysis of obtained maximum field strength values is offered in Table 4.

Table 4. *Maximum field strength values during the four-hour monitoring*

E_{max} [V/m]				
Location	***Min***	***Avg***	***Max***	***Std.* [%]**
1	0.275	0.347	0.406	3.366
2	0.433	0.507	0.637	4.831
3	0.702	0.793	0.862	3.729
4	0.250	0.383	0.694	9.409
5	0.785	0.911	1.664	13.618
6	**1.342**	**1.468**	**1.695**	**7.795**
7	0.966	1.129	1.355	8.539
8	0.794	0.905	1.020	6.690
9	0.308	0.424	2.389	32.474
10	0.851	1.024	1.181	6.717

Considering the results from Tables 3 and 4, it can be observed that the highest field strength values were obtained at Location 6.

Temporal changes of the average and maximum field strength values, at this location, are graphically presented in Fig. 2.

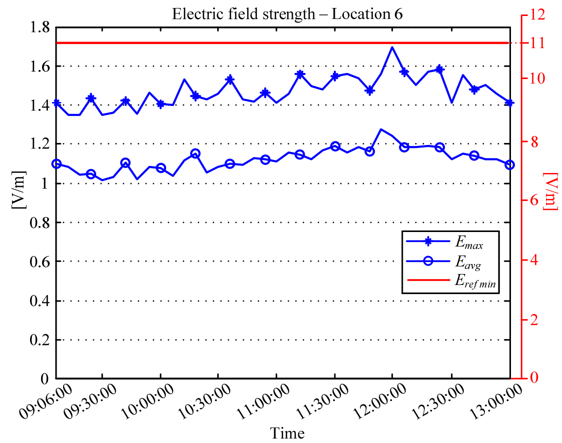

Figure 2. *Monitoring of the electric field strength at Location 6*

The analysis showed that all obtained values of E_{avg} and E_{max} are five or more times below the minimal reference level of $E_{ref\ min}$ = 11 V/m (red marked line in Fig. 2). Thus, the whole campus area can be considered as one with low intensity of the high-frequency electric field.

Additionally, low values of the standard deviation of E_{avg} for all locations lead to the conclusion about slow temporal changes of the high-frequency electric field over the campus area.

B) Exposure assessment results

The exposure boundaries were calculated by applying the expression (1), where E_{avg} values were used as E_m. Besides, the minimal and maximal reference levels had values $E_{ref\ min}$ = 11 V/m and $E_{ref\ max}$ = 34.8 V/m, according to the national legislation [19] and observed broadband frequency range. A brief statistical analysis of acquired GER_{low} values is depicted in Table 5.

Table 5. *Values of lower exposure boundaries*

GER_{low}				
Loc.	***Min***	***Avg***	***Max***	***Std.* [%]**
1	1.17×10^{-5}	2.70×10^{-5}	4.84×10^{-5}	8.96×10^{-4}
2	4.63×10^{-5}	7.30×10^{-5}	1.03×10^{-4}	1.58×10^{-3}
3	1.95×10^{-4}	2.52×10^{-4}	3.09×10^{-4}	3.10×10^{-3}
4	1.41×10^{-5}	2.84×10^{-5}	4.96×10^{-5}	9.68×10^{-4}
5	3.13×10^{-4}	4.16×10^{-4}	4.72×10^{-4}	3.21×10^{-3}
6	$\mathbf{8.46\times10^{-4}}$	$\mathbf{1.04\times10^{-3}}$	$\mathbf{1.33\times10^{-3}}$	$\mathbf{8.80\times10^{-4}}$
7	3.16×10^{-4}	4.38×10^{-4}	6.60×10^{-4}	6.76×10^{-3}
8	1.79×10^{-4}	2.20×10^{-4}	2.74×10^{-4}	2.60×10^{-3}
9	1.60×10^{-5}	4.06×10^{-5}	1.70×10^{-4}	2.38×10^{-3}
10	2.25×10^{-4}	3.45×10^{-4}	4.62×10^{-4}	6.02×10^{-3}

In addition, short statistical analysis of GER_{upper} values is given in Table 6.

Table 6. *Values of upper exposure boundaries*

GER_{up}				
Loc.	***Min***	***Avg***	***Max***	***Std.* [%]**
1	1.17×10^{-4}	2.70×10^{-4}	4.85×10^{-4}	8.97×10^{-3}
2	4.64×10^{-4}	7.31×10^{-4}	1.03×10^{-3}	1.58×10^{-2}
3	1.95×10^{-3}	2.52×10^{-3}	3.10×10^{-3}	3.11×10^{-2}
4	1.41×10^{-4}	2.84×10^{-4}	4.96×10^{-4}	9.69×10^{-3}
5	3.13×10^{-3}	4.16×10^{-3}	4.72×10^{-3}	3.22×10^{-2}
6	$\mathbf{8.47\times10^{-3}}$	$\mathbf{1.04\times10^{-2}}$	$\mathbf{1.34\times10^{-2}}$	$\mathbf{1.09\times10^{-1}}$
7	3.16×10^{-3}	4.39×10^{-3}	6.61×10^{-3}	6.77×10^{-2}
8	1.79×10^{-3}	2.20×10^{-3}	2.74×10^{-3}	2.60×10^{-2}
9	1.60×10^{-4}	4.06×10^{-4}	1.70×10^{-3}	2.38×10^{-2}
10	2.25×10^{-3}	3.46×10^{-3}	4.62×10^{-3}	6.03×10^{-2}

Finally, time fluctuations of exposure boundaries at Location 6, in the graphical form, are presented in Fig. 3.

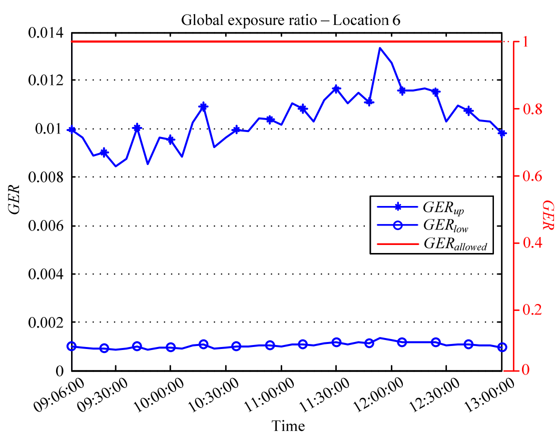

Figure 3. *The exposure boundaries at Location 6.*

The conclusions about exposure at campus locations are similar as for the case of the electric field strength values. All values of exposure boundaries are several hundred or thousand times below the maximal allowable level of $GER_{allowed} = 1$ (red marked line in Fig. 3). Thus, it was once again confirmed assertion about small spatial and temporal distribution of the electric field exposure, over the campus area.

CONCLUSION

Regarding places of EMF investigation, special emphasis should be on highly sensitive areas, where people spend a lot of time, such as the University campus area. Therefore, the outdoor broadband monitoring campaign was conducted over the campus area of the University of Novi Sad.

This campaign consisted of short-term measurements in a spatial domain, as well as of four-hour monitoring of the high-frequency electric field strength, at the campus' most frequently visited places.

All acquired results are far below reference levels prescribed by the national legislation, suggesting the small spatial and temporal distribution of the electric field. Additionally, low values of the general population exposure distinguish the campus as a low EMF exposed area.

Despite the obtained results, further periodical monitoring campaigns over the campus will certainly be indispensable, having in mind the everyday increase of a number of EMF sources in the surrounding.

Besides, some future campaigns should be oriented toward indoor measurements into campus' buildings.

REFERENCES

[1] Eurobarometer 347, Special Eurobarometer 347, Eurobarometer 73.3, "Electromagnetic Fields", 2010, http://ec.europa.eu/public_opinion/archi–ves/ebs/ebs_347_en.pdf.

[2] J. T. Rowley and K. H. Joyner, "Comparative international analysis of radiofrequency exposure surveys of mobile communication radio base stations", Journal of Exposure Science and Environmental Epidemiology, Vol. 22, Issue 3, pp. 304-315, 2012.

[3] P. Gajšek, P. Ravazzani, J. Wiart, J. Grellier, T. Samaras and G. Thuróczy, "Electromagnetic field exposure assessment in Europe radiofrequency fields (10 MHz–6 GHz)", Journal of Exposure Science and Environmental Epidemiology, Vol. 25, Issue 1, pp. 37-44, 2015.

[4] S. Sagar, S. Dongus, A. Schoeni, K. Roser, M. Eeftens, B. Struchen, M. Foerster, N. Meier, S. Adem and M. Röösli, "Radiofrequency electromagnetic field exposure in everyday microenvironments in Europe: a systematic literature review", Journal of Exposure Science and Environmental Epidemiology, Vol. 28, Issue 2, pp. 147-160, 2017.

[5] World Health Organization, "WHO research agenda for radiofrequency fields", WHO research agenda for radiofrequency fields, 2010.

[6] M. Gallastegi, A. Huss, L. Santa-Marina, J. J. Aurrekoetxea, M. Guxens, L. E. Birks, J. Ibarluzea, D. Guerra, M. Röösli and A. Jiménez-Zabala, "Children's exposure assessment of radiofrequency fields: Comparison between spot and personal measurements", Environment international, Vol. 118, pp. 60-69, 2018, https://doi.org/10.1016/j.envint.2018.05.028.

[7] K. Karipidis, S. Henderson, D. Wijayasinghe, L. Tjong and R. Tinker, "Exposure to Radiofrequency Electromagnetic Fields from Wi-Fi in Australian Schools", Radiation Protection Dosimetry, Vol. 175, Issue 4, pp. 432-439, 2017, doi:10.1093/rpd/ncw370.

[8] J. Karpowicz, S. De Miguel-Bilbao, P. Zradzńnski, K. Gryz, F. Falcone and V. Ramos, "Comparative Study of Radiofrequency Electromagnetic Exposure in the Public Shopping Centers", IEEE International Symposium on Electromagnetic

Compatibility (EMC Europe 2018), Amsterdam, The Netherlands, 27-30 August 2018, pp. 972-975.

[9] L. van Wel, R. Vermeulen, M. van Eijsden, T. Vrijkotte, H. Kromhout and A. Huss, “Radiofrequency exposure levels in Amsterdam schools”, Bioelectromagnetics, Vol. 38, Issue 5, pp. 397-400, 2017, http:// dx.doi.org/10.1002–/bem.22053.

[10] F. C. Kunter, “Students Exposure to Radio Frequency Electromagnetic Fields in Marmara University”, Marmara Science Journal, Vol. 27, No. 1, pp. 32-36, 2015, doi:http://dx.doi.org/–10.7240/mufbed.70492.

[11] C. Kurnaz, “An Empirical Modeling of Electromagnetic Pollution on University Campus”, Applied Computational Electromagnetics Society Newsletter, Vol. 33, No. 1, pp. 111-114, 2018.

[12] Basic standard on measurement and calculation procedures for human exposure to electric, magnetic and electromagnetic fields (0 Hz – 300 GHz), SRPS EN 50413:2010, 2010.

[13] Basic standard for the in-situ measurement of electromagnetic field strength related to human exposure in the vicinity of base stations, SRPS EN 50492:2010, 2010.

[14] “Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz)”, International Commission on non-ionizing radiation protection (ICNIRP), http://www.icnirp.de/documents/emfgdl.pdf,1998

[15] ITU-T K.83, Recommendation ITU-T K.83 – Monitoring electromagnetic field, 03/2011.

[16] Narda Safety Test Solutions GmbH, NBM-550 Broadband Field Meter User’s Guide, 2006.

[17] Narda Safety Test Solutions GmbH, EF 0691 Electric Field User’s Guide, 2006.

[18] N. Djuric, D. Kljajic, K. Kasas-Lazetic and V. Bajovic, "The measurement procedure in the SEMONT monitoring system," Environmental Monitoring and Assessment, March 2014, Volume 186, Issue 3, pp. 1865-1874, 2014.

[19] “Regulation on the limits of exposure to non-ionizing radiation”, the law of the Republic of Serbia, no. 104/09.

[20] D. Kljajic and N. Djuric, “The adaptive boundary approach for exposure assessment in a broadband EMF monitoring”, Measurement, Volume 93, pp. 515–523, 2016, DOI:10.10-16/j.measurement.–2016.07.055.

ACKNOWLEDGEMENTS

This work is supported by the Ministry of Education, Science and Technological Development of the Republic of Serbia, under the grant for project TR 32055.

BIOGRAPHY of the first author

Dragan Kljajić was born on April 29, 1987, in Novi Sad, the Republic of Serbia. He received a Ph.D. in Electrical and Computer Engineering, at Faculty of Technical Sciences in Novi Sad, at the Department of Power, Electronic and Telecommunication Engineering. He works as an Assistant Professor at the same Department. His scientific area is theoretical electrotechnics, while his research interests are in the field of theoretical electrical engineering, theoretical and applied electromagnetics and microelectronics. He is the author or co-author of more than 50 scientific papers, published in Proceedings of international conferences and high impact factor journals. He is a member of the IEEE society.

ISPITIVANJE EM POLJA VISOKIH FREKVENCIJA U OKVIRU KAMPUSA UNIVERZITETA U NOVOM SADU

Dragan Kljajić, Nikola Đurić, Karolina Kasaš-Lažetić

Rezime: *Problem zagađenosti životne sredine elektromagnetskim poljima (EMP) postao je naročito važan usled stalnog porasta broja veštačkih izvora EMP-a. Stoga se odgovarajuća merenja i kontrola nivoa EMP-a obavljaju na otvorenom i u zatvorenom prostoru. U ovom radu su predstavljeni detalji kampanje širokopojasnog merenja nivoa EMP-a u okviru kampusa Univerziteta u Novom Sadu. Merenja nivoa električnog polja visokih frekvencija na otvorenom su obavljena u prostornom i vremenskom domenu, na najfrekventnijim lokacijama u kampusu. Procena izloženosti opšte populacije je izvršena u skladu sa nacionalnim zakonodavstvom, pokazavši da su dobijene vrednosti nivoa polja daleko ispod propisanih referentnih graničnih nivoa, čime se oblast kampusa izdvaja kao oblast sa niskom EM izloženošću.*

Ključne reči: elektromagnetsko polje, monitoring, izloženost zračenju.