International Journal of Information, Control and Computer Sciences
ISSN: 2517-9942
Vol:8, No:8, 2014

The SEMONT Monitoring and Risk Assessment of Environmental EMF Pollution

Dragan Kljajic, Nikola Djuric, Karolina Kasas-Lazetic, Danka Antic

***Abstract*—**Wireless communications have been expanded very fast in recent decades. This technology relies on an extensive network of base stations and antennas, using radio frequency signals to transmit information. Devices that use wireless communication, while offering various services, basically act as sources of non-ionizing electromagnetic fields (EMF). Such devices are permanently present in human vicinity and almost constantly radiate, causing EMF pollution of the environment. This fact has initiated development of modern systems for observation of the EMF pollution, as well as for risk assessment. This paper presents the Serbian electromagnetic field monitoring network – SEMONT, designed for automated, remote and continuous broadband monitoring of EMF in the environment. Measurement results of the SEMONT monitoring at one of the test locations, within the main campus of the University of Novi Sad, are presented and discussed, along with corresponding exposure assessment of the general population, regarding the Serbian legislation.

***Keywords*—**EMF monitoring, exposure assessment, sensor nodes, wireless network.

I. Introduction

THE electromagnetic field (EMF) pollution of environment became unavoidable, since obvious increase in number of EMF sources, such as personal communication devices, base stations for wireless services, radio and TV broadcasting facilities, power lines, radars, etc. The existence of these sources in human surrounding, forces a safety problem both for the human health and the environment [1]. In order to raise the awareness of the public on present EMF pollution and possibly dangerous effects of long-term exposure to EMF radiation, our research team has started the development of the Serbian electromagnetic field monitoring network – SEMONT [2]. This system is intended for remote and continuous broadband EMF monitoring in the environment, acquiring real-time information on the present *in-situ* EMF strength and performing assessment of the daily exposure over the area covered by the SEMONT network.

In this paper, the brief explanation of the SEMONT concept is repeated in Section II, while performed initial monitoring and measurement results, which are acquired over one particular location, are presented in Sections III and IV. Section V describes the SEMONT's approach for daily exposure assessment of the general population, regarding the Serbian legislation [3]. Finally, Section VI brings conclusion on this work.

D. Kljajic, N. Djuric, K. Kasas-Lazetic, and D. Antic are with the Faculty of Technical Sciences, University of Novi Sad, Trg D. Obradovica 6, 21000 Novi Sad, Serbia, Europe (e-mail: dkljajic@uns.ac.rs, ndjuric@uns.ac.rs, kkasas@uns.ac.rs, danka.antic@uns.ac.rs).

II. The SEMONT System Design

The SEMONT monitoring system is based on modern autonomous wireless sensor nodes for monitoring of the present EMF pollution. The sensor nodes are intended to be spatially distributed over an observed area, as depicted in Fig. 1 [2].

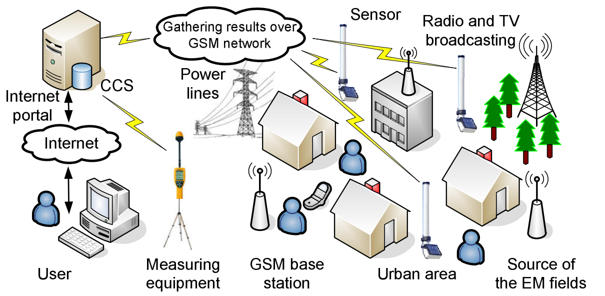

Fig. 1 The SEMONT utilization over an urban area

The central control station (CCS) of the Internet portal [4], [5], controls and coordinates activities of remote sensors, collects, processes and stores data into a centralized database.

Communication between CCS and remote sensor nodes relies on GSM cellular network and sensor nodes are equipped with a quad-band GSM/GPRS modem for remote control and for data upload/download [6], [7].

Additionally, the SEMONT system is enhanced with a feature to incorporate measurement data obtained by handheld equipment, as shown in Fig. 1 [8].

Several additional details on SEMONT system can be found in previously published papers. In this paper they will be omitted, while focus will be on the EMF monitoring of the high-frequency electric field at particular location on the campus of the University of Novi Sad, as well as the analysis of results of measurement and corresponding exposure assessment.

III. Measurement Location

The campus of the University of Novi Sad is central place of gathering of a large number of students, and unfortunately, in the past there was not any systematic EMF monitoring, even this area is usually considered as a highly sensitive area.

The initial EMF monitoring campaign was performed in a period of ten days, on most crowded locations over campus. Each day, measurements were conducted on a different location in time period from 10 AM until 2 PM, since it is the busiest period at the campus. The measurement grid was assigned to each location, positioned to cover the pathways of the daily high fluctuation of student population.

In this paper, the measurement results obtained at campus location near the corner of Dr S. Milosevica and Dr V. Savica Streets will be presented. This location was chosen, since in the vicinity there are: The Higher School of Professional Business Studies, the Faculty of Economy and the Student's sport center. Additionally, an elementary school and a kindergarten are located, as shown in Fig. 2.

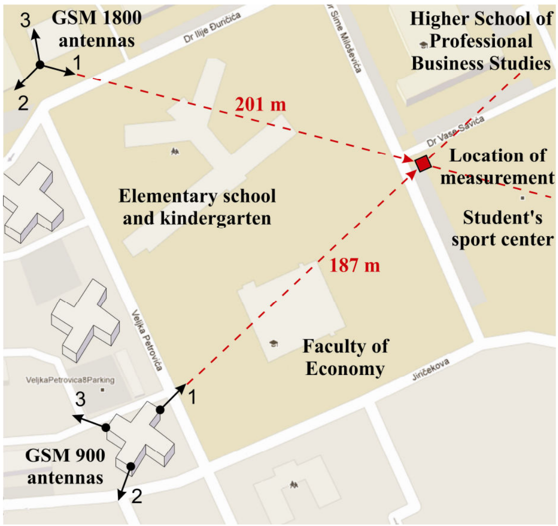

Fig. 2 Measurement location and surrounding base stations

Besides, two GSM base stations are active in the vicinity of this location, which main beams of sector 1 antennas intersect over the measurement location, as can be seen from Fig. 2 [9].

The open area measurement was performed, observing the so-called unperturbed field, without the presence of persons or any other objects that can influence EMF distribution. At this location, the measurement grid was formed, consisting of 25 squared arranged points with a matrix form. The measurement points were positioned equidistantly, with a distance of 1 m, according to standard SRPS EN 50400:2008 [10], which suggests that the minimum distance has to be 0.5 m, in case of the high-frequency measurements.

The measurement procedure was presented in a previous published paper [9], and here it will be shortly reintroduced:

- first, a preliminary field scan was conducted over the measurement grid, determining the spatial distribution of EMF strength and point of local maximum, the so-called hot-spot,
- next, detailed measurements were carried out within the hot-spot, using the continuous broadband monitoring approach, and
- finally, the exposure assessment of the general population was performed, according to Serbian legislation [3].

IV. Measurement Results

The measurements were performed using handheld NBM-550 broadband field meter [8], [11], with continuous measurement mode [11], equipped with the electric field probe EF 0691 [12], which frequency range is from 300 kHz to 6 GHz.

A. Preliminary Field Scan

Preliminary field scan was performed over the measurement grid at height of 1.1 m above the ground surface. The technical personnel held the instrument for a few seconds at the measurement point, recorded level of the electric field strength and moved forward to the next point. While measurements were being conducted, the field probe was positioned at least 50 cm from the operator's body, according to standard SRPS EN 50492:2010 [13], because dominant sources (GSM 900, GSM 1800) are in the range above 300 MHz.

Table I shows the results of the field scan procedure for high-frequency electric field over 25 measurement grid points.

TABLE I
Electric Field Strength [V/m]

P1	P2	P3	P4	P5
0.65	0.64	0.67	0.72	0.73
P6	**P7**	**P8**	**P9**	**P10**
0.67	0.73	0.74	0.79	0.85
P11	**P12**	**P13**	**P14**	**P15**
0.74	0.82	0.79	0.80	0.63
P16	**P17**	**P18**	**P19**	**P20**
0.86	0.89	0.85	0.74	0.79
P21	**P22**	**P23**	**P24**	**P25**
0.68	0.89	0.84	0.93	0.93

It can be observed that values of the electric field strength are in the range from 0.63 V/m to 0.93 V/m and the maximum value of electric field strength was found at points P24 and P25. Unfortunately, the presence of some metal objects in the vicinity of those points was noticed, which could cause interference and diminish the reliability and accuracy of results of monitoring. Thus, the point P22 was declared as a hot-spot, without any impairment on measurement validity.

B. Statistic Analysis of the Preliminary Field Scan

According to the preliminary field scan, it can be seen that spatial values of the electric field strength, at this location, are far below the Serbian prescribed reference levels [3], [14].

The highest value of the electric field strength is 0.93 V/m, which does not represent serious threat for the general population. Additionally, average and minimum values are also within the allowed limits, as shown in Table II.

TABLE II
Statistical Analysis of the Spatial Distribution

E_{max} [V/m]	E_{min} [V/m]	E_{avg} [V/m]	St.Dev [V/m]
0.93	**0.63**	**0.775**	**0.090651**

It can be seen that standard deviation of field strength is very small with value of 0.090651. This number is a measure of how all values are dispersed from the average value. It is calculated using following equation:

$$\sqrt{\frac{\sum_{i=1}^{n}\left(E_i - E_{avg}\right)^2}{n-1}} \tag{1}$$

where n=25 is number of measurement points, E_i is measured value of electric field strength at point i and E_{avg} is electric field average value of 0.775 V/m.

This statistical analysis confirms that chosen location is location with almost uniform spatial distribution and very small deviation of the electric field strength.

C. Continuous Monitoring in the Hot-Spot

After finishing first stage of measurement and declaring the so-called hot-spot point, continuous monitoring of the electric field was conducted in this point. It was done with 6 min averaging, as suggested in the guidelines [15], [16]. However, in this initial monitoring campaign measurement period was only four hours and during that time period continuous monitoring was performed by observing the maximum, minimum and the averaged field values. The NBM-550 instrument was set up on the wooden tripod and the probe was positioned at the height of 1.7 m, as shown in Fig. 3.

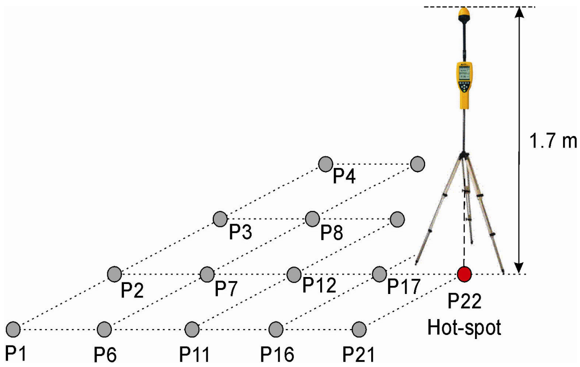

Fig. 3 Continuous monitoring of electric field strength at the hot-spot

Height of 1.7 m was chosen as the average human height, and the primary aim was to perform monitoring on highly sensitive position of the human head. During monitoring process, the instrument was set up to "Timer Logging mode" [11], recording values of the electric field without interruption during the time period of four hours.

Results of the continuous monitoring are shown in Fig. 4, where three curves are plotted on the graph describing fluctuation of the maximum, minimum and average level of the electric field during the monitoring period.

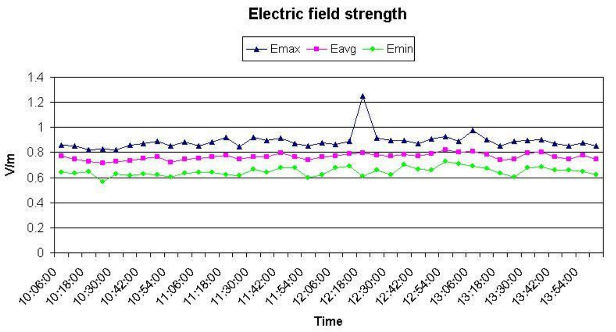

Fig. 4 Daily curves as a result of the continuous monitoring

The recorded values of the electric field strength are far below the Serbian prescribed reference levels [3], [14]. Averaged values are around 0.8 V/m, during entire period of monitoring, suggesting that chosen location is not dangerous for the general population. The peak in graph for the maximum value of the electric field, that can be noticed, is probably result of random increase of phone traffic, caused by the passerby at the site.

D. Statistic Analysis of the Continuous Monitoring

Observing acquired measurement results of the continuous monitoring and the graph for the average value of the electric field, it can be concluded that field strength remains constant during the time period of four hours. In Table III some statistical data are given, confirming such conclusion.

TABLE III
STATISTICAL ANALYSIS OF THE MEASUREMENT RESULTS

	Max	Min	Avg	St.Dev
E_{max} [V/m]	**1.248**	**0.819**	**0.888**	**0.066418**
E_{avg} [V/m]	**0.820**	**0.718**	**0.766**	**0.025271**
E_{min} [V/m]	**0.727**	**0.564**	**0.648**	**0.033754**

It can be noticed that maximum value of the electric field strength, during monitoring period, is within the range from 0.819 V/m to 1.248 V/m. That is quite below the Serbian prescribed reference levels [3], [14]. Additionally, analysis shows that average and minimum values of the electric field strength are also within prescribed reference levels.

The standard deviations of the maximum, average and minimum values are 0.066418 V/m, 0.025271 V/m and 0.033754, respectively. Such small deviation results that almost constant field strength is present, even though it is expected that EMF radiation can achieve its peak in monitoring period, since several telecommunication and broadcasting services are fully operable.

V. EXPOSURE ASSESSMENT

Based on permanent recording of the measurements during 24/7 period, the SEMONT system is able to detect fluctuations of EMF and daily exposure can be assessed for any instant of time.

A. Exposure Assessment at the Test Location

Unfortunately, if the broadband measurement approach is applied it is not possible to determine the frequencies at which EMF sources emit. Therefore, the exposure assessment needs to take into account the entire frequency range covered by the field probe.

In the SEMONT system, the lower and upper level of global exposure ratio (*GER*) was calculated according to the standard SRPS EN 50492:2010 [13]. The following expressions were used for *GER* level assessment [17]:

$$GER_{upper} = \left(\frac{E_{mes}}{E_{ref\,\min}}\right)^2, \quad GER_{lower} = \left(\frac{E_{mes}}{E_{ref\,\max}}\right)^2 \tag{2}$$

where E_{mes} is measured value of electric field strength, while $E_{ref\ min}$=11 V/m and $E_{ref\ max}$=34.8 V/m are the minimum and maximum reference levels of the electric field strength, prescribed by the Serbian legislation for the general population [3], [14], over the field probe frequency range.

While performing exposure assessment, the SEMONT system uses the average values of the measurements as E_{mes}. Results of performed GER assessment are shown in Fig. 5.

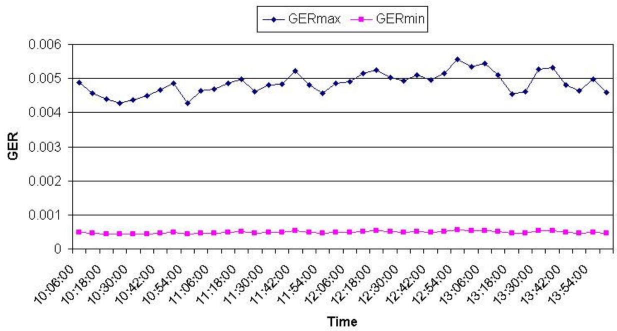

Fig. 5 The SEMONT *GER* assessment

The real exposure ratio lies between the lower and the upper limits, and monitoring shows that its level at the hot-spot ranges between 0.00042625 and 0.0055573, which is far below the allowed limit of GER_{max} = 1, prescribed by the legislation for the general population [3], [14].

B. Statistical Analysis of the Exposure Assessment

Observing obtained *GER* results during the time period of four hours, the statistical analysis was performed and results are given in the Table IV.

TABLE IV
STATISTICAL ANALYSIS OF THE EXPOSURE ASSESSMENT

	Max	Min	Avg	St.Dev
GER_{upper}	**0.0055573**	**0.0042661**	**0.0048579**	**0.00031986**
GER_{lower}	**0.00055526**	**0.00042625**	**0.00048538**	**0.000031959**

The maximum value of GER_{upper} is 0.0055573 and that result confirms that exposure is far below maximal allowed level, suggesting that EMF strength, present on the test location, is not dangerous, neither for humans nor the equipment.

Beside, statistical analysis shows that standard deviations of GER_{upper} and GER_{lower} are 0.00031986 and 0.000031959, respectively; confirming that at the monitoring location there is no any unexpected increase of EMF radiation in environment.

VI. CONCLUSION

Considering increased number of EMF sources, the development of modern systems for EMF monitoring became necessary, as a support for authorities in their efforts to timely inform public on current level of EMF strength in environment and their surroundings.

The SEMONT system is unique system at the national level in the Republic of Serbia, introducing an advanced and modern approach of the wireless sensor network implementation for daily supervision of the overall and cumulative level of the EMF, over an area of interest.

In order to test SEMONT functionality and to perform investigation of EMF over the area of the campus of the University of Novi Sad, initial monitoring was conducted.

In the vicinity of monitored location, the presence of two GSM base stations, as dominant sources, was noticed, indicating that significant electric field level could be expected in this area. However, results of preliminary spatial scan and continuous monitoring show that level of electric field strength is in acceptable range and far below allowed limit prescribed by the Serbian legislation for the general population.

The performed monitoring will be valuable for the verification of the SEMONT system functionality and for monitoring campaigns that will follow.

ACKNOWLEDGMENT

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.

REFERENCES

[1] EU Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR): Possible effects of Electromagnetic Fields (EMF) on Human Health, http://ec.europa.eu/health/ph_risk/committees/04_scenihr/docs/scenihr_o_007.pdf, 2007.

[2] N. Djuric, D. Kljajic, K. Kasas-Lazetic, M. Milutinov, M. Prsa, V. Bajovic, N. Pekaric-Nadj and V. Milosevic, "The Concept of the SEMONT Monitoring System and its Influence on the EM Pollution Protection," IEEE AFRICON 2013 Conference, Mauritius, 9-12 September 2013, pp. 1298-1302, 2013.

[3] V. Bajovic, N. Djuric and D. Herceg, "Serbian laws and regulations as foundation for electromagnetic field monitoring information network," 10th International Conference on Applied Electromagnetics, ΠΕC 2011, Nis, Serbia, September 25-29, paper O7_06, pp. 1-5, 2011.

[4] N. Djuric and N. Kavecan, "Internet portal of the SEMONT information network for the EM field monitoring," The 4th International Conference on Advances in Future Internet – AFIN 2012, Rome, Italy, August 19 – 24, pp. 55-59, 2012.

[5] N. Djuric, N. Kavecan and D. Kljajic, "The EM field register of the SEMONT Broadband monitoring network," IEEE 10th Jubilee International Symposium on Intelligent Systems and Informatics – SISY 2012, Subotica, Serbia, September 20-22, pp. 27-30, 2012.

[6] Narda GmbH, AMB-8057 User's Manual, Narda, 2007.
[7] Narda GmbH, AMB-8057 User's Guide to the GPRS/FTP communication, 2010.
[8] D. Kljajic, N. Djuric, K. Kasas-Lazetic and M. Prsa, "Procedure for Incorporation of NBM-550 Measurement Results into the SEMONT Database," IEEE 11th International Symposium on Intelligent systems and Informatics – SISY 2013, Subotica, Serbia, 26-28 September, pp. 309-312, 2013.
[9] 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.
[10] Basic standard to demonstrate the compliance of fixed equipment for radio transmission (110 MHz — 40 GHz) intended for use in wireless telecommunication networks with the basic restrictions or the reference levels related to general public exposure to radio frequency electromagnetic fields, when put into service, SRPS EN 50400:2008 (2008).
[11] Narda Safety Test Solutions GmbH, NBM-550 Broadband Field Meter User's Guide, 2006.
[12] Narda Safety Test Solutions GmbH, EF 0691 Electric Field User's Guide, 2006.
[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] "Regulation on the limits exposure of non-ionizing radiation", the law of the Republic of Serbia, no. 104/09, 2009.
[15] ICNIRP guidelines for limiting exposure to time-varying electric, magnetic and electromagnetic fields (up to 300 GHz), 1998.
[16] ITU K.83 – monitoring of electromagnetic field levels, 03/2011.
[17] N. Djuric and D. Kljajic, "Assessment of Daily Exposure in the Broadband Continuous Monitoring System – SEMONT," IEEE AFRICON 2013 Conference, Mauritius, 9-12 September 2013 pp. 903-907, 2013.