Area Monitor Sensor for Broadband Electromagnetic Environmental Pollution Monitoring

Miodrag Milutinov, Nikola Djuric, Dragisa Miskovic and Dragan Knezevic

Abstract: **The electromagnetic fields are generated by natural phenomena, but also by human activities, mainly through the use of electricity. Development of the man-made electricity and rapid technological progress have multiplied sources of those fields and diversified their characteristics. The present public opinion requires answer if the exposure to electromagnetic fields may increase the risk of some adverse health effects. Therefore, in this paper we present a broadband monitoring system as a solution for automated and constant supervision of electromagnetic fields. The Ministry of Sciences and Technological Developments of the Republic of Serbia recognized the importance of this system within the program of technological development of the Republic Serbia, for the period of 2011-2014.**

Keywords: **EM fields, monitoring, sensors network.**

I. INTRODUCTION

Development of the man-made electricity and rapid technological progress in variety of electrical applications have multiplied sources of the electromagnetic (EM) fields and diversified their characteristics, resulting in the so-called EM environmental pollution.

Exposure to man-made sources of EM fields, ranging from high radio frequencies (mobile phones) through intermediate frequencies (computer screens) to extremely low frequencies (power lines), has increased dramatically in the last few decades. Devices generating non-ionizing EM fields in frequency range from 100 kHz to 300 GHz are in widespread use [1]. The key sources of those fields include mobile phones, cordless phones, local wireless networks and radio and TV broadcasting towers.

Recently, it can be noticed the huge efforts that scientists devote for research, both potential effects on groups of people who have been exposed to electromagnetic fields in their daily lives (epidemiological evidence) and the potential effects observed in laboratory experiments carried out on human volunteers, animals, and cell cultures (experimental evidence). [1]-[3]. Information about the strength of EM fields generated by a given source is readily available and useful in determining compliance with safety limits [4]-[5], but it is also important to consider multi-source exposure and not to focus on single sources, e.g. mobile phone base stations. Therefore, the advanced systems for non-ionizing radiation brad-band monitoring are of vital importance.

In this paper a remote monitoring system, based on wireless sensor information network, for automated, remotely and selectively monitoring of the overall level of EM fields for non-ionizing radiation has been presented [6]-[8]. In addition, the Multi-band Area Monitor Sensor [9]-[10], as a key component of this system, is described.

This system has been recognized by Ministry of Sciences and Technological Developments of the Republic Serbia [11], as valuable support for municipal and provincial agency for non-ionizing radiation protection [12]. Ministry approves development of this monitoring system within the program of the technological development of the Republic of Serbia, for the period of 2011-2014.

The basic concept of the monitoring system is briefly described in Section II, while some details about multi band area monitor sensor in Section III and Section IV conclusion of this paper.

II. BASIC CONCEPT OF THE SYSTEM

The proposed monitoring system has been designed as the advanced solution available to meet the growing demands for systematic and continual, 24-hours, monitoring of cumulative EM fields, from all sources on the observed territory, as it is shown in Fig. 1.

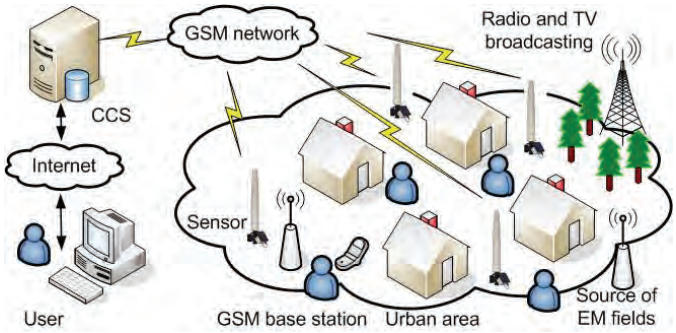

Fig. 1 EM field monitoring system

System performs monitoring both remotely and selectively, avoiding continuous surveillance of sites by technical personnel. This system implements the sophisticated technology of the wireless sensor networks and consists of the

a) spatially distributed autonomous sensors to monitor total level of the EM fields from all sources around the sensors over supervised territory,

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b) Central Control Station (CCS), that coordinates remote sensor elements, acquire monitoring data, processes and stores them in centralized database,

c) communication network, providing connection and inter-action between remote sensors and CCS, and

d) operating software that manage and supports employment of information network.

The proposed monitoring system is designed so that on a daily basis, investigates the overall level of the EM field and population exposure to the EM field at the particular location, especial over the sites of the special interest.

Compared with the conventional method of investigation, the proposed system does not require presence of technical personnel on the site. As a result, the system provides faster and more efficient monitoring and performs continuous investigation, 24 hours per day during desired period [6]-[9].

III. Multi-Band Area Monitor Sensor

The Multi-Band Area Monitor Sensor (Sensor) is one of the numbers of area sensors which is used for monitoring of electric (E) and/or magnetic (H) fields. The common characteristic of all monitoring equipment is continuous measuring of total electric and magnetic field. The Sensor described in this paper, manufactured by NARDA [10], fulfils investigation of EMFs in sense of public exposure to sources such as radio/TV, GSM, UMTS, or any other wireless system.

The Sensor has ability to measure total electric field over wide frequency range. Frequency range and measuring range depend on used probe. The Sensor has internal circuits for estimating average (AVG or RMS) or maximum (MAX) electric. With internal memory and power supply the Sensor measure and store electric field continuously 24 hours per day. The most important characteristic of this Sensor is ability to estimate contribution of electric field of specific pass bands (GSM, UMTS) to total electric field, as it described in Table I.

TABLE I.
Overall characteristic of Multi-band Area Monitor Sensor

Type of measurement	Total Electric field
Frequency range	100 kHz – 7 GHz
Measurement range	0.03 - 200 V/m
Stored field values	AVG, RMS, MAX
Duration of measurement	24 hours per day
Applications	Wideband, GSM900, GSM1800, UMTS

The Sensor consist of: probe, post-processing data logger with internal memory, GSM modem and RS232 connector and internal rechargeable battery power supply, as shown in Fig. 2.

Beside these, the Sensor has solar panel for recharging internal battery and external power supply during a day, which is highly important for autonomous work. Whit this autonomy Sensor accomplishes measurement in arbitrary long time period as a means of assessing the long-term public exposure to potentially hazardous electromagnetic fields. In case of total darkness internal battery provides full operation of the Sensor of more than 80 days.

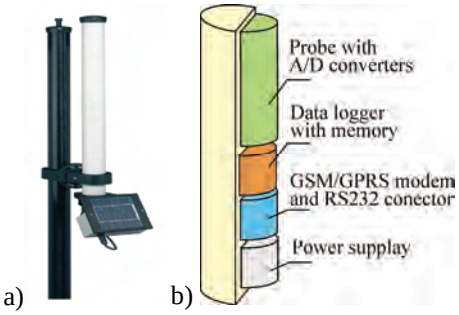

Fig. 2. a) Sensor unit with solar panel, b) Sensor's hardware component.

Functionality of the Sensor can be briefly described in three main stages, as shown in Fig. 3.

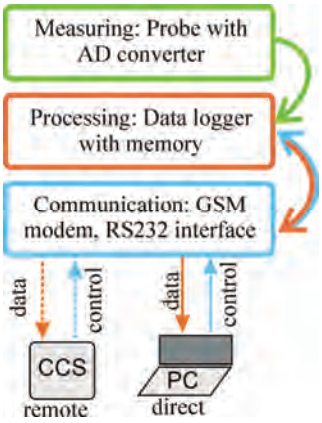

Fig. 3. Functionality of MBAMS

First, signal obtained from field probe and digitalized in A/D convertor continuously coming to the data logger. Second, data logger according the program setup processes and stores the signal in internal memory. Third stage is remote communication between the Sensor and CCS via GSM modem uploading stored data to CCS. Small amount of data like daily report could be sent by SMS to mobile phone. Additionally communication block has ability to receive instruction from CCS to setup data logger. RS232 interface enable direct connection to the Sensor for measurement and collection of stored data on the site.

One of the most appropriate and useful probe regard to high frequency EMF public exposure is a multiband quad electric probe, described in this paper. The main characteristic of the probe are frequency and measurement range described in Table II, frequency discrimination and isotropy.

The probe allows discrimination between the electric fields generated by different sources in frequency bands of GSM 900, GSM 1800 and UMTS 2100, inside the wide band. This

is useful in order to find GSM and UMTS contributions to total electric field.

TABLE II
ELECTRIC FIELD QUAD-BAND PROBE

Application	Frequency range [MHz]	Meas. range [V/m]	Meas. resolution [V/m]
Wideband	0.1–3000	0.2-200	0.01
GSM900	925-960	0.03-30	0.01
GSM1800	1805-1880	0.03-30	0.01
UMTS2100	2110-2170	0.03-30	0.01

The quad-band probe performs simultaneous three-axis measurements, as shown on Fig. 4, which allows obtaining the total field independently of the tri-axial orthogonal arrangement. Isotropic measurement avoids technical personnel on the sites and manual rotation of the sensor. Maximum probe anisotropy is calculated according IEEE Standard for Calibration of Electromagnetic Field Sensors and Probes, IEEE Std. 1309-2005 and it is ±0.8dB calculated at centre frequencies of each band [10].

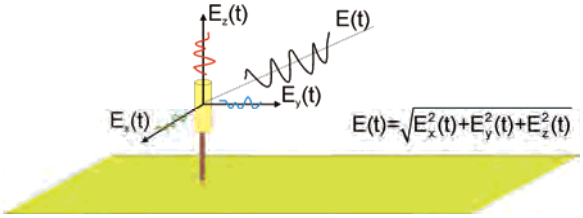

Fig. 4. Isotropic response.

Probe has internal pass band circuits, A/D converters a microcontroller and calibration data memory that produce measurement results in digital form, depicted on Fig. 5. With this filters the sensor has ability to processes data to yield the AVG or RMS and Peak isotropic result which are simultaneously output of all bands.

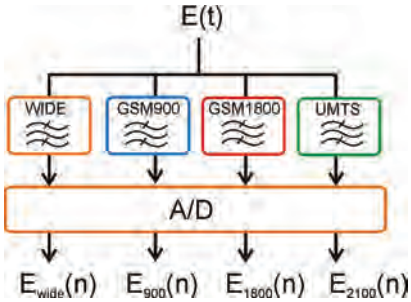

Fig. 5. Probe pass bands circuits

Other probe characteristic relevant for measurement uncertainty such as flatness, out of band attenuations, centre frequency drift, H-field rejection and temperature error are fully described in data sheet obtained from manufacturer [10].

The second part of the Sensor, named data logger, performs sampling, post-processing and storing of data obtained from the probe. The sampling time is 3 seconds, which mean that Sensor capture 20 samples of measurement data per minute.

Investigations of public exposure to electromagnetic fields for frequencies between 100 kHz and 10 GHz according to regulations [4], [5] demands measurement of the appropriate quantities (electric or magnetic field) averaged over any 6 minutes period. The Sensor has ability to perform averaging of numbers of sampled data, which is finding very useful in case of investigation public exposure to the EMFs. In order to meet regulations demands, the Sensor provides averaging over number of collected samples in arbitrary time period (t_{AVG}). The averaging can be arithmetic (AVG), appropriate for frequencies below 10 MHz as described in Eq.(1)

$$E_{AVG}=\frac{\sum_{n=1}^{N}E_n}{N}, \qquad (1)$$

and quadratic (RMS), appropriate for frequencies between 100 kHz and 10 GHz, described in Eq. (2)

$$E_{RMS}=\sqrt{\frac{\sum_{n=1}^{N}E_n^2}{N}}. \qquad (2)$$

Beside this, the Sensor detects maximum (MAX) value over the same time period as described in Eq. (3)

$$E_{max}=\max\{E_1, E_2, \ldots, E_n, \ldots, E_N\}. \qquad (3)$$

The number of samples N, depends on averaging time interval, as described in Eq. (4)

$$N = 20\left[\frac{\text{sample}}{\text{min}}\right]\cdot t_{AVG}\ [\text{min}]. \qquad (4)$$

Due to internal memory, the Sensor can perform storing of processed results at one of selectable time interval (30 sec, 1 min, 2 min, 6 min or 15 min). Fig. 6 shows an example of storing results of electric field measured data at every 1 min with averaging period of 6 min, based on 120 samples collected in the previous 6 minutes. The Sensor simultaneous process and stores E_{AVG}, E_{RMS} and E_{MAX} to the internal memory.

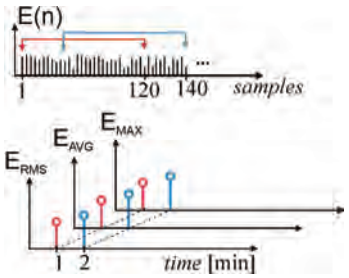

Fig. 6. Example of processing and storing measured values.

With 4MB flash internal memory, the Sensor provides autonomous work and logging from a number of days which depends on storing time. When the memory is full, the new data are overwritten on the oldest to ensure availability of the data for the most recent measurement period. The maximum

numbers of days before overwriting is described in Table III. Sensor provides automatic downloading data from Sensor's memory at selectable time avoiding data overwriting.

TABLE III.
MEMORY CAPACITY OF THE SENSOR.

Storing time	Memory capacity
30 sec	5 days
1 min	10 days
2 min	20 days
6 min	60 days
15 min	169 days

All data stored in Sensor's memory are downloading trough communication block (GSM modem) to the PC, described in Section I. The appropriate software creates separate ASCII files containing downloaded measurement results for each Sensor and for each storing time. Example of several successive measurements averaging in 6 minutes and storing every 30 sec is shown in Fig. 7

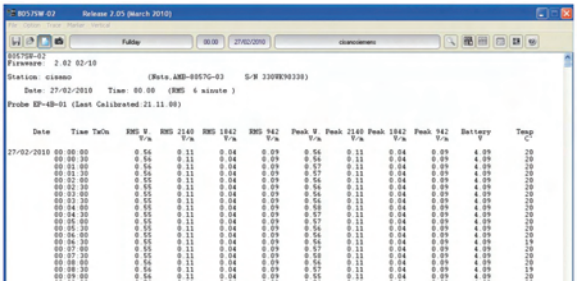

Fig. 7. Example of data table display.

Due to Sensor's small size and narrow shape as well as solid weather-proof unit, it is able to be easily installed indoor or outdoor. It is possible to use appropriate poles for mounting on the any surface. For example, sensor could be placed on the public square or playground in vicinity of base station, on the roof top of surrounding buildings or inside the schools, hospitals, or any other object of interest, as shown on Fig. 8. Moreover, several Sensors connected can be used to build reliable monitoring systems to cover large geographical areas, including nationwide coverage [6]-[8].

IV. CONCLUSION

The proposed project implements a modern and up-to-date technology that automatically and continuously performs investigation and monitoring of EM fields and records the overall level of electromagnetic pollution on environment.

The Sensor manufactured by Narda Sts. with its main characteristics described in this paper is finding very useful in monitoring high frequency electric field from sources such as TV/Radio, GSM, UMTS and WLAN. The Sensor estimate wide band total electric field and partial contribution of GSM and UMTS due to built-in band pass circuits.

System of numbers of Sensors can be placed anywhere and connected to build reliable monitoring systems to cover large geographical areas.

Fig. 8. Sensor located outdoor on the roof.

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