Sensor Communication in Wireless Electromagnetic Field Monitoring System

Bogdan Vukobratovic[1], Nikola Djuric[2], Dragisa Miskovic[3] and Dragan Knezevic[4]

Abstract – **The high level of attention about the environmental electromagnetic field pollution stimulates technical solutions that provide even more sophisticated systems for non-ionizing radiation monitoring. In this paper the communication of the sensor in a wireless electromagnetic field monitoring system has been considered. This system is intended for continuous, remote electromagnetic fields supervision and it has been recognized by Ministry of Sciences and Technological Developments of the Republic of Serbia, which grants its development within the program of the technological development of the Republic of Serbia, for the period of 2011–2014.**

Keywords – **EM pollution, monitoring, sensors, wireless.**

I. INTRODUCTION

Electromagnetic (EM) fields occur in nature and have thus always been present on earth. However, during the last few decades, the exposure to the man-made sources of EM fields has steadily increased due to social implementation of various electrical appliances.

Virtually entire population is exposed to EM fields through sources such as high-voltage power lines, household electrical appliances, computers, radio and TV broadcast facilities, mobile telephones and their base stations and a variety of wireless technologies systems. The frequencies of EM fields in the electrical applications vary between 0 Hz to 300 GHz with diverse characteristics [1].

Over the years, scientists made efforts in research about the potential health effects of EM fields and published theirs research results in many scientific papers about this topic [2]-[3]. Respecting the results of research in all these paper it prevails that in order to provide a high level protection of public health the establishment of a legal framework for the protection of workers and citizens is required.

As support for efforts of the Serbian municipal and provincial agency for non-ionizing radiation protection [4], our team has been proposed developments of a wireless sensor information network [5]-[7], for automated, remotely and selectively monitoring of the overall level of EM fields for non-ionizing radiation. This system is conceived as an answer for continual 24-hours supervision of all sources that emit EM fields, over the territory covered by sensor network.

Additionally, the system is capable for daily checking the protection limits set by the national regulations [8]-[10] and it has been recognized by Ministry of Sciences and Technological Developments of the Republic of Serbia, which approves its development within the program of the technological development of the Republic Serbia, for period of 2011–2014.

The crucial element of this monitoring system is multi-band area monitoring sensor [11]-[14], that is responsible for wireless and remote data acquisition in EM field measurements. In this paper the communication techniques implemented in this sensor are presented. In Section I the basic concept of the proposed remote monitoring system is given, while in Section II some details about sensors and central control station (CCS) communication. Section III presents GPRS/GSM protocol and Section IV conclusion of this paper.

II. EM FIELDS MONITORING SYSTEM

The monitoring system is proposed as the most suitable solution for constant, wireless supervision of EM fields and total level of the exposure to these fields. This system is a significant support in efforts to take systematic care of potential effects of non-ionizing EM fields on the health of the population, taking into account their concern about long-term exposure to EM fields.

This system implements the sophisticated technology of the wireless sensor networks and it is deliberate to supervise and control if the cumulative level of the EM fields is below the nationally prescribed limits [8], [10].

The basic concept of proposed monitoring system is shown in Fig. 1.

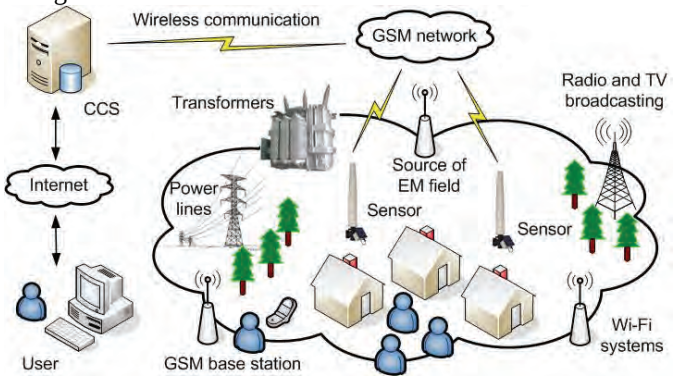

Fig. 1 Remote EM fields monitoring system

This system consists of the

a) autonomous sensor elements, which are spatially distributed to observe cumulative level of EM fields over super-

[1]Bogdan Vukobratovic is with the Faculty of Technical Sciences, University of Novi Sad, Trg D. Obradovica 6, 21000 Novi Sad, E-mail: vukobratovic@uns.ac.rs

[2]Nikola Djuric is with the Faculty of Technical Sciences, University of Novi Sad, Trg D. Obradovica 6, 21000 Novi Sad, E-mail: ndjuric@uns.ac.rs

[3]Dragisa Miskovic is with the Faculty of Technical Sciences, University of Novi Sad, Trg D. Obradovica 6, 21000 Novi Sad, E-mail: dragisa@uns.ac.rs

4Dragan Knezevic is with the Faculty of Technical Sciences, University of Novi Sad, Trg D. Obradovica 6, 21000 Novi Sad, E-mail: tomaja@uns.ac.rs

vised territory and from all sources around the sensors, in particular frequency range,

b) Central Control Station (CCS), that coordinates activity of the remote sensor elements, to collects data obtained by monitoring, processes and stores them in centralized database,
c) communication network, providing connection and interaction between remote sensors and CCS, and
d) operating software that manages and supports employment of information network.

CCS and sensors communication is performed using the existing GSM mobile networks. Both, the CCS and sensors are equipped with a quad-band GSM/GPRS modem for uploading/downloading data and remote control [13].

The monitoring system is able to perform investigation for a number of sources, that can be found in a power system and systems for the power transmission (transmission lines, distribution and substation equipment), through a system of radio and TV broadcasting, to the wireless communication networks (like GSM, UMTS or Wi-Fi systems) [5]-[7].

III. Sensor Communication Approaches

One of the major challenges in developing an acquisition network is collecting data from measurement nodes. Straightforward way of collecting data is to visit periodically remote and scattered measurement nodes and manually collect data. Sometimes, this is not adequate approach and therefore if the solution can be found such that it allows remote and automatic collecting of the measurement data, such acquisition network becomes a very powerful monitoring tool.

In our monitoring system sensors are based on GSM wireless communication. Using GSM/GPRS modem sensors have option of transferring data without intervention of technical personnel, as it is shown in Fig. 2.

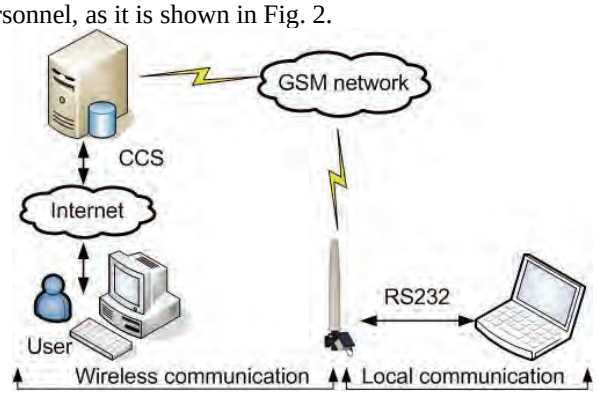

Fig. 2 Communication with sensor

Additionally, communication with sensor can be performed locally via RS232 protocol.

A. *Remote connection through GSM network*

Information network proposed here, takes advantage of GSM network and Internet for it's data transmission. National GSM mobile network covers more than 95% of Serbian territory, thus allowing GSM connection from nearly every spot within. This allows sensor elements to continuously communicate from the point of measurement with CCS, sending real time measured data. Furthermore, mobile operators give option for GSM modems to connect to the Internet through the GSM network that enables placing CCS virtually anywhere.

There are two ways for the sensor to connect to GSM network [13]:

a) using internal GSM/GPRS modem that allows connection or
b) connecting to GSM network via another device (laptop or PC) with GSM modem, as shown in the Fig. 3.

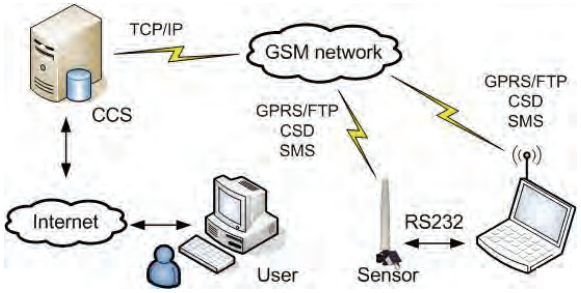

Fig. 3 Sensor-CCS connection over GSM

It should be noticed that laptop has to have the appropriate software, which will enable communication with sensor via RS232 protocol.

It is know that radio communication consumes energy, and the duration of autonomic sensor operation is crucial in wireless sensor networks. Thus, the GSM module is shut down for the majority of time. This means that sensor is unavailable for communication over GSM network but in short preset times of the day. Besides that, sensor switches on the module whenever an alarm condition occurs or when the normal conditions are restored.

Through the modem sensor can make use of three different protocol stacks commonly available in GSM networks:

a) Short Message Service (SMS),
b) Circuit Switched Data (CSD) and
c) General Packet Radio Service / File Transfer Protocol (GPRS/FTP)

In Table 1 the availability of various functions are given in respect of the protocol used.

TABLE I
List of all possible functions of the sensor and their availability through different protocols

Possible functions	SMS	GSM	RS232
Settings	YES	YES	YES
Reading status and alarms	YES	YES	YES
Reading max value	YES	YES	YES
Reading average value	YES	YES	YES
Download data	NO	YES	YES
Reading of battery	YES	YES	YES
Reading of internal temperature	YES	YES	YES
Spontaneous call	NO	YES	NO
Reporting alarms	YES	YES	NO
SMS reporting of daily maximum	YES	NO	NO

The following sections describe the communication with the sensor through various protocols listed above.

B. SMS Communication

SMS is the text communication service used for transfer of short text messages between the devices in network. Alarms, some settings and queries for some small amount of data can be communicated with SMS as shown in Fig. 4.

Fig. 4 SMS communication

The sensor can be set with up to two mobile phone numbers that will receive alarm and daily report messages. Daily report message contains: maximum measured field, minimum battery voltage and status of the sensor, telephone number of the sensor, time and date.

Sensor allows setting up several alarms that can be sent on following circumstances [13]:

a) when the measured property exceeds a threshold setting for attention (warning),
b) when measured property exceeds an alarm threshold,
c) when battery voltage is too low,
d) when one or more field probe parameters is faulty,
e) on exceeding the temperature limit inside the field monitor,
f) when the data memory is almost full and
g) when the external container is opened

Commands that can be sent to the sensor have the following format:

#F7Qcommand(parameters)*

while particular parameters are explained in Table 2

TABLE II
SMS COMMAND FORMAT EXPLANATION

Token	Use
#	opens the command string
F7	string always included
Q	? - for query commands S - for setting commands
command	command string
(parameters)	value of setting parameters (if any)
*	closes the command string

Additionally, commands that the sensor understands include the ones listed in Table 3.

TABLE III
EXAMPLES OF SMS COMMANDS

Command	Description
#F7?IDN psw*	request ID + password authentication
#F7?CLK*	request complete internal time
#F7?BAT*	request battery voltage status
#F7?PRB*	request field probe data
#F7SALR (par)*	set alarm threshold
#F7SAVG (par)*	set time of averaging

Every SMS sent to the sensor must contain as a first command the invitation to authenticate the password, which is the protection mechanism against unauthorized access [13].

C. CSD Communication

CSD is the type of the communication where the direct transmission line is established between two parties, identically as it is done with a voice call. Drawbacks of CSD over the GPRS protocol are: less bandwidth (9.6 kbps), need for a dial-up connection establishing and charging per duration of the connection (as with voice calls). Also the CCS has to have GSM modem to receive the calls and dial-up the sensors in order to communicate.

D. GPRS Communication

GPRS is a packet oriented mobile data service, which offers higher data transfer rates (for an example up to 53.6 kbps offered by Telenor GSM mobile operator in Serbia). Internet protocol TCP/IP can be used with GPRS, that enables the use of many standard internet application layer protocols, such as: FTP, HTTP, IMAP and many other.

The File Transfer Protocol (FTP) is standard protocol used to copy a file from one host to another over a TCP-based network. The sensor is able to use FTP application layer protocol when set to communicate via GPRS with CCS [14]. In order to use FTP communication the CCS must have internet access and has to have static IP internet address.

The advantage of using GPRS/FTP is reduced communication costs, because GPRS data communication is charged on the basis of the very low volume of data transferred. Furthermore, there is no additional cost related to the distance, as the FTP server can be accessed from anywhere that Internet connection is available.

E. Data exchange flow

Remote stations continuously perform field measurements and store results in their internal memory. At programmed time each station uploads the stored measurement data to the CCS.

In order to make the connection parameters, shown in Table 4, have to be set.

TABLE IV
SENSOR PARAMETERS

Parameter	Description
Access Point Name	The GPRS provider name
User Name	User Name required for GPRS
Password	Password required for GPRS
CCS IP address	IP address of FTP server
CCS user name	User name for accessing FTP server
CCS password	Password for accessing FTP server

When connecting to the server, the sensor will check for the existence of any request to modify its settings or to upload the results related to some specific time interval. Precisely what sensor does is as follows:

- first it loads, if any, all the settings which have been written by client,

- then it writes all measurement data that have not yet been uploaded
- finally it erases all previous required settings in order to avoid reloading them at the next connection (data related to field measurements are never deleted by the sensor) and
- after that connection is terminated, as shown in Fig. 5

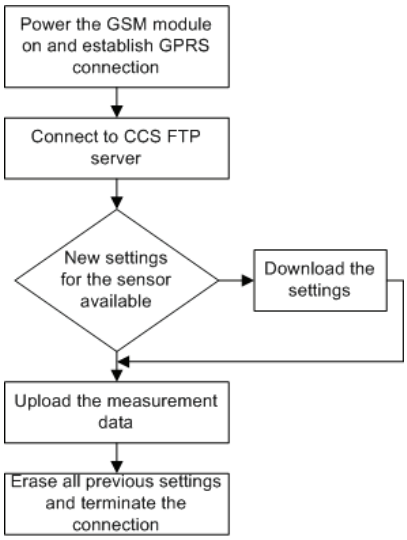

Fig. 5 Sensor – CCS Data exchange flow over FTP

The client software provided by vendor possesses all functions needed for controlling sensor elements. When client sets the parameters for the sensors, the control software will create on CCS one directory for each sensor, if it does not already exist, and place settings files inside. The directories are named after the serial numbers of the sensors, so that each sensor checks it's own folder. In the same folder the sensor places the measurement data.

F. RS232 Communication

RS232 (Recommended Standard 232) is the serial binary single-ended data and control signals standard. The sensor has an option of connecting to a local PC through RS232 for sending commands, downloading data or connecting to CCS over GSM if PC is equipped with GSM module.

The messages which sensor understands when RS232 communication is used are identical to the messages that can be sent over SMS with some exceptions:

- RS232 can be used to upload measurement data and
- RS232 can be used to download a new sensor firmware

The sensor has 4MB of flash storage and can keep the measurement data for up to several months, depending on the settings. So, in applications where real-time tracking of data is not important, client can collect data through RS232 periodically without the need of GSM communication.

G. Power supply

Crucial problem to be solved in designing an autonomic sensor is the power supply. The sensor comprises solar panel and an internal rechargeable Pb-gel battery for unlimited outdoor operation. For indoor applications, the autonomy of the sensor is at least 80 days, depending on the settings used.

IV. Conclusion

Thanks to the communication via widespread GSM mobile network, the proposed monitoring system has a high degree of mobility and can be installed in any part of the area of interest.

The mobility of the sensor elements enable their spatial deployment and integration in the information network for EM field monitoring over the large area of interest, which is virtually impossible using conventional approach.

By implementing the proposed monitoring system, municipal authorities for environmental protection [4], gain the valuable tool for interested users and the general public, in timely informing, prevention and population protection against exposure to the EM fields.

Acknowledgement

This paper has been supported by Ministry of Sciences and Technological Development of the Republic of Serbia, through the grant for project TR 32055.

References

[1] International Commission on Non-Ionizing Radiation Protection (ICNIRP) – "Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz)", 1998, http://www.icnirp.de/documents/emfgdl.pdf

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

[3] EU Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR) – "Health and electromagnetic fields", 2009 http://ec.europa.eu/health/archive/ph_determinants/environment/emf/brochure_en.pdf,

[4] Municipal Agency for the Environmental Protection – City of Novi Sad – http://www.environovisad.org.rs

[5] N. Djuric, "Razvoj informacione mreze za kontinualno i udaljeno isptivanje elektromagnetskih polja," submitted for the Serbian journal Telekomunikacije 2011

[6] N. Djuric, M. Prsa, K. Kasas-Lazetic, "Information network for continuous electromagnetic fields monitoring," submitted for conference PES 2011, Nis, 2011

[7] N. Djuric, M. Prsa, K. Kasas-Lazetic, "Serbian remote monitoring system for electromagnetic environmental pollution," submitted for conference TELSIKS 2011, Nis, 2011

[8] V. Bajovic, N. Djuric, D. Herceg, "Serbian laws and regulations as foundation for electromagnetic field monitoring information network," submitted for conference PES 2011, Nis, 2011

[9] "Law on Non-Ionizing Radiation Protection", the law of Re-public of Serbia, no. 36/09

[10] "Regulation on the limits exposure of non-ionizing radiation", the law of Republic of Serbia, no. 104/09

[11] M. Milutinov, N. Djuric, B. Vukobratovic, "Multi-band area monitor sensor in information network for electromagnetic fields monitoring," submitted for PES 2011

[12] M. Milutinov, N. Djuric, D. Miskovic, D. Knezevic, "Area Monitor Sensor for Broadband Electromagnetic Environmental Pollution Monitoring," submitted for conference PES 2011, Nis, 2011

[13] Narda Safety Test Solutions GmbH, AMB-8057 User's Manual, Narda, 2007

[14] Narda Safety Test Solutions GmbH, AMB-8057 User's Guide to the GPRS/FTP communication, 2010