MULTI-BAND AREA MONITOR SENSOR IN INFORMATION NETWORK FOR ELECTROMAGNETIC FIELDS MONITORING

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Abstract: In this paper the proposed project of development of an information network for area electromagnetic fields monitoring has been presented. Information network is based on wireless sensors network which includes the highly sophisticated multi-band area monitoring sensors for daily control and supervision of sources of electromagnetic fields. The information network has been designed so that it can cover territory of a large scale and it is a unique in our region. Its deployment takes place within the technological development of the Republic of Serbia, for the period of 2011-2014.

Keywords: EM fields, monitoring, sensors network.

INTRODUCTION

Recently, the installation and operation of several high-frequency wireless networks, such as the GSM, UMTS and Wi-Fi systems, has polluted our working and leaving environment in the sense of the electromagnetic (EM) radiation. Conjunction with traditional broadcasting systems, such as FM Radio and VHF/UHF Television, has led to increasing public concern about the health effects when human body has been exposed to electromagnetic radiation emitted by such sources. These concerns will continue in calling for the continuous information of the public about their exposure to EM radiation.

The interest recently shown by Ministry of Environment and Spatial Planning of the Republic of Serbia [1] and municipal agency for non-ionizing radiation protection [2], has created significant developments in field under examination. Therefore, in this paper we present project that develops system based on information network as support for continuous investigation and monitoring of the overall level of EM fields in range of non-ionizing radiation [3]-[4]. The proposed system is unique solution which is able to monitor all sources that emit EM field, over the territory covered by network [5], as it is shown in Fig. 1.

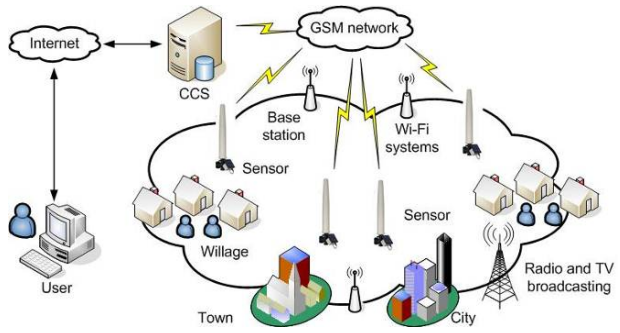

Fig. 1 - *Basic diagram of information network.*

The system is based on multi-band area monitor sensor (Sensor) that on a daily basis provides automatic monitoring of EM field. Sensor results are daily collected in a centralized database and compared with legally prescribed limits of exposure [6]-[8]. Results will be available through Internet to the institutions in charge for the environmental protection [2].

Therefore, this system is a significant support in efforts to take systematic care of potential effects of the non-ionizing EM fields on the health of population, taking into account their concern about long-term exposure to the EM field.

DESIGN OF INFORMATION NETWORK

In order to systematically and continuously investigate the sources of EM fields, as well as to monitor the level of population exposure to EM field, the project develops an information network, based on the wireless sensor network, which consists of:

a) autonomous sensors, that are spatially distributed to monitor the total level of the EM field, over supervised territory,

b) Central Control Station (CCS), which coordinates the activity of the remote sensor elements,

c) appropriate communication network for sensors and CCS, and

d) operating software, which manages and supports the proposed information network.

The system is able to perform investigation for a number of sources, that can be found in radio and television broadcasting and wireless communication (like GSM, UMTS or Wi-Fi), as shown in Fig. 2.

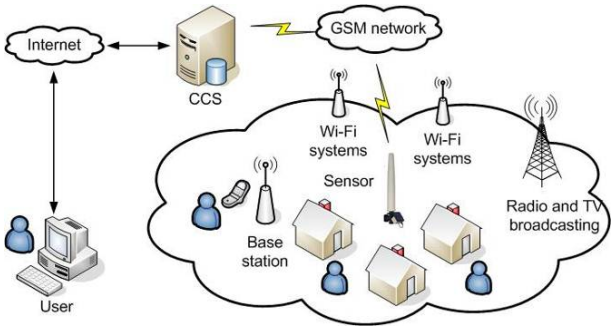

Fig. 2 – *Broadband monitoring of high frequency sources.*

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SENSOR'S CHARACTERISTICS

The Sensor, as core of the system, provides continuous broadband measurement of total electric(E) and magnetic (B) field over wide frequency range [10]-[11]. The frequency range and measuring range depend on used E/B field probe. In this paper the Sensor with electric field probe is presented.

The main advantage of the Sensor is its high level of autonomy, due to following features:

- Sensor's solar panel power supply – allowing continuous measurement on 24 hours basis, in arbitrary long period,
- Sensor's memory – storing amount of measurement results and enabling long-term data acquisition,
- Remote control and data collection – which avoids presence of any technical personnel on the site.

The Sensor is a small size, solid weather-proof unit able to be installed indoor or outdoor using appropriate poles, as shown in Fig. 3a. The Sensor consists of: interchangeable field probe, post-processing data logger with internal memory, GSM modem and RS232 connector and internal rechargeable battery power supply, as shown in Fig. 3b.

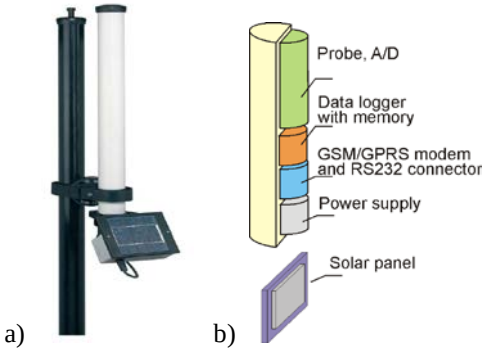

Fig. 3 - a) *Sensor unit with solar panel,*
b) *Component of the Sensor*

Beside these elements, the Sensor has solar panel that is used as external power supply and for recharging internal battery. Due to its own power supply, the Sensor has full autonomy allowing measurement in arbitrary long time period. In case of total darkness internal battery provides full operation of the Sensor over more than 80 days.

Functionality of the Sensor can be described in three main stages, as shown in Fig. 4.

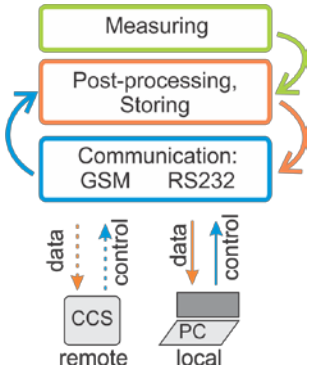

Fig. 4 - *Functionality of Sensor.*

A) Measuring

Field probe with internal circuits continuously measures and samples total electric field every 3 second, which means that Sensor captures 20 samples of measurement value per minute. These values are digitalized in an A/D convertor, inside the field probe, and send to the post-processing unit.

B) Post-processing and storing

Data logger, according to the setup of the Sensor's parameters, performs post-processing and storing of samples obtained from the field probe.

The Sensor has internal circuits that estimate averaging over window of collected samples. The averaging can be

- arithmetic (AVG), suitable for frequencies below 10 MHz [6]-[9], and
- quadratic (RMS), appropriate for thermal considerations, relevant for frequencies between 100 kHz and 10 GHz [6]-[9].

Beside the averaging, Sensor detects maximum (MAX) value, over the same window of samples.

The number of samples depends on averaging time interval which can be arbitrarily set, usually 6 min for public exposure to EM fields [7]-[8].

Estimated values, AVG or RMS and MAX, present output values from the Sensor [10]. Due to internal memory, the Sensor can memorize different amount of estimated values depending on selectable storing time interval as shown in Table 1.

Table 1.
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

An example of estimation of electric field values at every 1 min with averaging period of 6 min, based on 120 collected samples in the previous 6 minutes, is shown in Fig. 5. Sensor simultaneously processes E_{AVG} or E_{RMS}, and E_{MAX}, and stores them in to the internal memory.

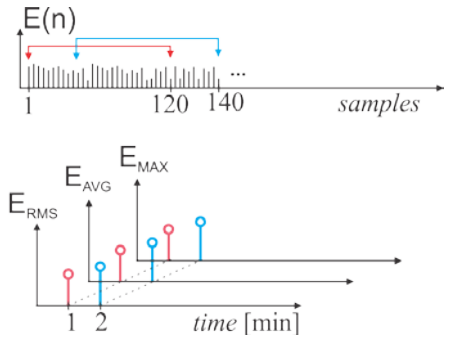

Fig. 5 - *Example of processing of the measured values (samples).*

With 4MB flash internal memory, the Sensor provides autonomous working and logging from a number of days which depends on storing time. When the memory is full, the new data overwrites the oldest to ensure availability of the data for the most recent measurement period. The maximum number of days before overwriting is described in Table 1. Sensor provides automatic downloading data from Sensor's memory at selectable time avoiding data overwriting.

C) Communication

Communication with the Sensor relies on existing GSM mobile network for remote communication [12], or RS232 interface for local communication, as shown in Fig. 6.

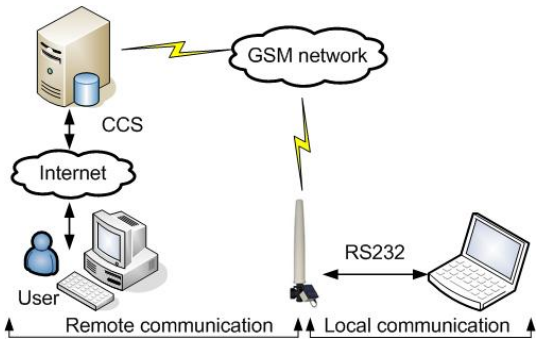

Fig. 6 - *Communication with sensor.*

Using GSM/GPRS modem sensors have option of transferring data without intervention of technical personnel.

E-FIELD PROBE'S CHARACTERISTICS

One of the most appropriate and useful field probe regard to high frequency EM field exposure is a multiband quad electric field probe, described in this paper [10]-[11].

One of the main characteristics of the field probe is frequency discrimination. The field probe allows discrimination between electric fields generated in different frequency bands from 100 kHz – 3 GHz, GSM 900, GSM 1800 and UMTS 2100 bands, as presented in Table 2.

Table 2.
The E-filed probe's characteristics.

Application	Frequency range [MHz]	Measuring range [V/m]	Measuring 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 field probe has internal pass band circuits and A/D converters that outputs the measurement samples in digital form, depicted in Fig. 7.

With filed probe filters, the Sensor has ability to simultaneously post-process collected samples of measured data, in all presented bands. The AVG, RMS and MAX of electric field are also outputted at the same time, in all presented bands.

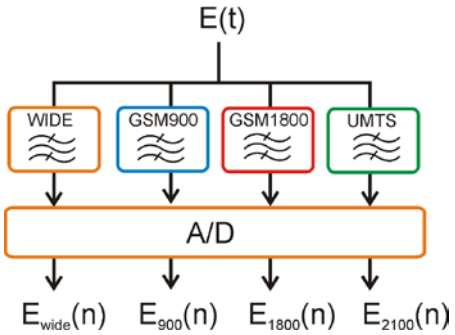

Fig. 7 – *Probe's pass bands and A/D circuit.*

It is important to notice that Sensor performs broadband measurements of total electric field in all presented bands.

The quad-band probe performs simultaneous three-axis measurements, obtaining the total field independently of the tri-axial orthogonal arrangement. The isotropic measurement avoids manual rotation of the sensor and does not care about Sensor orientation [10].

SENSORS AND CSS GPRS/FTP COMMUNICATION

The Sensor comprises a GSM modem with the capability of connecting through GPRS-FTP, where TCP/IP protocol stack is in use as transport protocol layer. The example of communication is presented in Fig. 8.

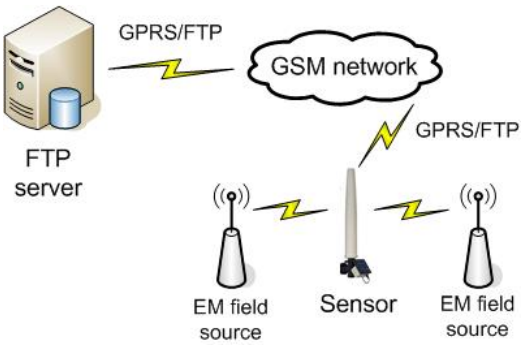

Fig. 8 - *Communication between sensor and CCS.*

The GSM modem is the biggest energy consumer of all sensor components and it should be turned of for the most of the time. Therefore, the sensor performs data exchange procedure in following steps:

a) powering the modem on,
b) connecting to FTP server running on CCS,
c) downloading the settings files, if any
d) uploading the measurement data
e) terminating the connection and shutting the modem down

In order to connect to the FTP server, for data exchange, sensor has to:

a) connect to the GSM network,
b) activate GPRS channel and
c) connect to the FTP server using FTP - TCP/IP protocol.

A subset of parameters, that have to be set in order to make the connection, are presented in Table 3.

Table 3.
Sensor connection 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	Static IP address of FTP server
CCS user name	User name for accessing FTP server
CCS password	Password for accessing FTP server

These parameters are set in settings files and at the first time when Sensor is used, they are uploaded using local RS232 communication, as described in [12]-[13]. During Sensor exploitation, these parameters can be changed and uploaded using remote communication.

THE FILES EXCHANGED VIA FTP

Each time the Sensor connects, a number of files are exchanged with FTP server. The settings files are read from FTP and measurement data files are written to FTP server.

A) Settings files

Settings files are placed on FTP server by user via control software. Once downloaded, Sensor applies the settings requested by the user. Two types of settings files are understood by sensor:

- CFG – configuration file contains desired settings for:
    - scheduling the FTP data exchange,
    - scheduling the SMS reports and alarms,
    - averaging period and type and
    - samples storing rate.
- FLD – file containing user requests for the Sensors to upload a specific set of data to server.

B) Measurement data and event files

The Sensor places the measurement data on FTP server in binary form. Each time that sensor connects to the server three types of files are created:

- Record File – where sensor places the data collected in memory since the last downloading.
- FLD File – where sensor places the measurement data specifically requested by user.
- Event File – which is populated with events that happened since the last connection.

More details about these files can be found in [13].

CONCLUSION

The project implements system with modern multi-band area monitor sensors and up-to-date technology of wireless sensors network. The proposed system automatically and continuously performs investigation and monitoring of EM field and records the overall level of the electric field in the environment.

The notion of continuous measurement of the electric field levels on a 24-hour basis is more appealing to the concerned public. Therefore, development of EM field monitoring and control systems unquestionably represents one of the major innovations in the range of methodologies for evaluating, through measurement, the so-called environmental electromagnetic pollution. This is very important in case of assessing the long-term public exposure to potentially hazardous EM fields.

The proposed system with it's remote communication allows absence of technical personal on the site which leads to price and time effectiveness.

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