Aspects of remote monitoring and recording system of non-ionizing electromagnetic radiation

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Aspects of remote monitoring and recording system of non-ionizing electromagnetic radiation

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Abstract - The paper discusses the possibilities and aspects of continuous, remote monitoring system of non-ionizing electromagnetic radiation using certain networks for measuring and storage of measurement results. First are stated the motives for the usage and installation of such networks and preliminary activities necessary for the proper design of systems, as well. Further, the system architecture and methodology of such measurements are described, where defined requirements are placed in front of the remote monitoring station. Control of measurements is achieved from a remote distance via GSM, GPRS or other telecommunication services. Such systems allow full control of remote monitoring stations, as well as continuous recording of all measurement results. Measurement results from all monitoring stations are collected in control centre, where a comprehensive analysis of all measurement data can be done and published on certain website afterwards.

I. INTRODUCTION

Mobile telephony is nowadays a commonplace worldwide spread communication technology, which still increasingly spreads by new base stations continuous installations. Over 1.4 million of GSM/UMTS base stations exist in the world nowadays [1] and a new generation of 4G systems of these devices is already introduced and installed in some countries. Installation and operation of several wireless network bands in the last decade such as GSM, GPRS, UMTS, TETRA and Wi-Fi systems, increased public concern about exposure to radiation emitted from these sources, [1, 2]. Together with the traditional, well-established broadband systems (FM and UHF-VHF television, radar systems, etc.) this requires continuous care to inform the general public about levels of their exposure to non-ionizing radiation. More or less all human population is exposed to electromagnetic radiation. One of several reasons for the general public's fear is media announced and unconfirmed "scientific" studies, which cause feelings of uncertainty and perception of unknown and undiscovered possibility damage. Other factors are subtle care and a sense of control or expertise lack in the process of determining the location of new base stations or transmitters of any kind [1]. The so-called "ad hoc" measurements are the first step to estimate the level of electromagnetic field radiation. However, such measurements are carried out in a specific, fixed-time interval (1-2 hours) at certain date and under the certain circumstances, [2]. More appropriate and more acceptable way of estimating electromagnetic radiation levels to the general public represents 24 hours continuous measurements of electric field strength. This allows recording of the current situation on the field and continuous comparison of measured values with the reference levels of radiation prescribed by the relevant organizations, such as ICNIRP (International Commission for Non-Ionizing Radiation Protection) or the local authority organizations. Therefore, the network for continuous monitoring and recording of electromagnetic radiation levels in non-ionizing radiation band may represent the best solution to this problem. Another important reason for the installation of such networks is a possible way of measurement results presentation on certain "website" domain, which could be available to general public [2]. Monitoring networks are useful tool and help reducing the public's concern about potential hazard effects and impacts of non-ionizing radiation on human health. For this purpose, such networks across Europe and Africa (Italy, Greece, Spain, Portugal, UK, Malta and Egypt) are set and implemented, so far. These networks require overcoming of many challenges in terms of hardware certification, network control, daily maintenance, etc. [1, 2]. Therefore, there is a need for development of such networks in Balkan countries and that need is a result of widespread public fears about hazard effects and unknown consequences on human health caused by exposure to electromagnetic radiation. Such networks would have multiple targets and aims [1]:

- to inform the general public about current scientific researches;
- to inform the general public about radiation exposure levels and percentage of measured levels compared to them;
- to activate the procedure for additional measurements if they are higher than reference levels;
- to activate the procedure for reducing the reference levels, if needed;
- to reduce social tensions generated by the fear of radio communication networks installation.

Having all this on mind, we can freely conclude about necessity of development and implementation of such systems in Balkan countries in the nearer future.

II. PRELIMINARY ACTIVITIES

Before designing and installing such a complex network, it is necessary to carry out preliminary activities that will provide optimal selection of measurement points within the meaning of the most objective presentation of the current situation in the monitored area, from the electromagnetic radiation point of view. In order the quality selection of measuring points to be achievable, it is necessary to have all the information in the form of a database about: a) the schedule and location of all electromagnetic radiation sources at observed area with their full technical characteristics; b) terrain configuration with all associated buildings and structures, etc. Thanks to different modern radio-waves prediction propagation software, it is possible to predict the signal levels for each point in the observed area. More information is given in [3]. Many of these software are modular and open for adaptation to specific problems that can serve certain types of radio systems. The quality of all modern methods for radio-planning system largely depends on the quality of the information database available to the designer. Considering that, a great attention to the databases must be devoted. Therefore, it is necessary to provide or make several type of information for quality databases such as:

- A number of observed area scanned maps the (i.e. in the scale of 1:25,000, 1:50,000, 1:100,000, the territory of the major cities' wider surrounding in the scale of 1:150,000, 1:50,000 and 1:5000, etc.);
- A number of base station locations and technical characteristics of all radio transmitters;
- The types of used antenna systems;
- Digital base of terrain heights with 50×50m horizontal resolution;
- Digital database of vegetation on the earth's surface for the entire territory, if possible;
- Vector base of streets for major cities;
- Database of digitized satellite pictures.

Comprehensive analysis is carried out to eliminate a huge number of potential measurement points and in accordance to certain criteria (i.e. the intersection method) real shortlist for future measurement points is made. Then, these measurement points are verified by means of mobile measuring systems (spectrum analyzers). Afterwards, a remote-controlled measuring stations (RMS) in each verified measurement point is installed.

III. ARHITECTURE OF MONITORING SYSTEM AND METHODOLOGY OF WORK

The concept of the system should be based on the principle of ensuring the independence of performed measurements, so the general public can be sure that the results presented on a certain domain are not under the influence of various interest groups such as: Telecommunication operators, political parties, Government authorities, etc., [1, 4-7]. Therefore, the monitoring network should be funded with public money in total, without any sponsorship by the operator or other non-institutional subjects. Also, it would be decentralized so the local administration could have absolute control in their administrative areas. The network would be composed of several remote measurement stations (RMS), several local control units (CU) and one central unit, [1]. Each RMS must have communication with the local CU via public wireless communication networks such as GSM, GPRS or UMTS. This connection allows the installation of RMS in every area covered by the mobile operators' signals. CU control RMS units and save the measured data to be hosted on the "website", afterwards. Any interested party can access to stored results via Internet, [1, 2, 7]. Data from all local CU are collected in the central unit. Similar implementations are presented on Figure 1. [1] and Figure 2. [2].

A. *Remote measuring stations*

Measuring equipment or remote measurement stations (RMS), must be a completely autonomous units able to, [2, 7]:

- operate continuously, 24 hours a day;
- measure electromagnetic radiation in the frequency range that covers all or most of the sources that contribute to the overall radiation exposure;
- save the measurement results in internal memory and transmit them to control unit via wireless interface;
- be powered from the low voltage network of 220V or more often from the preferred solar panels;
- be completely remote-controlled, with no need for human presence;
- solve any kind of abnormal or unusual operations (such as self-diagnosis, overheating, loss of power, a supply failure, etc.) and report that to the control units (CU).

In order to meet all of these requirements in full, RMS should include broadband isotropic three-axis electric field sensor, the module with the necessary electronics, GSM/GPRS/UMTS modem which is used for communication with the relevant local control centre (the downlink is used for remote configuration, programming and polling, while the uplink is used for reporting the measurements and other information such as alarms) as well as temperature and humidity sensors, [2, 7]. All these should be calibrated prior to installation in the network and every 6-12 months thereafter. In order to obtain more relevant data, measurements should be performed within a wide and a narrow range of frequencies. Broadband RMS would record electric field strength and/or power density in the frequency range 100 kHz - 3GHz, in which the majority of the radiation sources would be included.

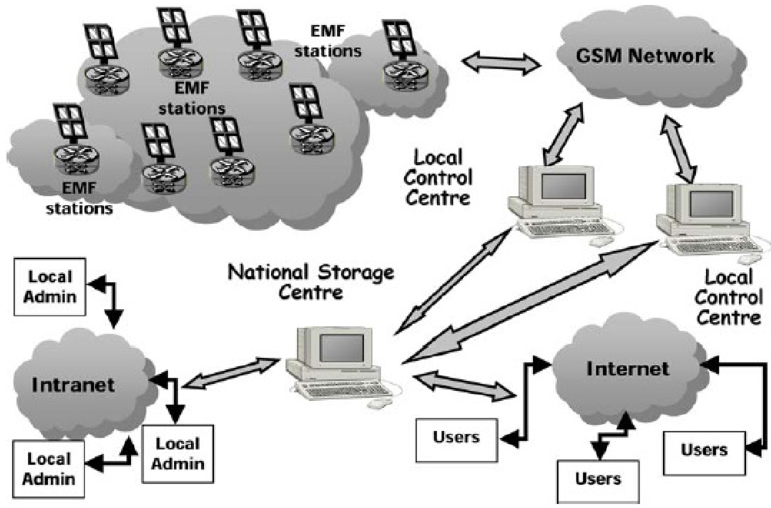

Figure 1. Architecture of monitoring system, National Storage Centre implemented

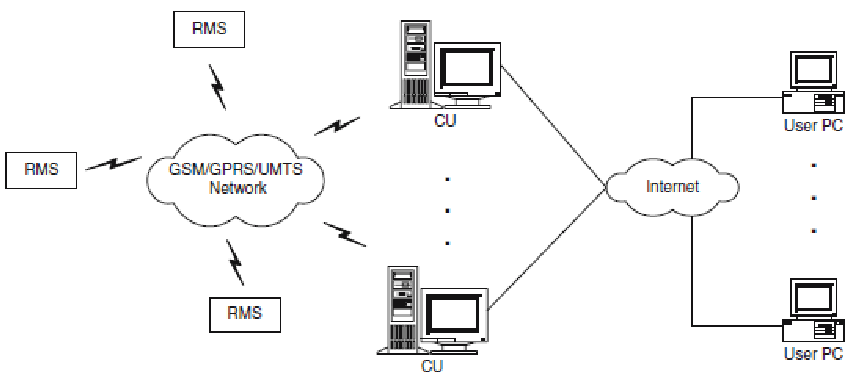

Figure 2. Architecture of monitoring system, local implementation

Figure 3. Examples of monitoring stations: EE4070-WB RMS station at Koskinou, Rhodes (left) and MCE-410 RMS station at Heraklion, Crete (right)

Other observed frequency ranges would be i.e. 880-960 MHz (GSM/UMTS 900 band), 1880-2100 MHz (DCS 1800 plus UMTS band), 2600 MHz (LTE - Long-term Evolution or 4G band) [8], etc. For frequencies above 100 kHz certain requirements must be met in order to avoid exceeding of electric field strength reference levels.

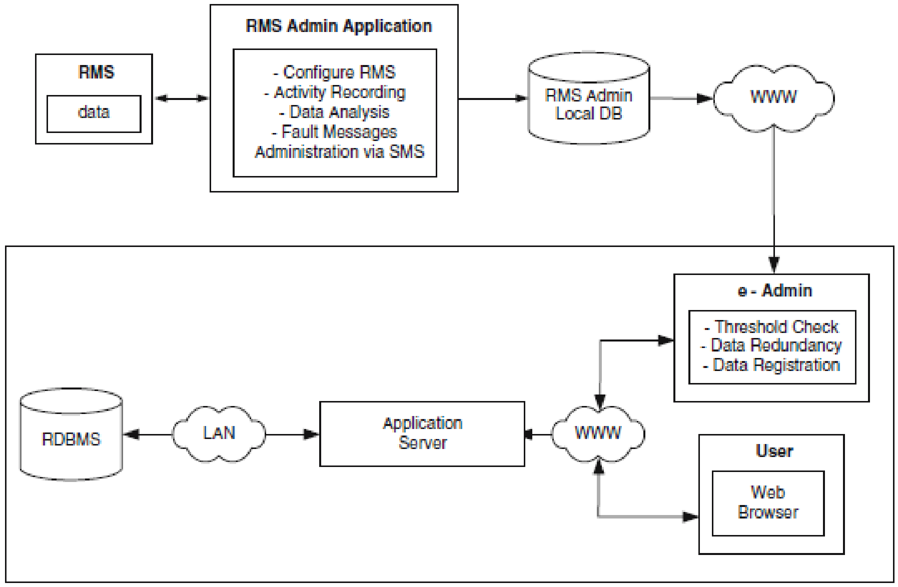

Figure 4. Software architecture

According to [9], the coefficient of total exposure to electric fields from multiple sources can be obtained by the following formula:

$$\sum_{i>1MHz}^{300GHz}\left(\frac{E_i}{E_{L,i}}\right)^2 \leq 1 \tag{1}$$

where : E_i is measured intensity of electric field at frequency i, $E_{L,i}$ is the reference level of electric field given in Table I, according to ICNIRP standard. The relation (1) must be satisfied for all values measured by remote measuring stations.

TABLE I. ELECTRIC FIELD STRENGTH REFERENCE LEVELS FOR GENERAL POPULATION EXPOSURE, ICNIRP

Frequency f (MHz)	**Electric Field $E_{L,i}$ (V/m)**
0.15–1.0	87
1.0–10.0	$87/f^{1/2}$
10–400	28
400–2000	$1.375\,f^{1/2}$
2000–300000	61

Nowadays, there are wide range of measuring devices from different manufacturers, which could be used as a RMS [6, 7]. These devices are completely autonomous and can be remotely controlled via GSM/GPRS protocol, [2]. Examples of remote monitoring stations are presented on Figure 3. However, there are some restrictions on this type of equipment. The broadband measurement cannot determine the contribution of inndividual frequency bands or equivalent radiation sources. Additionally, measuring in only one point actually represents the situation of the measuring the whole band and that would require a very rigorous criteria for the selection of that point. Therefore, there are multiple criteria for the selection of the measurement sites (points). High population concentration is among the most important criteria. The special features of each location must be chosen to cover places of special interests, to include the presence of buildings of particular interest for the local community (e.g., schools, homes, hospitals and public places including zones like gardens, parks, shops, etc.) and to include the existence of antennas in the close vicinity of the measuring sites, as well [2, 3, 7]. One of proposals for measuring site selection criteria can include public opinions where the representatives of the population can decide where the measuring stations will be placed in their town or part of the city [1, 2]. To overcome these limitations, it would be necessary, in every area, to perform additional "ad hoc" measurements periodically, with different mobile equipment, every 6 to 12 months. These measurements would not be replaced by continuous measurement but would only amend them. The effect of that action would be twofold, [2]. First, by using a spectrum analyzer or a highly selective radiation meter a separation between the radiation sources would be achieved. Above all, a verification of continuous measurement accuracy would be possible by simple results comparing of these two methodologies. The time interval between these measurements can vary and it is limited by the need of human presence in the observed area.

B. Control units

The control unit would be a computer server equipped with a wireless modem and software applications which can interact with different types of monitoring stations. This software is necessary for, [2]:

- control and configuration of the RMS;

- collection of data from RMS via wireless network;
- saving and storing data on a hard drive;
- data processing and presentation of it via certain website, Figure 2.

The software architecture that could allow all of the above is shown in Figure 4. Usually, manufacturers of RMS provide software application for control units and data collection. With this application, a system administrator would have the ability to change the measurement points and measuring station communication parameters. The software application of CU would collect the measured value from measuring stations and save them in the local database (such as MS SQL Server or MySQL), [2]. In this way, a complete history of measurements for a certain administrative area would be stored in the local control unit database. In addition, there would be a web server (such as MS IIS or Apache) that could host the website in order to print the measured values and export it to text format, [1, 2]. For collection, consolidation and data presentation from all control units a web-based application should be developed and that application would be hosted on the central server. This application should collect data from all local databases, process them, filter and display them to the final user in an appropriate form. Examples of such applications are RDBMS which is is a Relational Data Base Main Server (built on MS SQL server) and "e - Admin" which is a web-based network administrative tool (developed in Java), [2].

C. Central unit

It would also be a computer equipped with a wireless modem which would be located in the national storage centre. It would have a software application for:

- collecting the processed data at the regional level by CU via wireless network
- storing data on the hard disk
- processing of data collected at the national level and presentation of it via the corresponding website, Figure 1.

D. A website presentation

The website could contain both static and dynamic pages and aim at presenting the measurement results for all the monitored sites. It could also provide information concerning the non-ionizing electromagnetic radiation exposure limits. Through the website, the visitors could view graphs of the measured values for custom date/time interval selection. Furthermore, a comparison of the measured values with reference levels could be presented. A feedback form would be also available to the public for them to express questions or comments to the system administrators.

IV. CONCLUSION

A proposed and described system for remote monitoring and recording of non-ionizing radiation is based on the usage of modern technological solutions and available systems. Automation of this system is achieved using computer-based units and their networks and remote communication is achieved using available mobile services. Web-based application allows permanent access to all measured data from any place. Automated measurement and monitoring of the whole system or network can be carried out remotely using GSM, GPRS or other telecommunication connections. The system provides the full ability to program or set and define the parameters for each monitoring station and to monitor and save all the measurement results in 3D form in an automated, remote-controlled and continuous way. The control centre collects measurement results from all monitoring stations and perform a complete analysis of all measured data and store them for a long period of time. Such a system for monitoring and recording of non-ionizing radiation parameters would have a very useful social role. Direct communication with a large number of population would provide full information to the general public, in terms of exposure to non-ionizing radiation and build a long-term confidence in such monitoring systems. Periodic analysis of monitoring system measurement results by additional measurement with different spectrum measuring equipment, could establish the trust even more. The network could easily be expanded in order to gain the full coverage of the observed territory. That way, the entire population, government, mobile operators and other interested parties would have a direct, continuous information about the levels of non-ionizing radiation, which would be one of the contributors preventing a possible harmful radiation on human health side-effects. At the end, the installation of the monitoring network would have, as final objective, the creation of a “national map” describing the real situation and highlighting the possible “over-radiated” territories.

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