ГОДИШНИК на Департамент "Телекомуникации" - ISSN 2534-854X (online)
НОВ БЪЛГАРСКИ УНИВЕРСИТЕТ – София, 2014, том 3

СПЕЦИАЛИЗИРАНИ БАЗИ ДАННИ ЗА ИЗСЛЕДВАНЕ УПРАВЛЕНИЕТО НА СПЕКТЪРА, АНАЛИЗИ И ПРОГНОЗИ НА ВЪЗДЕЙСТВИЕТО НА РАБОТНИ ЕЛЕКТРОМАГНИТНИ ПОЛЕТА

гл.ас. д-р Георги Петров, доц. Анушка Станчева, доц. Васил Кърдев

SPECIALIZED DATABASES FOR SPECTRUM MANAGEMENT RESEARCH, ANALYSIS AND FORECASTING OF THE EFFECTS OF WORKING ELECTROMAGNETIC FIELDS

Georgi Petrov, Anushka Stancheva, Vasil Kadrev

Резюме: В тази статия дискутираме развитието и използването на специализирани бази данни, построени за събиране на информация, свързана с управлението на радиочестотния спектър с радиочестоти и мониторинга в контекста на тестване на работата на електромагнитните полета, създадени от широка гама от устройства и системи. Оперативната системна архитектура, описана от авторите споделя техния опит в областта на създаването и използването на тези инструменти на бази данни за сравняване на честотата и обхвата на покритие, и прогнозиране на разпространението на електромагнитните вълни за различни фиксирани и мобилни радиоуслуги. Действителният проблем има две страни, на първо място е свързано с излъчвателните кули и предавателите на базовата станция, втората е свързана с ръчни мобилни терминали, работещи в комплексна електромагнитна среда и в близост до човешкото тяло.
Ключови думи: специализирани бази данни, изследване управлението на спектъра, въздействие на електромагнитни полета

Abstract: In this article we discusse the development and use of specialized databases built to gather information related to the radio frequency spectrum management and monitoring in the context of testing the performance of electromagnetic fields created by a wide range of devices and systems. Operational system architecture described by authors share their experience in the field of creation and use of these databases tools for comparison of frequency and coverage plans, and predicting the electromagnetic waves distribution for various fixed and mobile radio services. The actual problem have two sides, first is related to broadcasting towers and base station transmitters, second is related to hand held mobile terminals working in complex electromagnetic environment and close to human body.
Keywords: specialized databases, research spectrum management, impact of electromagnetic fields

I. INTRODUCTION

In recent years, the introduction of large amounts of mobile and portable communication devices and systems lead to significantly higher levels of mutual interference and the background of electromagnetic interference particularly important in urban and densely populated and industrial areas.In connection with the study of the effects in environment with high levels of electromagnetic interference from different spectral bands, modulation types and levels of radiation more people and researchers started to investigate the potentional harmful effects of long-term exposure in this environment. This research trend is supported by the fact that in 2012 the number of mobile phone subscribers exceeds 6.9 billion.This caused a serious discussion at the World Health Organization [4] and the related international standardization organizations such as International Commission on Non-Ionizing Radiation Protection [1], International Telecommunication Union and IEEE [2].

There are many related researches to the possible harmful effect of cell phones and cell towers [5], [6], [7] etc. We will not be correct if don't mention the number of medical applications of elektromgnetic fields for the treatment of various diseases which effects are studied and proven as long: [8], [9] etc. In connection with the study of possible adverse effects and quality of life in densely populated areas within the project: Measurement, research, analysis and forecasting of the ef- fects of working electromagnetic fields of mobile devices on the health and quality of life of people living in densely populated areas - DFNI-B01/0017, our team provide various technical activities mainly related to the creation of web-based monitoring system for accumulating data from measurements of electromagnetic fields over a wide frequency range in a variety of locations. This information will be used for statistical analysis and forecasting of possible and achievable levels of exposure to living and working people in certain locations at Sofia, Bulgaria. Based on our experience with a number of national projects related to the analysis and comparison of operating frequency allocation plans and monitoring radiofrequency spectrum of the country under the project will be created a dedicated database for storing and comparing the results of actual EMF measurements and electromagnetic polution effects [30]. Europe has a number of projects in active phase realizing national monitoring systems to collect data from electromagnetic pollution well described in a project EHFRAN [10]. Regardless of the particular implementation of such a monitoring system aimed at long-term data collection for subsequent research, has been seen that many good practices still lacks openness. To easyer further research and easier comparison of the collected data from measurements over long periods of time it is reasonable to create an open project, which aims to integrate the capabilities and results already achieved with additional functionality.

The ultimate goal is long-term results of such measurements can be exchanged and compared by different professionals working in the scientific community related to electromagnetic pollution problems [3].This is reasonable to say that the implementation of such a system is related not only to environmental monitoring norms for electromagnetic pollution, but would have a number of other possible applicatons related to data collection for the national frequency monitoring of different radio services etc. In this article we discuss possible solutions concerning the creation of special- ized databases to gather information related to the analysis of electromagnetic pollution and forecasting of the possible side effects. Such an integrated approach assumes that the database must be open in order to facilitate interconnection with other systems that collect and analyze information. System should support multiple interfaces and visualization, report generation graphics, laminated maps and other features discussed below.

Considering the fact that most of such systems currently do not have such capabilities, and few of them have been created by experts in radio communications and spectrum management and monitoring, the average asumptions is that thsese systems do not have major scientific and experimental value. The main problem is that the majority of these products are made in order to prove one or another claim without the complying correct measurements procedures. Other common errors committed by IT professionals developing similar systems are mainly related to their lack of knowledge on the subject of the study. The team working on the project aims to integrate the accumulated knowledge on the subject by offering an integrative approach to web-based system for collecting, analyzing and processing the results of measurements of electromagnetic pollution in various real situations. Focus is placed over the data to be collected in the right way, the results are processed by standard methods used by professionals working in the field of radio, electromagnetic compatibility and also ecology and medical issues are also covered.

II. STANDARD SPECTRUM MANAGEMENT DATABASE STRUCTURE

Standard electromagnetic spectrum management plans, standard information for description of radio services, other related data. Main capabilityes, some modules are optional dependyng from the type of usage [13], [18]:

Administrative Application Processing Features

- System Tables

- Licensing (Existing and Transition Period Licenses)
- Reports (Technical and Financial)
- Notices (Registred Problems Pending for Solutions)
- International Regulatory Co-ordination
- Communications Equipment Type Approvals
- Frequency Allocation (Operator, Geographical, Temporal)
- Operator Fees and Taxes
- Accounting and tax policy
- Clients Complaints
- Operator Complaints
- Query Forms

Standard Engineering Analysis Tools

- LFMF (groundwave & skywave propagation models)
- HF (IONCAP propagation model)
- VHFUHF (Terrainintegrated propagation model)
- Microwave (Free-space propagation model)
- Intermodulation, Multiple Anthena Base Stations
- Electromagnetic Compatability
- Filtered measurement records
- Terrain Profile Plot
- Infrastructure Plot

Geographic Map Display and Simulation

- Security and Authorization
- Record Keeping
- Autodiagnostics of Data Integrity
- Hardware - graphics and extensive calculations
- Microwave (Free-space propagation model)
- Intermodulation, Multiple Anthena Base Stations
- Electromagnetic Compatability
- Registred Problems and Solutions
- Terrain Profile Visualization

There is another interesting new trend in spectrum management called - Dynamic Spectrum Management [11]. Most of national regulatory agencyes do not cover such features inside their spectrum management database and regulation plans. But it is important newly developed software systems to cover such features. Basically this changes the existing situation making possible multiple spectral bands and area of coverage to be used simultaneosly by multiple operators and for multiple services.

This new feature will become a reality in next genneration radiocommunication systems, as a simple example may indicate the use of bandwidth for digital TV simulcast video with high and low resolution, combined with the possibility of using different mobile TV standards and signal encoding option to transfer customer data and internet. It is easy to predict that databases used by the national regulator will not be able to take these opportunities and will be replaced, and government cannot take alone such task [19]. Dynamic Spectrum Management leads us to another information storage problem, new databases should allow dynamic updating of the records associated with the continuous monitoring stations installed in certain geogrphical positions. Without storing this information we can't draw accurate statistical models for the use of licensed and free range of EM spectrum [24]. The situation will be much difficult after full operator and services convergence.

Players in DSM market

- Government
- Military & Emergency
- National Regulatory Agency
- Licenced Operators
- Spectral Pull Brokers
- Comercial Users
- Unlicensed Users
- Neighboring Countries

III. SPECTRUM AND FREQUENCY PLAN COMPARISON DATABASE

Relativity to describe radio services - main characteristics, international standards, national standards, military standards, differences and similarities between standards. Specifics of the radio, data field and the particulars relating to the dis- tribution center, data relating to the seasons, joining data with information about other broadcasters and disturbing electronic devices and more. Often these spectral data plans too may be subject to classified information or state secrets, which makes handling the data more difficult.

Specialized international aproved database ITU-BR of frequency distributions and frequency plans use Microsoft Office Access format. This is done typically because of better usage and compatability. Even this such national databases do not exeed more than 1-2 GB of information. Access is better recognized because of a wide spread of Microsoft products in national regulation organizations.

Usually these databases include the following information:

- **TERRASYS** - radio record of terrestrial radio services
- **RCD** - radio glossary
- **RRP** - prescribed by the Radio Regulations Table
- **IFIC** - periodic posts of ITU-BR
- **RRC-06** - DTV international digital TV broadcasting
- **GTOPO** - world digital terrain maps
- **NRDP** - National Radio Frequency Plan

It is interesting to note that old GTOPO do not take into account the altitude deviation and city buildings, and even more line of side visibility of cross connected distance areas like Varna and Burgas this is why Bulgarian DVB-T map was recreated several times [21].

IV. DATABASES USED IN SPECTRUM PLANYNG SOFTWARE

Typically software for planning of radio networks use a lot more data and digital modules from standard libraries used by national regulators regarding the management of the radio spectrum [12] and depends from the type of communication service. The main characteristic of such systems is connected with the fact that they operate in two modes: statistical and simulation. In the statistical approach, network planning based on experience in the implementation of radio networks on a site in a given environment (buildings, hilly terrain and weather conditions etc..).This is the classical approach in which network designers rely on their previous experience suggests that the actual result will be similar to that already achieved. This approach is especially suitable for small radio network planning, for example low populated or open space, or installation of equipment of television transmitting towers with large area-of-sight, etc. The disadvantage of the statistical approach is that it can better predict the actual distribution of the signal in different coverage areas of radio network while enjoying a relatively simple calculations referring to our existing knowledge about radiowave propagation in the area of sight or through building walls (taking into account the average level of attenuation of the signal passing through the walls).

In the simulated approach designer has far more data, geographic, frequency, construction, and works with many more models of transmission and propagation in complex conditions.

This approach requires the use of databases containing large amounts of information, and is particularly suitable for forecasting and planning of modern radio networks in terms of indirect vision, the presence of obstacles and rugged terrain. Both approaches are combined well, provided that the system supports data from real measurements performed already planned radio networks, so the designer can consider also applied corrections simulative models. This will generate more data related to specific checks and adjustments in system should be used in future calculations and simulations of the coating. Frequently used models fall into two categories:

Simple models - for the study of the free space radio propagation - microwave lines, WiFi point to point links, analog terestrial and sattelite television and radio broadcasting, where propagation distances are much larger than the antenna size Fig. 1 [14], [15]. These models do not use complex and iterative calculations to achive simulation results. In practice they are known as: large-scale propagation models. Complex models - most often used for multipath prop- agation terrain maps, densely built-up urban environments, availability of radios and other embarrassment, these models are better suited for realistic situations including many features in the model - near surface water, specific structure of the soil, presence of large buildings constructed (Fig. 2) of metal and concrete, transmission options using different antennas, at different altitude and operating at different communication standards, etc. These simulations needs an extensive calcu- lations and most often are based on Finite Difference Time Domain (FDTD) technique [17] or fast fourier transform (FFT) to achive faster calculations [16] or wave propagation modelling by Beam Tracing [22].

Such models are very precize for local electromagnetic field transmission and in- duction of currents in near stated objects, anthenas, wires, other electrical or electromagnetic devices. FFT and FDTD are most often used while it is neaded to simulate very complex radiowave propagation models, just like biological objects, humman tissue, etc.

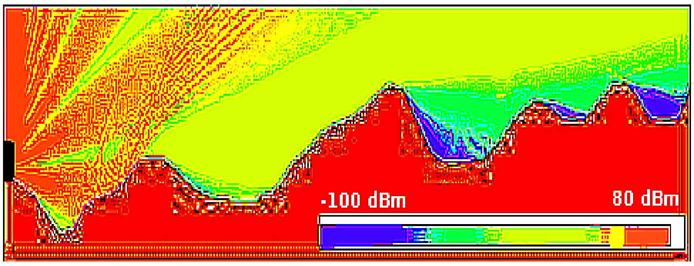

Fig. 1. Simple model for broadcasting transmission using 3D low resolution digital tarain map. http://www.remcom.com

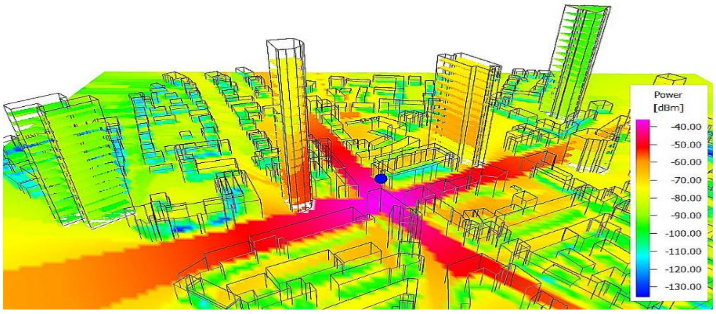

Fig. 2. Complex power density model for EMP using 3D high resolution digital tarain map.
http://www.awe-communications.com

V. DATABASES IN ELECTROMAGNETIC SPECTRUM ANALYSIS

The analysis of the radio spectrum is the main tool for determining the emission levels of various radio devices and generally used to examine the electromagnetic environment in a given area or in isolated laboratory conditions. Spectrum analysis allows us to measure what happens when different devices work together in the same perimeter. In this process we can occur intermodulation and other mutual interference leading to increased levels of electromagnetic radiation.

Such is the problem related to analysis and measurements of mutual interference of multiple mobile phones operating near or when installing multiple transmitting antennas of GSM base stations and other types of radio transmitters. Collection and comparison of the spectral maps of different devices and communi- cation systems in normal, isolated and severe electromagnetic environment is the only way to know what is happening with the real working levels of EM radiation. According to the working methods of spectral analysts, however, it is possible to collect additional information regarding specific communi- cation channels and other services. This requires a database to contain various types in structured information, which leads to problems in its interpretation and comparison. To simplify this approach required the results of each measurement to be turned into a probabilistic indicator of average RF power flux density level, which is not always possible with measurements made with different spectrum analyzers.

Often in practice have to be determined not only the spectral regions with high levels of EM radiation, but the exact electromagnetic troublemaker, which can only happen if the spectrum analyzer can show exactly which device is the source of high levels of EM radiation. This is a typical problem for CDMA and MIMO systems. This means that data collected by different measurement devices will allow us to analyze and accurately summarize the given electromagnetic environment. Not always using the integral spectram density model can gives us good results, this is particularly true in modern CDMA, UMTS, WIMAX systems. Also these spectrum databases should contain information regarding data transmission rates provided by the manufacturer pursuant catalog nomenclature of different hand heald devices and base stations making the solution even difficult [20].

Signal level measurements can be used in wide variety of applications, not only for EMP, some authors indicate different uses of the data collected by monitoring traffic and more [23]. This example is a good proposal for one additional problem solution in spectrum management databases - the Big Data problem.

VI. DATABASES FOR SPECTRUM M ONITORING APPLICATIONS

Real spectrum monitoring also has many aspects as differ- ent monitoring services may be interested in different kind of information. For example, the regulatory authority will require to collect and process information on licensed bands, whether a provider complies with conditions of the license and the geographical coverage area of a given service and limited levels of EM radiation from the point of view of the other systems interoperability. By the operator that issues have another aspect that all transmitters operate at nominal frequency and nominal levels of radiation in order all devices across the network to operate normal, whether the equipment works in programmed way and others. In terms of ecology will be important to determine whether the aggregate level of electromagnetic pollution meets health standards and whether stadnards and who worked over the EM radiation levels [25]. Interesting graphical based GIS user interface to display infor- mation is described in article [26].

But compliance with the health standards may also depend on the type of device, used modulation scheme, whether the device is pulsed nature of the EM radiation, etc. details, without which the evaluation of electromagnetic environment will not be correct. From a health perspective is not like that in the same room at the same time will work one or multiple phones at the same frequency, or devices of different frequencies and different models, although they may all use the same communication service. Speaking of electromagnetic measurements should mention that in such measurements should be associated and measurement results of high voltage lines and transformers [27].

Consideration of these and many other features imposes severe requirements and a wide variety of databases associated with the accumulation of information about the frequency monitoring making them difficult to reconcile with one another. An important part of SM applications is in-door measurements in large buildings, the industrial plants, public buildings etc. [28]. Because such applications must store large amounts of data, many problems regarding Big Data processing exist.

VII. MULTILAYER APPLICATIONS AND MULTI-USER APPROACH FOR DATA ANALYSIS

Typically, a system for planning and modeling a radio communication network is designed to be operated and used by a narrow circle of specialists. This could be radio engineers in network planning, designers of radio terminals, engineers and managers monitoring the network, government regulatory agencies or others who perform tasks narrow in range. The challenge for new databases that should be developed in part monitoring and control of electromagnetic radiation are great. With such systems will not work only one group of specialists or experts in a particular field.They will need to support multi- user and multi-profile interface for varios types of specialists: radio engineers, mathematicians, software developers, physi- cists, ecologists, medical staff, students, especially in monitor- ing and planning of radio networks and the general public. This imposes many demands to the way how the same information will be presented in to different users, a problem absent in the professional specialized database systems for planning and monitoring of radio networks.Also similar systems should be able to exchange data and results of analyzes made by different measurement devices and methods for analyzing data, making them more complex. Thus including simulation models and education procedures and online collaboration groups.It seems that it is more convenient such a system to be developed using the social network approach by using crowd sourcing, so all users must have access to web based tools for mathematical, statistical and visualization features making their work more convinient and useful.

VIII. CONCLUSION

Databases for analyzing, predicting and monitoring the electromagnetic environment and working levels of EM ra- diation of devices and systems in the context of health and environmental regulations have not yet been developed. They should combine the characteristics of the above types of databases used in practice by radio engineers and managers, including the new features and capabilities to the character- istics needs by their users.

It should be taken in to account the fact that such systems for measuring of electromagnetic polution are not yet been introduced. So that the systems currently available may undergo much change in the near future. Development of norms and standards to limit levels of radiation on different devices and systems will cause a significant impact on the processes of development and design of terminal equipment and radio communication systems. This will require the analysis of many statistics, the introduction of new methods of transmission and reception of very low signal levels, which would be used to require highly accurate models for simulation of radio networks and devices.

We think these changes in legislation concerning health and quality of life of people and life in urban and densely populated areas will result in a number qualitative changes in the currently used systems for radio planning and monitoring. Therefore the only way such a system to ensure the needs of as many users is to be initially developed as a modular, open architecture. The new systems must cover much wider context of capabilities for data storige, analysation and these data must be available for specialist working in very different fields: engeniers, medical However, we believe that it is imperative to fully developed new systems for storing data from environmental monitoring radio networks and levels of electromagnetic pollution in densely populated areas. Should seek closer collaboration between experts from national and international regulators, operators, NGOs, organizations for consumer protection, med- ical experts, biologists, etc.

This makes the task set before us all the more difficult because the intervention of envi-ronmental monitoring in typical engineering monitoring and maintenance of radio networks will require the integration of these systems already established information infrastructure for environmental and medical monitoring. Due to the complexity of the problems associated with the introduction of dynamic spectrum monitoring is justified as the base platform of the system to be selected completely open approach with very precise specification of the security and data integrity measures [29], thus SM can become a reliable part of e-Government applications. Due to the volume of work, we believe that the State can not alone solve current problem in this process is to engage as many stakeholders with leading universities and research institutions, which again supports a proposition to adopt an open platform as a base for future development. Dynamic-SM.

ACKNOWLEDGMENT

This work is supported by the project: Measurement, research, analysis and forecasting of the effects of working electromagnetic fields of mobile devices on the health and quality of life of people living in densely populated areas - DFNI-B01/0017, funded by Bulgarian National Science Fund - http://www.bulfund.com.

REFERENCES

[1] International Commission on Non-Ionizing Radiation Protection (IC- NIRP). Statement on the "Guidelines for limiting exposure to time- varying electric, magnetic and electromagetic fields (up to 300 GHz)",2009.

[2] Institute of Electrical and Electronics Engineers (IEEE). IEEE standard for safety levels with respect to human exposure to radio frequency electromagnetic fields, 3 kHz to 300 GHz, IEEE Std C95.1,2005.

[3] G.Petrov, A.Stancheva, I.Marinova, V.Mateev, Electromagnetic fields efects on living organisms, Izvestia, Sliven 52, 18, 2011 . page.52-55, ISSN 1311 2864

[4] Electromagnetic fields and public health: mobile phones, Fact sheet N193, June 2011, http://www.who.int

[5] Girish Kumar, Radiation Hazards from Cell Phones/Cell Towers, Elec- trical Engineering Department IIT Bombay, Powai, Mumbai

[6] R. K. Singh, International Journal of Medical and Biological Sciences 6 2012, Estimation of Electromagnetic Radiation from Base Station Antenna

[7] Samuel Milham, Dirty Electricity: Electrification and the Diseases of Civilization, 2010

[8] A. M. Berkutova, V. I. Juleva, G. A. Kuraeva, E. M. Proshina, Systems for complex electromagnethic therapy, Binom, Moscow, 2000

[9] Robert O. Becker, The Body Electric: Electromagnetism and the Foun- dation of Life, 1998

[10] Report on the level of exposure (frequency, patterns and modulation) in the European Union, Part 1: Radiofrequency (RF) radiation
[11] InterDigital, Inc. WHITE PAPER, Dynamic Spectrum Management - Spectrum harvesting through the allocation and aggregation of con- tiguous and non- contiguous licensed, unlicensed, and TV white space frequency channels, October 2012
[12] ATDI, WHITE PAPER, Route planning functions Network design dedicated to track coverage, 2013
[13] TCI, Spectrum Management Software, www.tcibr.com
[14] Christopher Haslett, Essentials of Radio Wave Propagation, Ofcom, UK, Cambridge University Press 2008
[15] Yelena Chaiko, Simulation of Radiowave Propagation Using Propaga- tion Models, Transport Communications and Information Systems, Riga Technical University Institute of Railway Transport, Latvia
[16] Sheng Zhao, FFT-based Optimization of terrain in radio wave propa- gation model, Environmental Electromagnetics (CEEM), 2012 6th Asia- Pacific
[17] Nurulhuda binti Ismail and Mohd. Zarar bin Mohd Jenu, Modeling of Electromagnetic Wave Propagation in a Humman Head due to Emissions from Cellular Phone, 2007, Melaca, APCAE
[18] Mike Willis, Ken Craig, Nick Thomas, Measurement Data for Imrov- ing ITU-R Recommendation P.1812 Database of filtered measurement records, Radio Communications Research Unit, STFC Rutherford Ap- pleton Laboratory, UK
[19] Radio Spectrum Managemen, Workshop on Radio Spectrum Manage- ment for a Converging World Geneva ITU New Initiatives Programme 16-18 Feb. 2004
[20] Per Line, Wayne A. Cornelius, Michael J. Bangay and Monica Grollo, Levels of Radiofrequency Radiation from GSM Mobile Telephone Base Stations, Australian Radiation Protection and Nuclear Safety Agency
[21] Plan for the introduction of digital terrestrial television broadcasting (DVB-T) in Bulgaria, 2012
[22] A.Schmitz, T.Rick, T.Karolski, T.Kuhlen, L.Kobbelt, Simulation of Radio Wave Propagation by Beam Tracing, Eurographics Symposium on Parallel Graphics and Visualization (2009)
[23] S.Promnoi, Road traffic estimation with signal matching in mobile phone using large-size database Dept. of Control Syst. & Instrum., Eng. King Mongkut"s Univ. of Technol. Thonburi, Bangkok, Thailand
[24] John A. Stine, Model-Based Spectrum Management Enabling Dynamic Spectrum Sharing, ISART 2012
[25] P.Getsov, D.Teodosiev, E.Roumenina, M.Israel, G.Mardirossian1, G.Sotirov1, B.Srebrov, S.Velkoski, P.Gajesek, D.Simunic, Methods for monitoring electromagnetic pollution in the western Balkan environmentsens, 2007, Third Scientific Conference with International Participation, SPACE, ECOLOGY, NANOTECHNOLOGY, SAFETY, 2729 June 2007, Varna, Bulgaria
[26] L.Paolino, M.Sebillo, G.Tortoa, G.Vitiello, Methods for Monitoring Electromagnetic Pollution a GIS Based Visual Approach, Dipartamento di Mathematica e Informatica, Universitia degli Studi di Salerno, Baronissi (SA) Italy
[27] D.Vatau, F.-D. Surianu, A.-E. Bianu, A.-F. Olariu, Considerations on the Electromagnetic Pollution Produced by High Voltage Power Plants, Proceedings of the European Computing Conference
[28] J. Agbinya, Z. Chaczko, K. Aboura, Radio Frequency Pollution Map- ping, 4th International Conference On Broadband Communication, In- formation Technology & Biomedical Applications, Wroclaw, Poland
[29] Kristian Tomov, B. Balabanov, Frame/Methodology for the Information Security Management in an e-Government Environment, ITU Regional Forum on Cybersecurity for Europe and CIS, 23-25 October 2012, Sofia, Bulgaria
[30] St. Petrov, A. Stancheva, B. Stanchev ”Wireless communication equipment - the impact on the human body, ”Security ”, No. 1, 1998

За контакти:

Гл.ас. д-р инж. Георги Петров , Департамент”Телекомуникации” на НБУ, ул. Монтевидео № 21, 2609,
Тел.: 02 8110609, e-mail: gpetrov@nbu.bg
Доц. инж. Анушка Станчева , Департамент”Телекомуникации” на НБУ, ул. Монтевидео № 21, 2609,
Тел.: 02 8110609, e-mail: astancheva@nbu.bg
Доц. д-р инж. Васил Къдрев , Департамент”Телекомуникации” на НБУ, ул. Монтевидео № 21, 2609,
Тел.: 02 8110609, e-mail: vkadrev@nbu.bg