AKTET
Journal of Institute Alb-Shkenca
Revistë Shkencore e Institutit Alb-Shkenca

ISSN 2073-2244
www.alb-shkenca.org

DEFINING A PRACTICAL AND RELIABLE METHODOLOGY FOR EVALUATING THE LEVEL OF ELECTROMAGNETIC FIELD EMITTED BY CELLULAR ANTENNAS

PËRCAKTIMI I NJË METODOLOGJIE PRAKTIKE DHE TË BESUESHME PËR VLERËSIMIN E NIVELIT TË FUSHËS ELEKTROMAGNETIKE TË EMETUAR NGA DISA ANTENA CELULARE

QANI MUKA
Faculty of Information Technology
Polytechnic University of Tirana, Tirana, ALBANIA
qani.muka@fti.edu.al

AKTET VI, 2: 97 - 102, 2013

PËRMBLEDHJE
Zhvillimi i shpejtë i rrjeteve radio ka sjell një shenjë mosbesimi tek njerëzit të cilët i druhen efekteve të mundshme negative të rrezatimit elektromagnetik nga stacionet bazë të komunikimit mobile. Për të përmbushur të gjitha kërkesat e udhëzimeve, direktivave, standarteve kombëtare dhe ndërkombëtare dhe për kërkesat e publikut të gjerë për informacion, duhet të formulohet një metodologji vlerësimi e saktë dhe e besueshme për të përcaktuar nivelin e ekspozimit mbi njerëzit. Në këtë material përshkruhet proçedura e matjes e adoptuar për vlerësimin e rrezatimit elektromagnetik të gjeneruar në prani të disa stacioneve të transmetimit të operatorëve mobile, e cila bazohet në rekomandimet ndërkombëtare për proçedurat e matjes së fushës elektromagnetike sipas ECC/REC(02)04 nga CEPT në bandën e frekuencave 9kHz–300GHz. Në lidhje me proçedurën e matjes propozohet edhe një metodë për përcaktimin e pikave të matjes, e cila konsiston në disa hapa, në varësi të topologjisë së antenave dhe numrit të transmetuesve.
Fjalët çelës: proçedurë, vlerësim, fushë elektromagnetike, emetim, transmetues.

SUMMARY
The rapid development of radio networks has brought a sign of doubt to general public which are concerned about possible negative biological effects caused by electromagnetic field emitted by antennas of base stations. To meet all the requirements of national and international guidelines/standards/recommendations and for the general public is required to define a practical and reliable methodology for evaluating the level of exposure on humans. In this paper is described the evaluating methodology adopted for monitoring the electromagnetic radiation generated nearby several BTS, that is based on international recommendations (ECC/REC (02)04 from CEPT) for in-situ measurement procedures to assess electromagnetic fields at frequency 9kHZ-300GHz. Regarding to measurement procedure, is proposed and a method for defining measurement points which consist at several steps at dependence of antennas topology and number of transmitters.
Key words: procedure, evaluation, electromagnetic field, emission, transmitter

1. INTRODUCTION

In recent years, society has been witnessing of the rapid growth of radio-base stations as a necessity for more capacity and services to a large number of users. On the other hand, society is concerned about negative effects on humans who are exposed on electromagnetic fields (EMF). Several agencies and government organizations around the world have established guidelines and recommendation regarding exposure to EMF [1, 2, 3]. Reference levels are developed on a conservative way using worst case condition of electrical coupling and they ensure that the reference levels are not exceeded.

Table 1. Recommended values from international standards for GSM 900/1800 MHz

Frequency	E (V/m)	H (A/m)	B (mT)	S (W/m^2)
900 MHz	41.25	0.111	0.138	4.5
1800 MHz	58.33	0.157	0.195	9

E – electric field intensity
H – magnetic field intensity
B – magnetic flux density
S – power density

For the assessment of EMF exposure has been proposed various methods, but the selection of one is depended by type of measurement (assessment to verify compliance with standards or in-situ measurement) and by distance of measuring field (near field or far field) [4]. In principle there are three sets of exposure measurement methods: a) Broadband measurements – estimation of field level as a whole, including all sources; b) Frequency selective measurements – extended estimation of the selected frequency; c) Code selective measurements – estimation of the field from UMTS system.

To be able to calculate the levels of EMF in a particular environment or around the given source, is necessary to realize the measurement campaign or application of theoretical methods (analytical or numerical). In most real situations we find several transmitting antennas that work at different systems that cover the same space or the radiation models are superposed with each other at main lobes. Of course it's necessary to evaluate the electrical field by taking into account radiation by each antenna at the same time. Equation (1) shows the far field formula for evaluating EMF by considering a system of n antennas. General EMF is obtained by superpose of electrical field intensity evaluated for each antenna. Approximation of far field can result in an overestimation of the measured EMF.

$$E = \sqrt{\sum_{n=1}^{n} E_n^2} \qquad E_n = \frac{\sqrt{30 \cdot G_n(\theta_n, \phi_n) \cdot P_n}}{r_n} \qquad (1)$$

Calculation parameters are:
E – electric field intensity produced from all antennas at calculation point.
E_n – electric field intensity produced by nth antenna at calculation point.
P_n – power of nth antenna.
θ_n , ϕ_n – angles that determine the direction from n-th antenna to calculation point.
θ – angle at horizontal plane between direction of observation of antenna and direction of maximum radiation of antenna.
ϕ – angle at vertical plane between direction of observation of antenna and direction of maximum radiation of antenna.
$G_n(\theta_n,\phi_n)$ – gain of nth antenna during this direction, given by manufacturer in ASCII file at two column format (degree, gain) at 360° radiation on horizontal and vertical plans.
r_n – distance between nth antenna and calculation point.

Usually chosen criteria for observed points, sampling frequency and measuring system properties depend from environment of the area that will be monitored. In particular, are distinguished radiation sources (number, spatial distribution, characteristics of radiation) and radiated EMF levels (definition of “hot-spot” locations and monitoring priorities). When the characteristics are known for the source, it's appropriate to make a prediction for expected values of the field strength and extract prior data for choosing the appropriate instrument and sensor. Next, reference points are defined for which the detailed evaluation of the EMF will be done at measurement points.
This paper handles two main issues: a) evaluation procedures at a certain point according to recommendation ECC/REC(02)04 from CEPT, which specify a method to evaluate human exposure to electromagnetic radiation at frequency band 9kHz-300GHz; b) procedures that determine measurement points according to different topologies of installed BTS, their

number at a specific area and their configuration in relation with each other.

2. MATERIALS AND METHODOLOGY

This section describes adopted procedures for measuring electromagnetic field that aims to evaluate EMF radiation at public places and to compare the results with recommended levels. All procedures for the method of measurements at different points are made on the basis of the recommendations of international organizations [5, 6].

For measurements is used RF radiation meter with isotropic probe. Narda SRM-3000 [7] is a selective radiation meter used for measurement from 100kHz to 3GHz and can analyze deeper a narrow frequency range and all spectral components that contribute at whole exposure. SRM-3000 operates at three different modes of EMF measurement: a) spectrum analysis; b) safety evaluation; c) time analysis. SRM-TS it's a program that remotely controls radiation meter and store/post-process results of measurements.

Measurement procedures

After determining the environment where measurement will be made, some measurement points are resolved and their results will be compared with reference levels. With determination of measurement point, the measurement with radiation meter starts. Referring to European recommendations, measurement point is located at the height of 1.5m from the ground. Measurements at this point are made for 6 minutes (time period over which exposure is averaged for purpose of compliance with EU recommendations) with radiation meter. These measurements are repeated at different time intervals and then the results are compared with reference levels. If they are lower than reference levels, then they are in compliance with levels of human exposure and can be published. If the results are higher than reference levels, then measurements are repeated but now at different heights around the determined point, precisely at the heights of 1.1m, 1.5m, 1.7m that match the dimensions of the human body. The field strength value that will be used in further calculations is the averaged value of the three values taken at different height, called spatial average, equation (2). When results are within predetermined rates then they can be published, otherwise, is needed a detailed measurements with spectrum analyzer.

$$E_{spatial\_avg} = \sqrt{\frac{\sum_{i=1}^{3} E_i^2}{3}} \quad H_{spatial\_avg} = \sqrt{\frac{\sum_{i=1}^{3} H_i^2}{3}} \qquad (2)$$

Detailed measurements with spectrum analyzer allow measurement of each source's contribution that led to those measurement values and then the results are compared with reference levels determined for each frequency band. Before starting the measurement, initially is needed to determine several parameters such as: frequency band, bandwidth, antenna polarization, critical level.

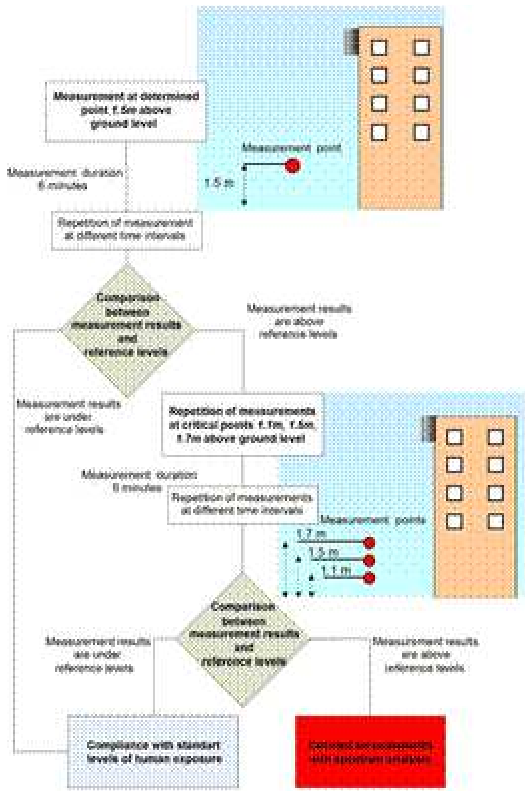

Figure 1. Measurement procedure flowchart

Selected bands are: a) 100kHz-30MHz; b) 30MHz-300MHz; c) 300MHz-3GHz; and spectrum analyzer is configured at these bands. The selected critical level is 40dB below the reference level of human exposure. Measurements will be made for antenna at the two polarizations at determined points using a spectrum analyzer. Measurement duration is 6 minutes for each band and at the end; results are compared with rates of critical level and with all standardized coefficients for human exposure to electromagnetic radiation. At the best case, when results are lower than reference levels then they can be published, otherwise should be reported immediately to the relevant authorities for results of measurements.

Selection of measurement points

In determining measurement point should be taken into account several factors that directly affect the measurement results. Two are the main factors that affect the procedure of determination of measurement points: a) installation topology of BTS [8]; b) BTS number.

Table 2. Typical installation topologies

Type	Installation topology	Reference
Rural	Tower, Mast, Water sump, Tree	Rtower
Urban	Roof-top	Uroof
	Building façade	Ufacade
	Light pole or other	Upole
	Tower	Utower
In-building	Roof	Iroof
	Walls	Iwall

MonoBS procedure is followed in the case when there is only a transmission station in the area. Measurement points are determined based on installation topology of the transmitter.

Procedure for topologies as Rtower, Upole, Utower (fig. 2):

- Determination of points along field radials based on local geometry of BTS
- Identification of points along closed paths based on local geometry of BTS
- Repetition of above procedure to avoid possibilities of signal disturbance
- Measure as many field points for more accurate results to comply with reference levels

The same procedure is followed in principle for topologies as Uroof and Ufacade, and for topologies as Iroof and Iwall.

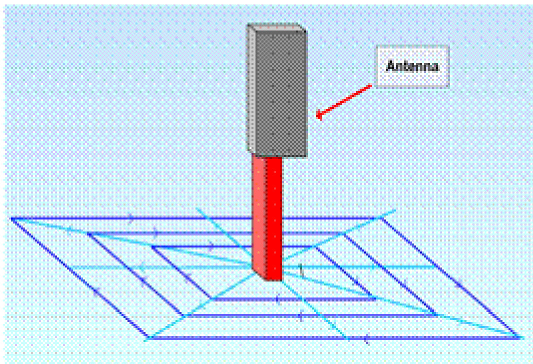

Figure 2. Schematic representation of the field for Utower, Rtower, Upole

MultiBS procedure described here is applied at those cases where there are more than one BTS on the area. This is suitable for any type of scenario, as when two (or more) transmission stations are line of sight (LOS) and when they are non-line of sight (NLOS). Initially is made determination of measurement points and then their measurements considering each station separately. This is done as in monoBS procedure.

In case where stations are line of sight, measurement points are subject to a more detailed analysis of the measurement. Analysis is required in this case because waves are superposed at a given point of measurement, which is due to the existence of two (ore more) BTS. In this case is made an analysis called "grid analysis" (fig.3) that determines the mode of measurement at these points. Considering different topologies then exists a large number of combinations of these measurement points.

Determination of measurement points in the grid analysis includes:

- Identification of field points along lines that form grid analysis
- Repetition of above procedure to avoid possibilities of signal disturbance
- Marking as many field points on grid analysis

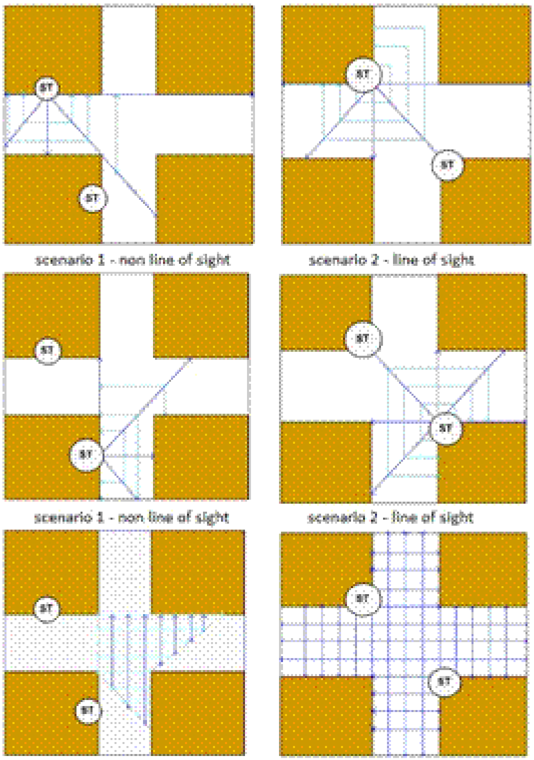

Figure 3. Determination of measurement points according to grid analysis

At the end, measurements are made on marked points in grid analysis. In case when stations are line of sight, measurements are made for each station separately according to above procedures then the results are processed.

3. RESULTS AND DISCUSSION

Measurements taken in several stations in Tirana city were based on methodology presented above. Because scenarios are in the far field case, the spreading surface of the waves is cylindrical and the measurement distance has not passed 15m from the antenna. The following charts represent results of measurements (6 minutes) taken on a building roof nearby four BTS that works on GSM900/1800 at an urban area in Tirana city (topology: Uroof). These results are compared with reference levels recommended from international organizations. **Er** value in all measurements is the effective value of electric field intensity measured by the radiation meter in its criteria for broadband measurements and max value measured during measurement time. At table 3-4, *Er @ALL* represent measured values (time averaged) for entire frequency range, while *Er @900 /@1800* represent measured values at 900 and 1800 MHz. At chart 1-2 **Er** is the resultant effective value measured at 900 and 1800 MHz, while the values with indexes*: E(1/4), E(2/4), E(3/4), E(4/4)* yield respective weight in these four operator frequencies. So the names of operators are represented with above indexes. The degree of recommended values is taken 10 times lower to better express the effective values measured at 900 MHz and 1800 MHz.

Table 3. Measurements results at different time intervals at the same point during Day_1

Time	***Day 1***		
	Er @ALL	**Er @900**	**Er @1800**
2:00	10.9642	1.1427	2.0718
5:00	10.9574	1.1498	2.0765
8:00	10.9838	1.1684	2.0995
11:00	11.0792	1.1806	2.1065
14:00	11.1093	1.1927	2.1087
17:00	11.1071	1.1863	2.1075
20:00	11.0326	1.1651	2.1034
23:00	11.0151	1.1585	2.1016
Average	11.03109	1.168013	2.09694
Standard Deviation	0.061653	0.017623	0.014447

Table 4. Measurements results at different time intervals at the same point during Day_2

Time	***Day 2***		
	Er @ALL	**Er @900**	**Er @1800**
2:00	10.9638	1.1446	2.0734
5:00	10.9587	1.1517	2.0758
8:00	10.9845	1.1629	2.0986
11:00	11.0763	1.1821	2.1053
14:00	11.1106	1.1938	2.1093
17:00	11.1085	1.1842	2.1081
20:00	11.0315	1.1637	2.1042

23:00	11.0138	1.1569	2.1021
Average	11.03096	1.167488	2.0971
Standard Deviation	0.061639	0.017344	0.014293

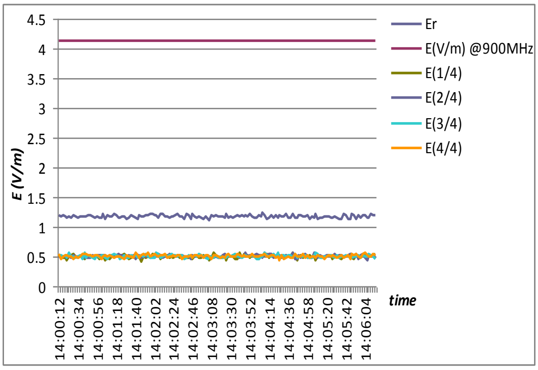

Chart 1. Measured values at time domain for 900MHz band compared with recommended value (one measurement at Day_1)

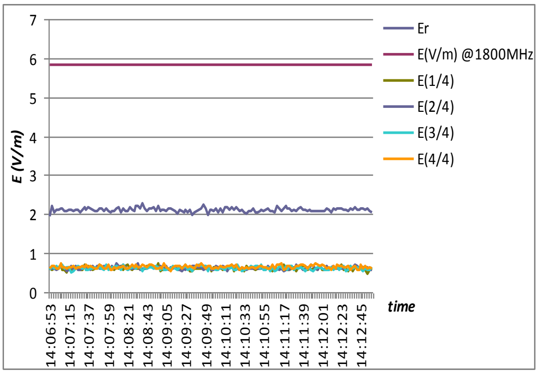

Chart 2. Measured values at time domain for 1800MHz band compared with recommended value (one measurement at Day_1)

By comparing the results obtained from practical measurements of EMF level carried out on the ground with our proposed methodology, with reference values recommended by European Council [1999/519/EC] (which are based on ICNIRP guidelines), we can say that measured values of electric field intensity, at all measured points were several times lower than reference values given by recommendations. In conclusion, should be noted that never was reached to measure a value greater than reference values for human exposure set by European Council. Also, average of all results and standard deviation of Day_1 and Day_2 are in balance with each other and within predetermined rates by international recommendations.

4. CONCLUSIONS

Evaluation of the radiated EMF in the vicinity of several base-stations is done based on proposed methodology. The choice of one method versus the other depends largely on the results that needed to deal and legal obligation to fulfill.

EMF measurement procedures, for monoBS (one base-station) and multiBS (more than one base-station) provide results in compliance with standards for human exposure. Standard use of this procedure allows direct comparison between results and the real analysis.

The accuracy of this method can be improved on sequel since cases scenario and topologies are very complex and depend by the environment of the installation of BTS.

BIBLIOGRAPHY

[1] Council Recommendation of 12 July 1999 - on the limitation of exposure of the general public to electromagnetic fields (0 Hz to 300 GHz) 1999/519/EC, Official Journal, 1999.

[2] ICNIRP Guidelines, Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz), Health Physics, Volume 74 (4), 1998.

[3] IEEE Standard for Safety Levels with Respect to Human Exposure to RF Electromagnetic Fields, 3kHz to 300GHz, IEEE Std. C95.1, 1999.

[4] Balanis C. A., Antenna Theory 3-rd edition: Analysis and Design, John Wiley & Sons, 2005.

[5] Bergqvist U, Friedrich G, Hamnerius Y, Mobile telecommunication base stations – exposure to electromagnetic fields, Report COST 244bis,2001.

[6] ECC Recommendation (02)04 revised, Measuring non-ionizing electromagnetic radiation (9 kHz–300 GHz), Official Journal, 2003.

[7] Portable EMF Measurement System, Operating manual, Narda safety test solution, Germany, 2007.

[8] Oliveira C, Fernandez C, Reis C, Definition of Exclusion Zones around typical Installations of Base Station Antennas, monIT project, 2005.