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SURVEY OF RADIOFREQUENCY RADIATION LEVELS AROUND GSM BASE STATIONS AND EVALUATION OF MEASUREMENT UNCERTAINTY

by

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This paper is a summary of broadband measurement values of radiofrequency radiation around GSM base stations in the vicinity of residential areas in Belgrade and 12 other cities in Serbia. It will be useful for determining non-ionizing radiation exposure levels of the general public in the future. The purpose of this paper is also an appropriate representation of basic information on the evaluation of measurement uncertainty.

Key words: non-ionizing radiation, electromagnetic field, radiofrequency radiation, GSM base station, measurement, measurement uncertainty

INTRODUCTION

The use of wireless communications devices has been increasing rapidly over the past decades. Along with the development of these technologies, public concerns about health risks of exposure to radiofrequency (RF) radiation for people residing in the vicinity of GSM base stations (GSM BS) antennas and possible adverse effects on health are on the rise, as well. The increasing number of cellular telephony subscribers has led to an expansion of networks and installation of more base stations.

The Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR) points out that scientific studies still fail to provide support for the effect of electromagnetic fields (EMF) on self-reported symptoms, but indicate that the expectation or belief that something is harmful may play a role in symptom formation. Further epidemiological and laboratory investigations are needed [1].

In order to evaluate population exposure, the knowledge of field levels is of great importance. Measurements are essential both for the verification of the results obtained through the use of numerical models and for the evaluation of field levels when the sources are unlikely to be simulated because of their number, working condition, and complex distribution. Uncertainty in the scientific or technical context has a very specific meaning. If a measurement is made many times, a range of results which are close to the "true" value is obtained. This spread in measured results can stem from differences in the exact measurement position, statistical variation in the response of the measurement instrument or differences in the way different people read the instrument display. The uncertainty of the used measuring equipment has to be known and considered in the final assessment [2].

MEASUREMENT METHOD AND RESULTS

The European Conference of Postal and Telecommunication Administrations (CEPT) has produced the ECC Recommendation (02)04 covering RF radiation [3]. It defines generally applicable measurement methods without mentioning any limit values. For such values, it refers to the EU Council Recommendation 1999/519/EC on the protection of the general public [4] and to corresponding national regulations. This has enabled CEPT to specify a strategic procedure that can be applied to public and occupational safety alike, which does not conflict individual regulations or specific local situations. Based on the ECC Recommendation (02)04, health and safety executives can specify clear procedural instructions to cover their areas of responsibility, without being forced into "do it yourself" solutions with attendant risk of legal uncertainty.

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The ECC Recommendation envisages three cases for evaluating situations involving exposure to RF radiation:

Case 1 – Quick overview,
Case 2 – Variable frequency band, and
Case 3 – Detailed investigation

Case 1 – Quick overview is sufficient, as all the measured values remain below the Decision Level (the thresholds below the reference level of the International Commission on Non-Ionizing Radiation Protection, ICNIRP, limit values or nationally-determined limit values). Broadband measuring equipment is ideal for case 1. The following properties are essential – measuring instruments and isotropic (non-directional) field probes must be capable of measuring the root mean square (rms) value [5].

The goal of this paper is the characterization of RF electric field levels with an electric field probe (Type 8.3) of the EMR-300 RF radiation meter [6]. All measurements were done at points of around 1,5 m-1,8 m above the ground/floor and at a distance from GSM BS antennas beyond 1 m (»far-field conditions«), in the daytime, between 12:00 p. m. and 16:00 p. m.

In order to minimize the influence of other sources of RF radiation, GSM BS were selected according to the criterion that they have to be the sole source of RF radiation within an 150 m wide area.

Measurements were divided into four groups:

Group 1 – Measurements on roofs where GSM BS are mounted,
Group 2 – Measurements in rooms below GSM BS,
Group 3 – Measurement in rooms situated at about the level of GSM BS, and
Group 4 – Measurement around masts of GSM antennas.

In terms of the assumption of valid survey points (4 group of measurements with altogether 20 observing locations), our survey disposes of following figures:

– 75 measurement points in group 1 – on 9 locations,
– 111 measurement points in group 2 – on 9 locations,
– 342 measurement points in group 3 – on 10 locations, and
– 135 measurement points in group 4 – on 9 locations.

The selection of the number of measurement points per location is directly assessed by [5]:

– for group 1 – 2-25 measurement points per location,
– for groups 2 and 3 – 10 measurement points per location in places where people spend most of their time during the day (offices, living rooms or bedrooms), and
– for group 4, omnidirectional antennas – 4 measurement points per circumference of circles $r = 5$-150 m; sector antennas – 3 measurement points in the direction of "main beam" antennas on a visual distance ranging up to 150 m.

Figure 1 is a representation of the accumulative percentage of measurement values *vs.* RF electric field
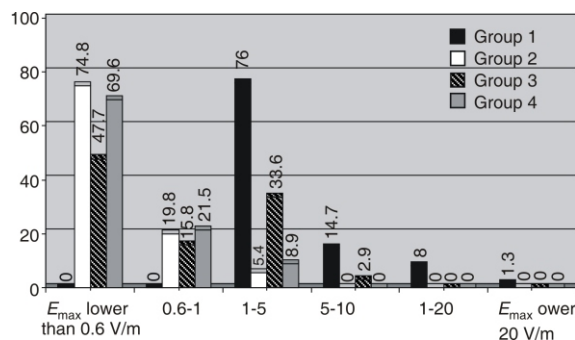

Figure 1. Percentile distribution of measurement values

strength (100 kHz-3 GHz) for all four groups of measurements, in the region of GSM BS, in "the worst case scenario" (maximal value on display). Meaningful comparison is possible only between the result of EMF measurements obtained following these methods on one hand and reference levels and basic restrictions of contemporary safety standards (*i. e.* IEEE C95.1) and guidelines from the International Commission on Non-Ionizing Radiation Protection (ICNIRP).

THE EVALUATION OF MEASUREMENT UNCERTAINTY

The evaluation of uncertainty should be performed following the ISO/IEC Guide [7]. The European Committee for Electrotechnical Standardization (CENELEC) issued standard EN 50413 [8], where useful information can be found about the identification of uncertainty components.

In the high frequency range RF : 100 kHz-300 GHz), several field types exist which should be assessed differently, depending on the distance r from and the biggest dimension D of the radiating source. Table 1 indicates whether to measure electric (E) or magnetic (H) field strength, or both, at different distances from the field source.

Table 1. Evaluation parameters for high frequency range [8]

	Reactive near field	Radiating near field	Far field
Distance (r)	$r \ll \lambda$	$r \ll 2 D^2/\lambda$	$r \gg 2 D^2/\lambda$
$E,H \sim 1/r$	No	No	Yes
$Z_0 = E/H$	$\neq Z_0$	$\neq Z_0$	$= Z_0$
To measure	E and H	E or H	E or H

Reliable assessment procedures have to be able to distinguish between the contributions from different RF sources and also to estimate individual exposure. Possible dosimetric approaches are the use of frequency selective monitoring equipment to assess variation *vs.* time, and of frequency selective equipment like dosimeters, to assess individual exposure. Procedures based on the use of broadband measure-

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Table 2. Example of an uncertainty budget for field strength measurement using a broadband measurement system [8]

Influence factor	Reference	Specified uncertainty [%]	Distribution	Division factor	Standard uncertainty $u(x_i)$ [%]
Frequency response	Calibration report	15	Rectangular	1.73	8.7
Uncertainty of frequency response	Calibration report	14	Normal ($k = 2$)	2	7
Linearity deviation	Calibration report	3	Rectangular	1.73	1.7
Uncertainty of linear deviation	Calibration report	2.5	Normal ($k = 2$)	2	1.3
Isotropic deviation	Data sheet	12.2	Rectangular	1.73	7
Modulation response	Data sheet	5	Rectangular	1.73	2.9
Temperature response	Data sheet	3.5	Rectangular	1.73	2
Repeatability	Measuring series	15	Normal ($k = 1$)	1	15
	Combined standard uncertainty (u_C [%])				20.4
	Expansion factor (k)				1.96
	Expanded uncertainty (U [%])				40.0

Table 3. Example of an expanded uncertainty for electric field strength measurement EMR-300, E-Probe: Type 8.3 (100 kHz-3 GHz) [2, 9]

Input quantity	Relative uncertainty (dB) (conf. interval of 95%)	Relative uncertainty (num.) (conf. interval of 95%)	Relative standard uncertainty (conf. interval of 66%) $u(x_i)$
(a) (0.6-1.25 V/m; 100 MHz-3 GHz); Temperature: 25 °C			
Isotropy	1	0.12	0.06
Linearity	3	0.41	0.21
Flatness	2.4	0.32	0.16
Temperature	0.2	0.02	0.01
Combined standard uncertainty	$u_C \sqrt{\sum_{i=1}^{n}(c_i u_{xi})^2}$ 0.27		27% (2.1 dB)
Expanded uncertainty [95%]	$U = 1.96\, u_c = 0.53$		53% (3.7 dB)
(b) (1.25-2.5 V/m; 100 MHz-3 GHz); Temperature: 25 °C			
Isotropy	1	0.12	0.06
Linearity	1	0.12	0.06
Flatness	2.4	0.32	0.16
Temperature	0.2	0.02	0.01
Combined standard uncertainty	$u_C \sqrt{\sum_{i=1}^{n}(c_i u_{xi})^2}$ 0.18		18% (1.4 dB)
Expanded uncertainty [95%]	$U = 1.96\, u_c = 0.35$		35% (2.6 dB)
(c) (2.5-400 V/m; 100 MHz-3 GHz); Temperature: 25 °C			
Isotropy	1	0.12	0.06
Linearity	0.5	0.06	0.03
Flatness	2.4	0.32	0.16
Temperature	0.2	0.02	0.01
Combined standard uncertainty	$u_C \sqrt{\sum_{i=1}^{n}(c_i u_{xi})^2}$ 0.17		17% (1.4 dB)
Expanded uncertainty [95%]	$U = 1.96\, u_c = 0.33$		33% (2.5 dB)

Note: Input quantity data are used from Operating Manual in ref. [6]; Conversion: $X[\text{dB}]$ $20 \log \frac{x[\%]}{100}$ 1
Conversion: $x[\%]$ $(10^{X[\text{dB}]/20}$ 1) 100

ment equipment are suitable for epidemiological studies if one source is dominant or if other reliable procedures, such as analytical calculations, are applied, that make it possible to distinguish between the contributions from different sources [5].

These are some of the uncertainty contributions [2, 9]:

– probe calibration, which should be carried out in an accredited laboratory,
– frequency interpolation, due to the fact that the probe calibration curve is determined for discrete frequencies of the reference EMF,

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– the measuring procedure, followed to estimate the measured quantity and differences due to different staff carrying out the same type of measurement, and
– the effects of environmental conditions (*i. e.* temperature, humidity) in the measurement setup.

In tab. 2, an example of CENELEC standard EN 50413 is reported for electric field strength measurements performed with a broadband measurement system. Relative combined standard uncertainty was calculated following the ISO/IEC Guide [7]:

$$u_C \sqrt{\sum_{i\ 1}^{N} [c_i\, u(x_i)]^2}$$

where sensitivity coefficient $c_i = 1$, resulting from a presumption of the case where the measurand is already a linear function of the quantities on which it depends. The relative expanded uncertainty is obtained by multiplying relative combined standard uncertainty by the coverage factor $k = 1.96$; the confidence level is approximately 95%.

For comparison of a measurement result with the "limit" fixed by the standard for human exposure to electric, magnetic, and electromagnetic fields, "total value" (the measured values plus the expanded uncertainty) is needed. Based on ref. [9], levels of field intensity measured with a relative uncertainty within 3 dB (41%) can be directly compared.

Table 3 presents the results of measurement uncertainty determination for the isotropic electric field probe (Type 8.3) of EMR-300 RF radiation meter [2, 9]. Case A shown in the table is not in line with the said qualification.

DISCUSSION

With the introduction of the new concept of measurement uncertainty, all errors were defined as stohastic variables and, consequently, a practicable measuring method was created, suitable for efficient application in all sorts of experimental measurements [2].

Field levels obtained with instruments having a relative uncertainty greater than 3 dB are to be considered only informative. In this case, if the total value is still lower than the limit, there is a strong probability that the "presumed" field level is below the limit. In other cases, a decision cannot be taken and it is necessary to repeat the measurement with an instrument that can ensure greater accuracy.

REFERENCES

[1] ***, European Commission, SCENIHR, Health Effects of Exposure to EMF, (Available Online: http://ec.europa.eu/health/ph_risk/committees/04_scenihr/docs/scenihr_o_022.pdf)
[2] Vulević, B., Osmokrović, P., Evaluation of Uncertainty in Measurement of Environmental Electromagnetic Fields, *Radiat. Prot. Dosim., 141* (2010), 2, pp. 173-177
[3] ***, Electronic Communications Committee (ECC). ECC Recommendation (02)04 (Revised Bratislava 2003, Helsinki 2007): Measuring Non-Ionizing Electromagnetic Radiation (9 kHz-300 GHz), Edition 060207 (2007)
[4] ***, EC, Council Recommendation of 12 July 1999 on the Limitation of Exposure of the General Public to Electromagnetic Fields (0 Hz-300 GHz), Official Journal of the European Community, L199/62, 1999
[5] Vulević, B., Determination of Radiofrequency Radiation Levels in Area of GSM Base Stations, M. Sc. thesis (in Serbian), Faculty of Electrical Engineering, University of Belgrade, 2006
[6] Freeden, J. von, EMR-200/300 Radiation Meters Operating Manual, BN 2244/98.22, 2001
[7] ***, ISO/IEC Guide 98-3:2008.Uncertainty of Measurement, Part 3: Guide to the Expression of Uncertainty in Measurement (GUM:1995), 2008
[8] ***, CENELEC EN 50413:2008, Basic Standard on Measurement and Calculation Procedures for Human Exposure to Electric, Magnetic and Electromagnetic fields (0 Hz-300 GHz), 2008
[9] Vulević, B., An Estimate of Measurement Uncertainty when Assessing the Level of Electromagnetic Fields in the Environmental, Ph. D. thesis (in Serbian), Faculty of Electrical Engineering, University of Belgrade, 2010

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ИСПИТИВАЊЕ НИВОА РАДИОФРЕКВЕНТНОГ ЗРАЧЕЊА У ОКОЛИНИ ГСМ БАЗНИХ СТАНИЦА И ПРОЦЕНА МЕРНЕ НЕСИГУРНОСТИ

У овом раду приказани су резултати широкопојасних мерења нивоа РФ зрачења у околини ГСМ базних станица јавне мобилне телефоније које се налазе у близини насеља у Београду и 12 градова Србије. Исти ће бити од користи у неком будућем одређивању нивоа излагања становништва нејонизујућим зрачењима. Поред наведеног, сврха овог рада јесте и одговарајуће представљање основних информација о процени мерне несигурности.

Кључне речи: нејонизујуће зрачење, електромагнетско поље, РФ зрачење, ГСМ база станица, мерење, мерна несигурност