Human exposure assessment in the vicinity of 900 MHz GSM base station antenna

MIMOZA IBRANI-PLLANA, LUAN AHMA, ENVER HAMITI,RUZHDI SEFA
Faculty of Electrical and Computer Engineering
University of Prishtina
Bregu i Diellit, pn
KOSOVO
mimoza.ibrani@fiek.uni-pr.edu, luan.ahma@fiek.uni-pr.edu
enver.hamiti@fiek.uni-pr.edu, ruzhdi.sefa@fiek.uni-pr.edu
www.uni-pr.edu

Abstract: Daily exposure to GSM electromagnetic fields has raised public concern of possible adverse health effects to people living in the vicinty of base station antennas.
International guidelines and standards established for limiting human exposure to electromagnetic fields are given in two categories: Basic restrictions (SAR, induced current density, and induced power density) and Reference levels (free space electric field intensity, magnetic field intensity and power density). In order to check compliance for both categories, in this papers are presented measurements of incident electric field and obtained results are used for numerical prediction of SAR.
Measurements of field strength and power flux density are performed on locations few meters away from base station antenna, in different levels, with and without usage of mobile phones, during day and in peak hours of GSM system usage.
Results are compared with ICNIPR Guidelines, IEEE and CENELEC standards.

Key-Words: base station antennas, field strength, power density, GSM, measurement

1 Introduction

Increased use of cellular mobile communication led to sitting of GSM base station antennas even in close of houses, schools etc, in densely populated areas.
This raised public concern regarding safety of population exposed to such radiation. Many studies have been done and are on going regarding potential biological and thermal effects of GSM electromagnetic fields.
Cancer, hyperthermia , neural and behavior effects of people exposed to GSM fields are being studied.
Interaction of GSM electromagnetic fields and humans should include all particularities of "system": [3]

- The "material"(human body)has very unusual electromagnetic properties values: electric permittivity, electric conductivity
- These properties are not well known and depend on activity of person
- This material is an active material at cell scale
- In most cases, the problem is actually a coupled problem: the thermal effect is one of the major effects and it is affected by the blood circulation
- The geometry is complex and generally environment of the human body has to be taken into account

In the other hand, relevant bodies have established guidelines for limiting exposure to electromagnetic fields. International standards and guidelines are given on two categories:

- Basic restrictions- Restrictions on exposure to time varying electromagnetic fields based directly on established health effects. On GSM frequencies physical quantity used to quantify these restriction is SAR.
- Reference levels- Provided for practical exposure assessment in order to estimate whether basics restrictions are exceeded. Physical quantities used at this regard are : electric/magnetic field intensity etc

The fundamental question in checking compliance during human exposure to electromagnetic field is to satisfy the given basic restrictions. For this reason all guidelines and recommended limits on human exposure to GSM electromagnetic fields are given in terms of SAR (Specific Absorption Rate).

SAR is defined as:

$$SAR = \frac{\sigma\left|E^2\right|}{\rho_m} \text{ W/kg} \ldots\ldots\ldots\ldots\ldots\ldots\ldots.. (1)$$

σ -Conductivity of body tissue, E- root mean square of intensity of electrical field at considered point, ρ_m -mass density of tissue at that point.

Since SAR, time rate of RF energy absorbed per unit mass, is very difficult and complex to be measured in biological tissues, standards permit the use of reference levels of power flux density(W/m^2)s in free space.

IEEE standard established the limits for rms electric and magnetic fields, so called maximum permissible exposure(MPE) and similarly ICNIRP standard defines reference limits for free-space incident fields. Meeting these limits SAR compliance should be ensured.

So instead of complex SAR measurements, for compliance assessments above mentioned standards let us use simpler field measurements as rms of electric field.

In this paper we have presented results of measurements of field strength and power density flux in the vicinity of base station antennas. Exposure assessment is done on request of Ministry of Environment in order to give feedback regarding level of exposure, assessment of radiation, to concerned people living on the vicinity of GSM 900 MHz base station antenna.

Based on obtained results, using SAR prediction expression, SAR values are calculated and presented.

2 Measurement of field strength and power density in vicinity of base station antenna, SAR calculation

In order to have more accurate results power flux density is measured at considerable distances from radiating antenna.

When the humans are located in near field of antenna, significant influence in antenna parameters is to be expected. If distance is greater than 0.7m-0.8 m the human phantom influence can be almost completely omitted [2].

Assuming far-field exposure, magnitude of electrical field can be expressed as superposition of the incident field and reflected field components. [1-2]

Figure 1 shows ground-plane of suburb Emshir, Prishtina –Kosovo, where is located GSM 900 MHz base station antenna.

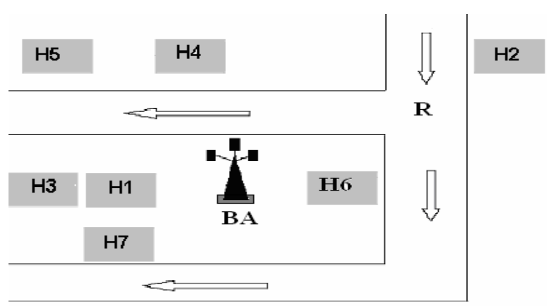

Figure 1

H1- House Nr.1; H2- House Nr.2; H3- House Nr.3, H4- House Nr.4; H5- House Nr.5;
H6- House Nr. 6; H7- House Nr.7; R- Road, BA- Base of Antenna.

Measurements are performed using radiation meter EMR-300, sensor type 8 E- field probe, 200 KHz -3 GHz, three axial sensors, so measurements are done independently of direction or polarization of emitter.
For more technical parameters of instrument check at www.wg.com.

Based on given parameters the field strength can be calculated as follows:

P- Effective Isotropic Radiated Power
S-Power density flux W/m^2
Z_v- Air Impedance $=120\pi$

$$P = S\frac{\lambda^2}{4\pi} \quad \text{..............................(2)}$$

$$S = \frac{E^2}{Z_v} \quad \text{................................. (3)}$$

$$10\log S = 10\log P - 20\log\lambda + 10\log 4\pi \quad \text{... ....(4)}$$

For downlink GSM frequency 935 MHz:

$$10\log S = 10\log P - 0.2 \quad \text{............... (5)}$$

Referring to expression (3) we obtain:

$$20\log E = 10\log PmW + 55.5 \quad \text{... ......(6)}$$

$$E\frac{V}{m} = 10^{(measuredvalue+55.5)/20} \quad \text{............. (7)}$$

In far-field human exposure to base station radiation can be considered as exposure to plane-waves.
At GSM frequencies 900 MHz, the average conductivity of the human body is $\sigma = 1.4S/m$ while corresponding relative permittivity is $\varepsilon_r = 55$.
Taking in to consideration above given facts, SAR can be calculated in function of incident electric or magnetic field using the following expressions [12]:

$$SAR = \frac{\sigma}{\rho}\frac{\mu\omega}{\sqrt{\sigma^2+\varepsilon^2\omega^2}}(1+\gamma_r)^2\left|H_{inc}\right|^2 \quad \text{..(8)}$$

$$\gamma_r = \frac{2\left|\sqrt{\varepsilon'}\right|}{\left|\sqrt{\varepsilon'}+\sqrt{\varepsilon_0}\right|} - 1 \quad \text{.....................(9)}$$

$$\varepsilon' = \varepsilon + j\frac{\sigma}{\omega} \quad \text{...........................(10)}$$

$$H_{inc} = \frac{E_{inc}}{Z_0} \quad \text{...........................(11)}$$

$$SAR = \frac{\sigma}{\rho}\frac{\mu\omega}{\sqrt{\sigma^2+\varepsilon^2\omega^2}}(1+\gamma_r)^2\frac{\left|E_{inc}\right|^2}{Z_0^{\,2}} \quad (12)$$

γ_r - Corresponding reflection coefficient
ε' -complex permittivity of the medium
H_{inc} -rms of the incident magnetic field
E_{inc} -rms of the incident electric field

3 Results of measurements and SAR values

The precise experimental determination of power density on complex and dynamic environment is a difficult task. This is mainly due to reflection, absorption and interference of electromagnetic waves. Different measurements can lead to quite different results due to changing of conditions[5].
In Table 1 are presented results of measurements of instant values of electrical field, average values over 6 minutes, power density and power level. Presented measurements are done at 11:30 at different sites, different heights from ground level, indoors and outdoors, with and without usage of few mobile phones. In order to include worst case scenarios we have presented as well maximum of instant values and maximum of average values.

In order to assess exposure at peak-usage time, we have measured and presented in Table 2 values of electrical field and power density and in peak –usage of system, at 21:30.

In Figure 2 are compared measurements of average intensity of electrical field at 11:30 with measurements of 21:30 at two sites, House 3, 31 m far from base of antenna and at point 4 m far from base of antenna.

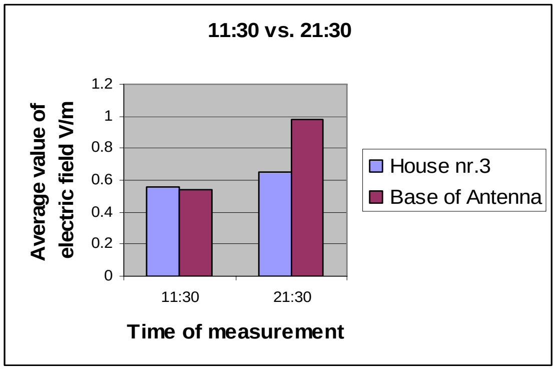

Figure 2

In Figure 3 are presented values of electric field at different sites surrounding base station antenna. Measurements are done at same ground level, at garden of houses.

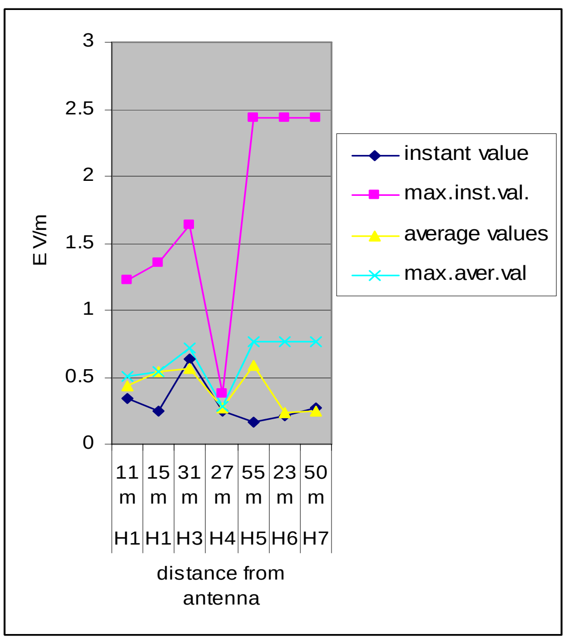

Figure 3

In Table 3 are presented SAR values calculated using SAR prediction formula in function of measured electric field intensity. Calculated values are for humans located on ground floor, while on Table 4 are presented SAR values for humans located on second floor of houses.

Loca-tion	Distance from base of antenna(m)	SAR ($\mu W / kg$)
H1	11 (garden)	0.20
H1	15 (garden)	0.23
H3	31 (garden)	0.41
H4	27 (garden)	0.06
H5	55 (garden)	0.46
H6	23 (garden)	0.46
H7	50 (road)	0.46

Table 3

Loca-tion	Distance from base of antenna(m)	SAR ($\mu W / kg$)
H1	11 (second floor)	0.20
H2	56 (second floor)	0.29

Table 4

Nr.	Place of measurement	Distance from base of antenna (m)	Intensity of electrical field E(V/m)				Others		
			Instant value	Maximum of instant values	Average value	Maximum of average values	Power density (mW/cm^2)	Power level dBm	Chanal of main frequency
1.	House nr.1	11 (garden)	0.34	1.22	0.44	0.51	-	-33	62
2.	House nr.1	11 (second floor)	0.4	1.22	0.47	0.51	-	-40	62
3.	House nr.1	15 (garden)	0.25	1.35	0.54	0.54		-47	62
4.	House nr.2	56 (second floor)	0.59	1.35	0.48	0.59	-	-42	65
5.	House nr.2	66 (third floor)	0.61	1.35	0.48	0.59	0.0001	-35	65
6.	House nr.3	31 (garden)	0.64	1.63	0.56	0.72	0.0001	-38	62
7.	House nr.3	31 (garden- with usage of mobile phones)	0.64	1.63	0.55	0.72	0.0001	-	-
8.	House nr.4	27 (garden)	0.25	0.38	0.27	0.28	-	-48	23
9.	Base of antenna	4	0.63	1.45	0.54	0.55	0.0001	-38	23
10.	Base of antenna	4	0.63	1.45	0.54	0.55	0.0001	-45	65
11.	House nr.5	55 (garden)	0.16	2.43	0.59	0.76	0.0001	-35	62
12.	House nr.6	23 (inside a house)	0.16	2.43	0.43	0.76	-	-	-
13.	House nr.6	23 (garden)	0.21	2.43	0.24	0.76	-	-40	65
14.	House nr.7	50 (road)	0.27	2.43	0.25	0.76	0.0002	-40	62

Table 1

Nr.	Place of measurement	Distance from base of antenna (m)	Intensity of electrical field E(V/m)				Others		
			Instant value	Maximum of instant values	Average value	Maximum of average values	Power density (mW/cm^2)	Power level dBm	Chanal of main frequency
1.	House nr.3	31 (garden)	0.75	1.34	0.65	0.83	0.0001	-38	62
2.	Base of antenna	4	1.12	1.16	0.98	0.83	0.0003	-36	23

Table 2

Conclusion

Analyzing results of practical measurements performed in limited number of locations, the field strength and power density levels from GSM 900 MHz base station antenna never exceed the reference levels as per ICNIRP guidelines.

We can conclude that even in peak-time of usage, in different sites, different heights from ground level, indoors and outdoors, with and without usage of few mobile phones, in the vicinity of base station antennas, measured field strength and power density levels were well below safety guidelines. Moreover, numerical predicted SAR values are satisfying basic restrictions as well. At the end we should mention that currently there are few ongoing studies for non-thermal effects during human exposure to GSM electromagnetic fields!

References:

[1] Dragan Poljak, Niksa Kovac A Simplified Electromagnetic-thermal Analysis of Human Exposure to Radiation from Base Station Antennas, *Automatika 45(2004*), 1-2, 11-17

[2] Dariusz Wojcik, Tomasz Topa and Krzysztof Szczepanski, Absorption of EM energy by human body in the vicinity of GSM base station antenna *2005 Journal of telecommunications and information technology*, pg34-38

[3] Laurent Nicolas, Interactions between Electromagnetic Fields and Biological tissues

[4] J.Klima, R.Scehovic, The field strength measurement and SAR experience related to human exposure in 110 MHz to 40 GHz, *MEASUREMENT SCIENCE REVIEW, Volume 6, Section 2, No.4, 2006*

[5] S. Miclaus, P. Bechet, Estimated and measured values of the radiofrequency radiation power density around cellular base stations, *Rom.Journ.Phys, Vol.52, Nos.3-4 P.399-409. Bucharest, 2007*

[6] Andre Vander Vorst, Arye Rosen and Youji Kotsuka, *RF/Microwave Interaction with Biological Tissues*, 2006 by John Willey & Sons, Inc. pg 7-50

[7] *ARRL Handbook for Radio Amateurs*, 1996 American Radio Relay League, Inc. Chapter 9

[8] www.arpansa.gov.au

[9] ICNIRP "Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields up to 300 GHz, *Health Physics 74*, pg 494-528,1998

[10] www.land-sbg.gv.at/celltower

[11] Vesna Hrvoje, Wire Antenna Theory Applied ti the Assessment of the Radiation Hazard in the Vicinity of the GSM Base Station, *Serbian Journal of Electrical Engineering*, Vol.1, No.1, November 2003, 15-26

[12] Dragan Poljak, *Human Exposure to Electromagnetic Fields*, Witt Press 2003

[13] Outi Kivekas, Tuuka Lehtiniemi, Pertti Vainiakainen; On the general energy-absorption mechanism in the human tissues, *Microwave and Optical Technology Letters* / Vol.43,No.3,November 5 2004

[14] IEEE C95.1-1991 Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, kHz to 300 GHz, Standards Coordinating Committees

[15] M.Ibrani,L.Ahma,E.Hamiti and R.Sefa, Exposure assessment in the vicinity of 900 Mhz GSM base station antenna, *Proceedings of 11th WSEAS Conference on Communications*, Crete.