Electromagnetic radiation on GSM base station antenna Human exposure & reference levels

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Abstract: This paper tests the radiation compliance of a GSM base station antenna located in a rural area in Greece. The installation in consisted of a single antenna mast and is build on a hill. In this paper there will be an analysis of the actual measurements taken on that site, as well as theoretical references regarding the calculations of the electromagnetic field. We will also review the RF safety reference levels adopted by the Greek national law and compare those levels with the actual measurements. By doing that we will clearly deduce that the measurements taken were well bellow the given standards.

Key-words: Electromagnetic radiation, Electromagnetic emissions, RF safety measurements, radiation exposure limits.

1. Introduction

The GSM antenna in question is located east of Athens in the island of Evia. The nearest village named Lepoura is located in approximately 800 m distance. The scope of this study is to measure the electromagnetic emissions of that antenna and clearly clarify that the radiation levels are below the limits set by the national law and thus below the limits set by the European community.

Communication via cellular phones was introduced to Greece in the early 90's and as the technology on that field was rapidly expanding and evolving, in the same pace cell phones acceptance was increasing by the Greek public. We now have reached a point were, according to the statistics, for every Greek citizen corresponds 1.5 cell phones. That wide acceptance though was the main reason that led to the increase of the antennas used to cover the needs of that public and that also was the reason to establish strict safety regulations regarding the emissions of those antennas [1-4].

2. Theoretical prediction methods

In the process of measuring the human exposure to RF fields' factors that should be taken into account in assessing the potential for exposure are: main beam orientation, antenna height above ground, location relative to where people leave or work and factors such as feeding power and the operating frequency [1], [4].

2.1 Power density

Power density at the antenna aperture can be approximated by the following equations:

In general:

$$S = \frac{PG}{4\pi R^2}$$

Where: S = power density (in appropriate units, e.g. mW/cm2)
P = power input to the antenna (in appropriate units, e.g., mW)
G = power gain of the antenna in the direction of interest relative to an isotropic radiator
R = distance to the center of radiation of the antenna (appropriate units, e.g., cm)

In the case of aperture antennas a better theoretical estimation of the power density can be determined by using the equation showed below:

$$S_{surface} = \frac{4P}{A}$$

Where: $S_{surface}$ = maximum power density at the antenna surface
P = power fed to the antenna
A = $\pi*(D/2)^2$ physical area of the aperture antenna and D is the antenna diameter

2.2 Near field region

In the near field region of the antenna the energy is largely confined within a cylinder pattern of diameter D. The power density in that region can reach a maximum before it begins to decrease with distance and the extent of the near field can be theoretically calculated by using the following equation:

$$R_{nf} = \frac{D^2}{4\lambda}$$

Where: Rnf = extent of near-field
D = maximum dimension of antenna (diameter if circular)
λ = wavelength

The corresponded maximum value of the power density is given by the following equation:

$$S_{nf} = \frac{16\eta P}{\pi D^2}$$

Where: S_{nf} = maximum near-field power density
η = aperture efficiency, typically 0.5-0.75
P = power fed to the antenna
D = antenna diameter

2.3 Transition region

The transition region extents from the end of the near field R_{nf} and it goes up to the beginning of the far field R_{ff}. Power density in the transition region decreases inversely with distance from the antenna. To calculate the distance of the transition region we can use the following equation:

$$R_{ff} = \frac{0.6D^2}{\lambda}$$

Where: R_{ff} = distance to beginning of far-field
D = antenna diameter
λ = wavelength

The power density can be given by the following equation:

$$S_t = \frac{S_{nf}\, R_{nf}}{R}$$

Where: S_t = power density in the transition region
S_{nf} = maximum power density for near-field calculated above
R_{nf} = extent of near-field calculated above
R = distance to point of interest

2.4 Far field region

The far-field region extents for distances R > R_{ff}. The power density in the far-field region of the antenna pattern decreases inversely as the square of the distance. The power density in the far-field region of the radiation pattern can be estimated by the general equation discussed earlier:

$$S_{ff} = \frac{PG}{4\pi R^2}$$

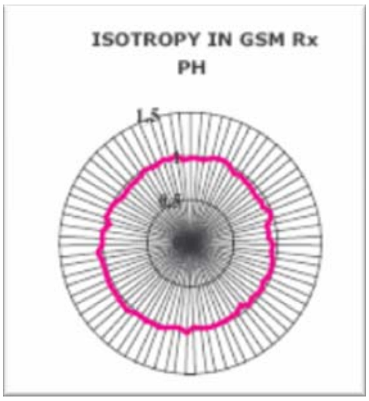
Where: S_{ff} = power density (on axis)
P = power fed to the antenna
G = power gain of the antenna in the direction of interest relative to an isotropic radiator
R = distance to the point of interest

3. Measurement campaign

During the experimental campaign, electric field strength measurements were recorded from various distances in order to completely cover the near and far field regions and by doing that better assess the RF radiation emitted by the antenna in question.

3.1 Instrument basic characteristics

Personal exposure meter	
Manufacturer	Antennessa
Model	EME SPY 120
Frequency range	88 MHz – 2.5 GHz



Main characteristics		
Frequency range		**Axial isotropy**
FM	88 MHz → 108 MHz	± 0.3 dB
TV3	174 MHz→ 223 MHz	± 2.5 dB
TETRA	380 MHz → 400 MHz	± 1.1 dB
TV4&5	470 MHz → 830 MHz	± 1.1 dB
GSM Tx	880 MHz → 915 MHz	± 0.8 dB
GSM Rx	925 MHz → 960 MHz	± 1.0 dB
DCS Tx	1710 MHz → 1785 MHz	± 2.0 dB
DCS Rx	1805 MHz→ 1880 MHz	± 1.6 dB
DECT	1880 MHz → 1900 MHz	± 1.3 dB
UMTS Tx	1920 MHz → 1980 MHz	± 1.4 dB
UMTS Rx	2110 MHz → 2170 MHz	± 1.8 dB
WIFI	2400 MHz → 2500 MHz	± 3.2 dB

Probe	Built in tree axis E probe
Lower detection limit	0.05 V/m
Upper detection limit	5 V/m

Data	Number of	7168 (max)

Recording G	samples	
	Recording Period	4s – 255s
	Duration of the recording	>7 hours with a rate of 1 sample per 4 seconds
Temperature, humidity		-10 to 50°C 85% humidity
Battery autonomy		>7 days (120sec period)
Link		USB

Technical characteristics	
Dimensions	193 x 95.6 x 69.4 mm (L,W,H)
Weight	450g
Protection	IP 43

3.2 Results

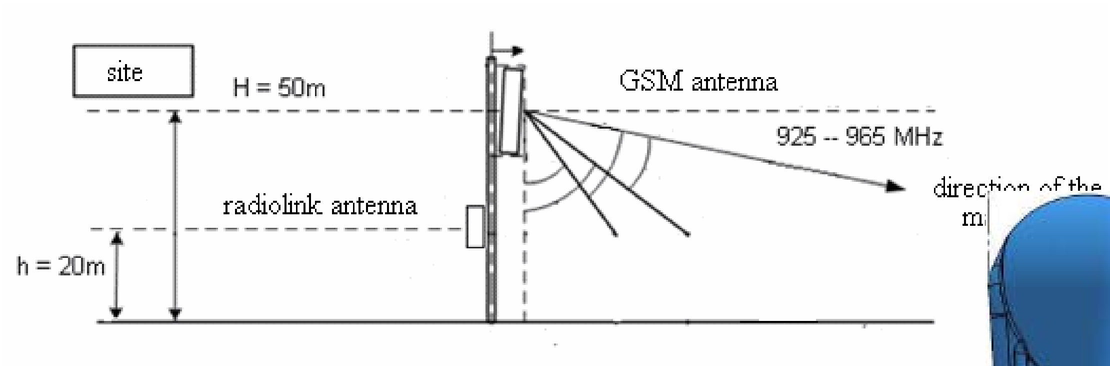
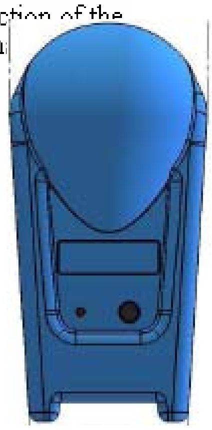


figure 1: Graphical representation of the GSM antenna.



For the first set of measurements we will examine the RF field of the main lobe in various distances.

Table 1: Electric field strength values under the main lobe's radiation

Distance from base station	Average Electric field strength Eav V/m	Maximum Electric field strength Emax V/m	Average Electric field strength in total V/m	Safety reference according to national law [4]
2m	0.19	0.22	0.13	GSM

40m	0.16	0.24		34,9 V/m
80m	0.10	0.22		

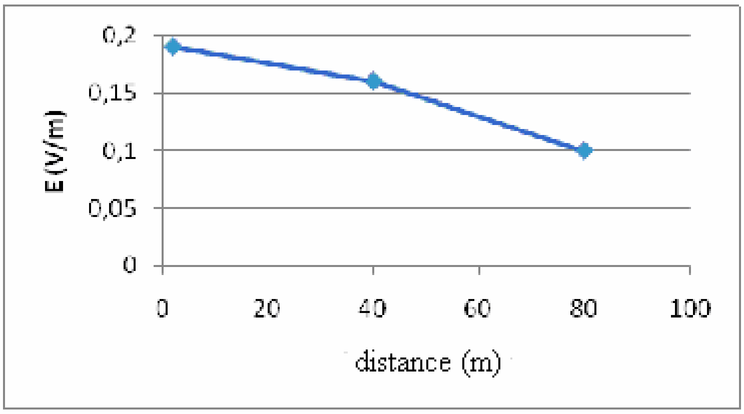


figure 2: Electric field strength vs distance

For the second set of measurements we will examine the RF radiation levels on the left and right side of the main lobe.

Table 2: Electric field strength on the left side of the main lobe

Left side of the main lobe			
Distance from base station	Average Electric field strength Eav V/m	Maximum Electric field strength Emax V/m	Safety reference according to national law [4]
15m	0.18	0.25	GSM 34.9 V/m
30m	0.20	0.30	
Fire observatory, 32m+3m height	0.27	0.46	
Inside the observatory	0.21	0.24	

Table 3: Electric field strength on the right side of the main lobe

Right side of the main lobe			
Distance from base station	Average Electric field strength Eav V/m	Maximum Electric field strength Emax V/m	Safety reference according to national law [4]
15m	0.09	0.16	GSM 34.9 V/m
30m	0.12	0.39	
62m (church)	0.11	0.17	

4. Conclusions

4.1. Conclusions regarding the results.

After seeing the results taken by the exposure meter we can deduce that the radiation emitted by the antenna in question is far below the safety reference level provided by the Greek legislation. In fact in some cases it can be 200 times lower than the safety reference.

The fact that the total Electric field strength on the left side of the lobe was slightly increased compared to the radiation of the main lobe was due to interferences created by the radio link antenna that couldn't be measured by the specific instrument. The frequency of the radio link antenna is about 20 GHz.

4.2 General conclusions

This research clearly showed that the above base station antenna was well below the given limits. That though, doesn't mean that every base station antenna follows the same practice (despite the fact that it should). In any case for the installations of antennas like that or similar to that and in order for the citizens not only to feel but to actually be protected the providers should follow the rules given below.

1. Justification: The provider must be able to prove that the local society will be benefited by the specific installation.

2. Delimitation: There has to be some limits in the installation and use of such antennas. That shouldn't necessarily mean that those limits should be set according to sanitary or environmental rules.

3. Optimization: The installation must achieve its goal but at the same time it must cause the least amount of trouble to the environment and to public health.

In conclusion it would be good to mention that even though the national law has adopted reference levels that are below the ones chosen by the European community there aren't any references regarding occupational exposure limits and also there aren't any references regarding the acceptable time period one can be exposed to such RF fields.

References

[1]. Federal Communications Commission Office of Engineering & Technology: "*Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Fields" – OET Bulletin 65 Edition 97 – 01.*

[2]. European Union Council (1999/519/EC): "*Council Recommendation of 12 July 1999 on the limitations of exposure of the general public to electromagnetic fields (0Hz to 300GHz)."*

[3]. International Commission on Non – Ionizing Radiation Protection (ICNIRP): "*Guide lines for limiting exposure to time – varying electric, magnetic and electromagnetic fields (up to 300GHz)."*

[4]. Greek Atomic Energy Commission (GAEC)