

Calculations of Radiation Safety Distance for GSM, DCS, and UMTS Macrocell Mobile Base Station

(on site measurements)

Ibraheem M. Fayed, Eman S. El-Din

Abstract— Wireless mobile communication networks have become essential for human life. A great booming and huge investments are devoted to develop the services without taking into considerations the health effect of electromagnetic radiations of the base stations concerning with these services. Base stations for wireless mobile communication have brought Electromagnetic Field (EMF) sources to the permanent residences of people. A global increase in the level of electromagnetic background has taken place leading to its continuing presence in the environment. Cellular mobile radio communications have developed rapidly in Egypt and are one of the most actively growing sectors of the national economy. Many studies were made in this field and they did not prove that there is no effect for the EMF radiated from the mobile base stations. So, in this paper a procedure will be proposed to calculate the safety distance that the human beings can exposure from macro-cell of mobile base station. An on field measurement has been done to confirm this safety distance.

Keywords— Electromagnetic Field Radiation; EMF exposure; Exposure Limit; SAR.

I. INTRODUCTION

The EMF radiated from mobile base station is too small to break the bonds between molecules in human cells and, therefore, cannot produce ionization unlike the ionizing radiation (such as cosmic rays and X-rays). So EMF of mobile base station is called 'non-ionizing radiations' (NIR). Figure (1) shows the relative position of NIR in the wider electromagnetic spectrum [1]. Many medical scientific researches are made to study the EMF effects from mobile base station. Exposure to EMF has an impact on human tissues and cell development, experts do not agree on how much exposure may lead to health risks for adults or children and some research results seem to contradict previous results [2],[3]. The exposure interval time is an important factor that must be considered with a small amount of EMF radiation from mobile base station. The effect of long term exposure to base stations and mobile phones on human health has been studied in [3]. In [4] a survey for 82 students was done. 12 students identified with specific health hazards in a questionnaire of 25 questions with different parameters of the daily usage and identified disease during the period of past one year.

The authors are with the Network Planning Department
National Telecommunication Institute (NTI)
Cairo, Egypt. Fayed.ibrahim@gmail.com, emanserag@gmail.com

The conclusion is shown in table (1). While the Deoxyribonucleic acid (DNA) and the effects of EMR was studied in several work as mentioned in [2]. The International Bodies, Governmental and Private Organizations for Limiting Exposure to Electromagnetic fields (up to 300 GHz) are listed as follow:

- The International Radiation Protection Association (IRPA) In 1974.
- International Non-Ionizing Radiation Committee (INIRC) in 1977
- The Environmental Health Division of the World Health Organization (WHO).
- International Commission on Non-Ionizing Radiation Protection (ICNIRP) is an independent scientific organization on May 1992.
- The Federal Communications Commission (FCC) in United States of America (US).
- Several countries all over the world established their governmental bodies to regulate the usage of wire and wireless communications (National Telecommunications Regularity Association) NTRA and get the responsibility to introduce a code for limiting the exposure of human beings to electromagnetic fields.
- More details for these organizations are shown in [5]

After the previous introduction about the biomedical hazard due to the exposure to EMR, standard exposure limits was done by WHO and ICNIRP as an International Organizations. The telecommunications and health regularities in different countries use these standards to eliminate EMR effects on human beings.

S. No.	No of years used	No of calls made	No of calls received	Diseases Identified
1	3	3/day	10/day	Ear Problem
2	2	166	176	Fever, Drozziness
3	2	300	--	C, Fever
4	1	--	9678	Ear Problem
5	2	2/day	2/day	Headache, Fever
6	2	400	800	Ear Problem

7	5	15000	20000	Headache, Teeth Problem
8	5	500	1000	Ear Problem
9	4	10000	20000	Headache
10	2	1000	2000	Ear Problem
11	3	15/day	5/day	Headache, Sleeping disturbance
12	2	10/day	7/day	DIP

II. STANDARD EXPOSURE LIMITS

The quantity of EMF doses absorbed by the human body is an important factor and is measured in units called the specific absorption rate (SAR) or gray [6]

$$SAR = c\Delta T/\Delta t \quad (1)$$

$$SAR = \sigma E^2/\rho \quad (2)$$

where ΔT is the temperature rise (in °C) within the time interval Δt (in seconds), and c is the tissue (or phantom material) specific heat capacity in J/Kg°C, σ is the tissue conductivity (S/m), E is the rms electric field strength induced in the tissue (V/m) and ρ is the mass density (kg/m³).

Doses of more than 400g SAR can severely damage the human vascular system, which can lead to death within 48 hours. Whole-body doses between 10-40g SAR causes less vascular damage, but they lead to loss of fluids and electrolytes in the intercellular spaces, death occurs within ten days due to imbalance of fluid and electrolytes[6], [7].

Absorbed doses from 1.5-10g SAR cause destruction of human bone marrows leading to infections and death within 4-5 weeks after exposure. Radio sensitivity of the body has to do with allergy of our body systems on exposure to EMF waves. That is to say two persons of the same body weight can be exposed to the same amount of radiation and yet respond differently in terms of health effects [6], [7]. For mobile base stations, the ICNIRP recommends that the general public exposure should be limited to 2 W/kg in any 10g for the head and body, 4 W/kg in any 10g for limbs and in addition 0.08 W/kg for the whole body and all of these subject to an averaging period of 6 minutes [8].

III. THE EMF UNCERTAINTY PROBLEM

The EMF uncertainty problem means that there is no certainty relation between EMF and human being health, the certainty ratio must be more than 95%. More information about the uncertainty problem exists in [9]. A comparative study in 5 countries (France, UK, Spain, Belgium and Switzerland) was done by Olivier Borraz and Danielle Salomon in Workshop on base stations and wireless networks organized by World Health Organization (WHO) in 2005. France, UK and Spain adhere to the ICNIRP guidelines however Belgium and Switzerland not.

Another comparison study between Australia and New Zealand Government Responses in WHO 16th Seminar in

Geneva by David Black MBChB FAFOM MARPS June 2005 and he saw that:

- Strict compliance required in Australia
- Good practice required in New Zealand

Still some legal challenges in Australia, but less Environment Court Cases in New Zealand now rarely reach Court.

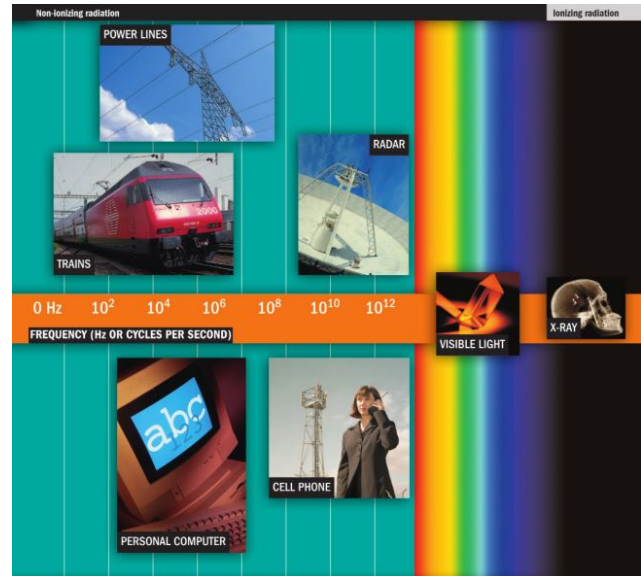


Fig. 1. The electromagnetic spectrum [1].

Many countries had taken some actions to eliminate the exposure to EMF depending on the recommendations of international authorities, such as the WHO, the ICNIRP and ITU. Some of them make their own protocol to control the establishment of the mobile base stations other was contented with define the exposure limit like in Italy, the government defined three level for radiation Exposure limit less than 60 V/m, Attention level equal to 6 V/m and the Quality goal is 6 V/m [10].

Russia established its own protocol by define the Obligatory maximum permissible levels (MPL) near BS in Russia are contained in the Sanitary-epidemiological norms and regulations SanPiN 2.1.8/2.2.4.1190-03 "Hygienic requirements for installation and operation of terrestrial mobile radio communication equipment". This norm was issued by the Ministry of health of Russia in 2003. For BS operating in UHF range (300-3000 MHz), the norm limits the MPL of equivalent plane wave power density to 10 μ W/cm² under non-occupational exposure conditions. This MPL for public exposure was introduced in 1984 for the first time.

Providing electromagnetic safety for the population around BSs is under state control and has a multi-stage character [11].

1. Before any BS installation is permitted a calculation of the EMF intensity in the surrounding territory is made.

2. On the basis of the calculation results the operator obtains the permission for BS installation

3. After completion of the BS installation EMF intensity measurements are carried out. Measurement results are submitted to the territory authority of the Federal service who issues permission to allow BS operation.

4. Periodic checks are carried out once every 1–3 years.

How can the safety distance from the source of radiation be calculated? The answer will be introduced in the next section.

IV. SAFETY DISTANCE CALCULATIONS FOR MACROCELL

From the infield sites, the maximum power sent from transmission unit to the antenna is 50 Watt (for one directive antenna). Suppose we have four antennas serve four sectors, they may be represented by one Isotropic radiation source with input power equal to 200 Watt which equivalent to 53dBm. Due to cable losses (3dBm) and combiners losses (6dBm).The maximum input power to the antenna = $53-9 = 44$ dBm

For the directive antenna that used in mobile base station for macrocell; it has gain between 16 dB and 17 dB (high gain antenna) in the main beam direction and decreases about 20 dB in the back loop direction.

THE Effective Isotropic Radiated Power (EIRP) from the radiated source is equal to:

$$(EIRP) = \text{Max. Power} + \text{Ant. gain} \\ = 44 + 16 = 60 \text{ dBm}$$

$$EIRP (\text{main}) \cong 60 \text{ dBm} \cong 1000 \text{ Watt}$$

The power spectral density can be calculated from [12],

$$\text{Standard Isotropic Power Density (SIPD)} = \frac{EIRP}{4\pi D^2} \quad (3)$$

Where D is the distance from the radiation source.

If we consider the safety limit for United States of America which equal to 0.57 mW/cm^2 so;

$$D_{\text{main}} = \sqrt{\frac{EIRP}{4\pi \times (0.57)}} = 3.74 \text{ m} \quad (4)$$

For the ICNIRP exposure level which equal to 0.4 mW/Cm^2

$$D_{\text{main}} = \sqrt{\frac{EIRP}{4\pi \times (0.4)}} = 4.46 \text{ m} \quad (5)$$

Considering the directivity of the source (antenna) and human behavior, the safety distance may be considered equal to 6 meter in the direction of the main field.

V. ON SITE MEASUREMENTS

The on field measurements had been done for 3 directive antennas fixed on a pole on a roof top serve 3 sectors. Each antenna height from the roof top is 6 meters so the

measurements taken were in the distance of 6 meter. Figure (2) shows the site description.

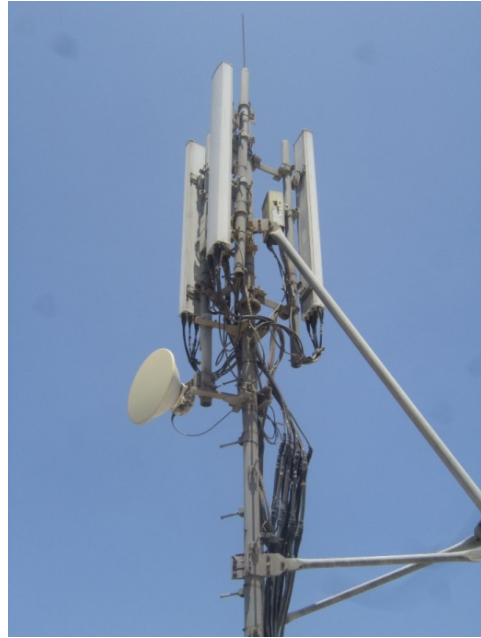


Fig. 2. Site description

The measurements were done using calibrated EME Spy measurement device. EME Spy information is shown in figure (3). The measurements were taken in three positions in the direction of the main beam of each antenna on the surface of the roof top.

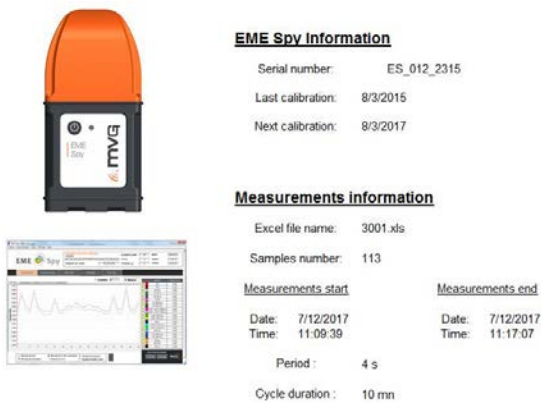


Fig. 3. EME Spy measurement device information

The measurements results is shown in figure (4)

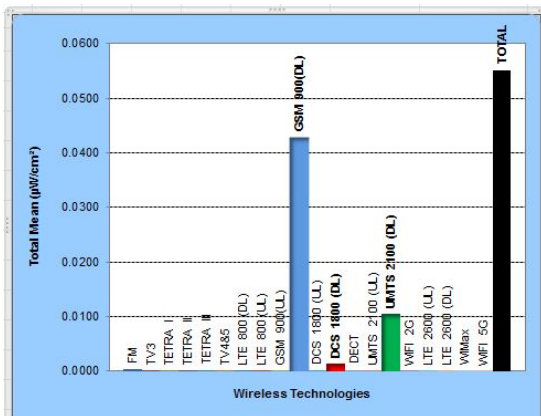


Fig. 4. The total power spectral density measured by EME Spy device

From figure 4, a detailed power spectral density for each mobile wireless technology is shown. It is notice that the total power spectral density for all mobile wireless technologies equals $0.055\mu\text{W}/\text{cm}^2$ that's below the ICNIRP exposure level which equal to $0.4\text{mW}/\text{cm}^2$. That is mean the 6 meters distance from the mobile base station antenna is a safe distance for RF exposure.

A detailed power spectral density curve for each wireless mobile technology (GSM900, DCS1800, and UMTS2100) is illustrated in figure 5, 6, and 7. These curves ensure that the site under measurement was working properly and the main radiated power from the GSM900.

Comparing the measurements results with results in [13] that Compares power density radiated from GSM base station at certain time (6:00 AM) and (11:30 AM rush hour) it is found that, the measurements results agree with the its measurements results. In [13], the power spectral density at 6.00 Am equals to $4.5\mu\text{W}/\text{cm}^2$, at 11.00 AM the power spectral density equals to $17\mu\text{W}/\text{cm}^2$, and the power spectral density due to the maximum traffic equals $25\mu\text{W}/\text{cm}^2$. All these calculations are done at horizontal distance 10 meters from the base station. As shown in figure (5) the average maximum value of GSM power spectral density equals $0.55\mu\text{W}/\text{cm}^2$ which is comparable with [13].

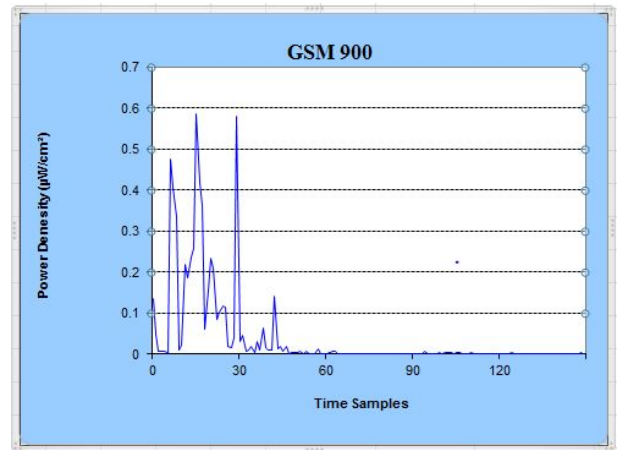


Fig. 5. The power spectral density for GSM900

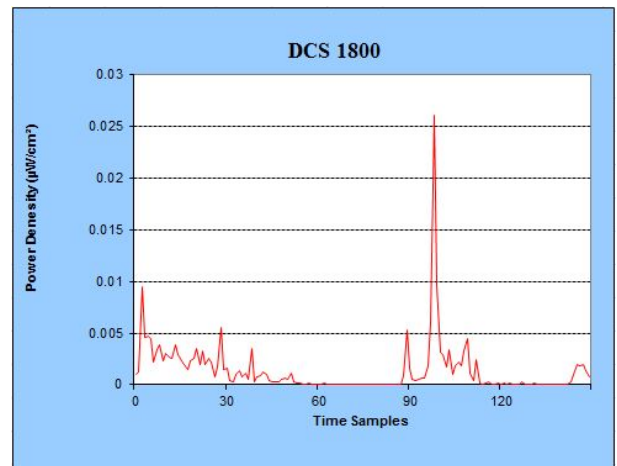


Fig. 6. The power spectral density for DCS1800

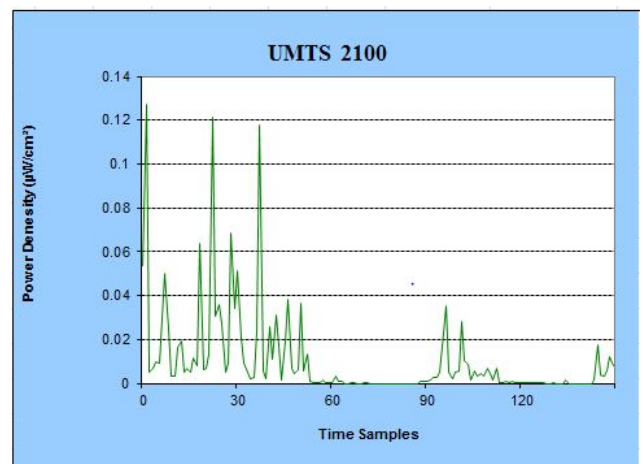


Fig. 7. The power spectral density for UMTS2100

VI. CONCLUSION, RECOMMENDATIONS AND FUTURE WORK

There is no confirmation that the electromagnetic radiation from mobile base station has no effect on human beings and the EMF uncertainty problem still exists. So, it is required to make some precautions to ensure that the human beings exposure to EMF for a long time period will be safe.

According to the previous calculations that is agree with the ITU recommendations [14] shown in figure 4 it's recommended that:

- The nearest distance allowable for human beings from the radiation source is 6 meters.
- Periodical measurements for power spectral density radiated from mobile base stations for a long term exposure to ensure that it not exceed the ICNIRP defined threshold.

An analytical model will be assigned as a future work to represent the power spectral density for power radiated from mobile base station depending on the base station technical specifications and the distance away from the directive antennas that are the major used in macro cells of mobile base stations.

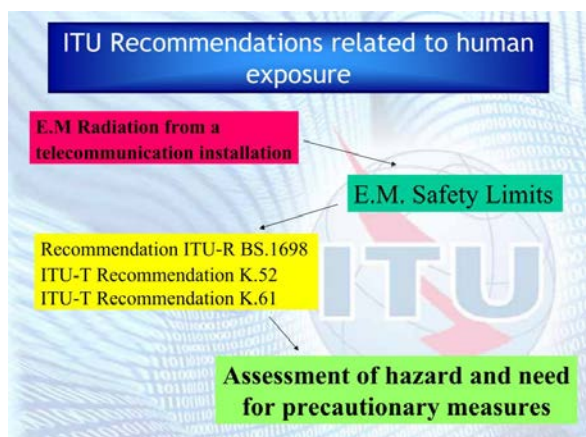


Fig. 1. The ITU recommendation to eliminate the EMR effect on human beings. [14]

References

- [1] "Establishing a dialogue on risks from electromagnetic fields", Radiation and Environmental Health department of protection of the human environment World Health Organization Geneva, Switzerland, 2002.
- [2] Claudia Roda, and Susan Perry, "Mobile phone infrastructure regulation in Europe: Scientific challenges and human rights protection," *Environmental science policy* 37, Science Direct and Elsevier, 2014, pp: 204-214.
- [3] Emad F. Eskander, Selim F. Estefan, and Ahmed A. Abd-Rabou, "How does long term exposure to base stations and mobile phones affect human hormone profiles?," *Case Report, Sci Verse, Science Direct, Elsevier, Clinical Biochemistry* 45, 2012, pp: 157-161 12
- [4] R.Seetharaman,G.S.Uthayakumar,N.Gurusamy and N.Kumaravel," Mobile Phone Usage and Cancer," 10th International Conference on Electromagnetic Interference & Compatibility, Bangalore, IEEE, 2008.pp: 627 – 632.
- [5] Ibraheem M. Fayed, Mouldi Bedda, "Electromagnetic Radiation Effects on Human Beings: Survey, Modeling, and Environmental Recommendations", *Canadian International Journal of Science and Technology*, Volume 1, January 2015, (CRCHS), ISSN 2356-9085 pp 163:175.
- [6] Boniface O. Anyaka, and Udochukwu B. Akuru, "Electromagnetic Wave Effect on Human Health: Challenges for Developing Countries", *International Conference on Cyber-Enabled Distributed Computing and Knowledge Discover*, IEEE Computer Society, 2012
- [7] Dragan Poljak, Andres Peratta, and Carlos A. Brebbia, " The boundary element electromagnetic-thermal analysis of human exposure to base station antennas radiation," *Engineering Analysis with Boundary Elements* 28, Elsevier, 2004,pp: 763–770.
- [8] Sven Kühn, Axel Kramer, Urs Lott, and Niels Kuster, "Assessment of Human Exposure to Electromagnetic Radiation from Wireless Devices in Home and Office Environments," *Proceedings International Workshop on Base Stations and Wireless Networks: Exposures and Health Consequences Switzerland, Geneva, June 15-16, 2005.*
- [9] Lisbet Berg, Dag Slettemeås and Harald Throne-Holst," The EMF uncertainty problem related to mobile phones: where do consumers place their trust?" *International Journal of Consumer Studies* 34, 2010, pp:121–132.
- [10] Paolo Vecchia," *Government Responses In ITALY*," *Workshop on Base Stations and Wireless Networks*, National Institute of Health, Geneva, 15-16 June 2005.
- [11] Yury Grigoriev, Oleg Grigorev, and Anton Merkulov," *Mobile Radio Communication Base Stations And Safety Of The Population: General Situation In RUSSIA*," *Russian National Committee on Non-Ionizing Radiation, WHO Workshop on Base Stations and Wireless Networks. June 15–17, 2005.*
- [12] Public Safety Tech. Topic #17 FCC.gov. [Online]. Available: <http://www.fcc.gov/print/node/34806>.
- [13] Qing Qing He, Wan Chun Yang, and Yan Xia Hu, "Accurate Method to Estimate EM Radiation from a GSM Base Station", *Progress In Electromagnetics Research M*, Vol. 34, 19{27, 2014, pp:19–27.

- [14] Kevin Hughes, "International Standardization of Wireless Technologies and EMF" , Radio-communication Bureau, ITU, 2013 .