Performance Study of the Radio Frequency Radiation Power Density of Mobile Base Station

Layla Mahdi Salih

College of Engineering,University of Kirkuk, Kirkuk, Iraq

ABSTRACT

Since 2003 the number of mobile phone subscribers extraordinary increased in Iraq. All over the world there is a tremendously growing in cellular communication systems resulted in increasing the number of mobile phones and mobile base stations. This distribution of mobile base stations in dense populated areas, near schools and hospitals has raised the public concern about possible health hazards. The ministry of environment/ Iraq in 2010 has set guidelines to perform measurements of the electromagnetic fields radiated from base stations used in mobile phone networks.
In this study the electromagnetic power density radiated from mobile base station (downlink) and mobile phones to base station (uplink) were measured by TEMS software. This tool simplifies the prediction and measurement of electromagnetic power density. The measurements were conducted within 300 meters from the mast of the major GSM service provider in Kirkuk city. The obtained data were analyzed for uplink and downlink. The measured values then were compared with the antenna prediction pattern and with the employed safety guidelines to ensure compliance with these limits. All the measured values were within the limits.

Keywords: Electromagnetic Radiation (EMR), GSM system, mobile base station, non-ionizing radiation, TEMS software.

1. INTRODUCTION

Many natural and man-made sources emit electromagnetic radiation (EMR) which is a fundamental aspect of the life. The EMR from the sun warms us and our eyes detect the visible portion of the EM spectrum. The frequencies (3kHz-300 GHz) of the EM spectrum is known as radio frequency [1].The EM waves with different frequencies are shown in Fig.(1). Each portion of these frequencies has its own name, properties and characteristics. The ionizing and non-ionizing radiation (IR and NIR) are two classes of EMR. In IR class, the radiation has the satisfactory energy to remove the bound electrons from an atom. These ionized atoms may cause health hazard. While in NIR class the EMR does not has enough energy to ionize the atoms [2]. The main and important media to carry signals to their desired destination from a certain source are the electromagnetic fields and waves; these signals can be data, voice or image. In free space these waves are propagating at speed of light ($3x10^8$ m/s)[3].

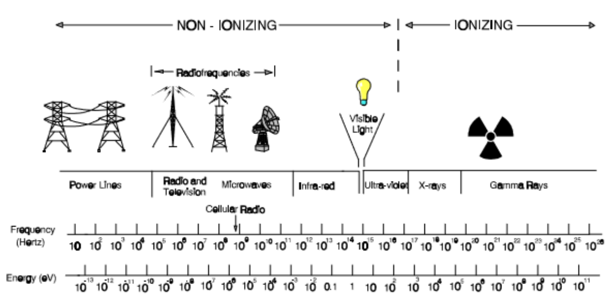


Fig.(1) The electromagnetic spectrum

Our bodies are always exposed to EMR. We are surrounded by the electrical devices such as: fans, washing machines, microwave ovens, mobile phones and telecommunication base stations ….. etc.[4]. An integral part of the modern society is the mobile or cellular phone. In many countries, mobile phones are used by more than half of the population and mobile phone market is rapidly growing. Mobile phones are the only phones available or the most reliable in some parts of our world[5].

As the number of the electromagnetic equipment started to be used increasingly in work places in the seventies of the last century, the impact of the emissions from these equipments on human health received bigger attention. Public debates, worries and concerns about the likelihood of adverse health consequences as a result from the exposure to RF fields emitted from mobile telephony components also have increased [6]. To avoid any probable health hazards from the short/ long term exposure to EMR, many guidelines and limits have been issued by several international organizations. The Electrical and Electronic Engineers Institute (IEEE) [7], Federal Communications Commission (FCC) [8], National Radiological Protection Board(NRPB) [9], International committee on Non-Ionizing Radiation Protection (ICNIRP) [10], and the Australian Radian Protection and Nuclear Safety Agency (ARPNSA)[11] are examples of these organizations.
Random siting of antennas and telecommunication masts near residential and official quarters, the daily exposure to the radiation of this electromagnetic environment raises public concern. Particularly the possibility of health hazards from the exposure to EM energy emitted from the antennas of cellular system. This is because of the fact that the mobile telecommunications uses the microwave range of the EM spectrum. The EM fields of different frequencies and power levels penetrate human body. Lack in public information, absence of directives with suitable policy for installation of cell towers, monitoring, effective execution and control at all levels by governmental entities, and the lack of clear nationally and internationally accredited procedures to grant permits to the installations of RF antennas have contributed in the public fear that the exposure to the emissions of RF EM fields could be harmful[12-13]

1.2- THECELLULAR SYSTEM:

Installation of a tremendousnumber of base stations is required as a result of the ongoing growth in the demand of cellular communication services. More than 65% of the exposure to RF radiation has been accounted from wireless communication technologies, with the dominant contributor of mobile phones[14].
Because of the limited number of frequency bands, there are only a relatively small number of channels available for speech in mobile radio network. As an example is the 900 GSM system with allocation of 25 MHz (890-915)MHz bandwidth for uplink and the (935-960)MHz band for downlink. This amounts to maximum of 125 channels each having a bandwidth of 200 kHz. Within the Time Division Multiple Access (TDM) technique an eightfold for each carrier, a maximum

number of 1000 channels can be reached. But this number is reduced by guard bands. To enable millions of subscribers to be served, the channels must be spatially reused in a geographic area. This concept of reuse of spatial frequency led to the improvement of cellular technology. Table 1 shows GSM frequency spectrum

Table 1. GSM frequency spectrum

GSM band	**Uplink (MHz)**	**Downlink(MHz)**
900	890-915	935-960
1800	1710-1785	1805-1880
1900	1850-1910	1930-1990

This channel spacing for the most widely frequency bands devoted to the operation of GSM systems yields a different number of carrier frequencies for each band. The GSM 900 band has total of 124 carrier frequencies while the GSM 1800 band has total of 374 carrier frequencies. The channels for each band have absolute radio frequency channel numbers (ARFCNs) associated with them and for GSM 900 they are numbered as (1-124), for GSM 1800 numbered as (1710-1785) [15-16].

1.3- THE ELECTROMAGNETIC RADIATION AND THE INTERNATIONAL STANDARDS

The hazards on human health from exposure to EMRs are of public concern in locations near television and radio transmitters, wireless networks, mobile base stations and the like. NIR levels resulted from these sources and their possible effects on humans have been the utmost concern to be investigated [17]. When a change in a biological system can be measured after introduction of some stimuli, a biological effect occurs. However, a biological hazard existence does not necessarily suggested if a biological effect been observed. A biological effect can be considered a safety hazard when it results in detectable impairment in the individual health or of his/her offspring. Thermal effects are the biological effects resulted by heating the tissue from RF energy [18].

The main concern of exposure to RF energy started sixty years ago. Several international and national standards, recommendation and regulations for exposure to RF energy were developed for those working with EM field (occupational or conditional exposure) and the general public (public or unconditional exposure). Usually these exposure guidelines are similar and they are based on thresholds of known adverse effects. To protect people from possible health effects for short and long term exposure to RF radiations, safety margin is included in these guidelines. For situations of exposure to EM source at a distance of 20 cm or less, the power absorbed in partial or whole body must be used for comparison with the limits and recommendations. The specific absorption rate (SAR) is a quantity used to measure the rate at which the body absorbs the electromagnetic energy. SAR is expressed in watts/kilogram (W/kg). The recommended maximum permissible exposure (MPE) for power density depends on the value of threshold SAR [2].

The ICNIRP human exposure safety standards for the occupational and general public exposure gives two types of limitations which can be adopted in compliance assessment: basic restriction given in Table 2 that limits the SAR for the frequencies of mobile-communication and reference levels that limit the magnetic field strength **H** and/ or electric field strength **E** and the electromagnetic power density **S** given in Table 3. The details are given in [10].

Table 2. The basic restrictions and SAR adopted by ICNIRP

Exposure charact-eristics	Frequency range	Current density for head and trunk (mA/m^2) (rms)	Whole body average SAR (W/kg)	Localized SAR (head and trunk) (W/kg)	Localized SAR (limbs) (W/kg)
Occupat-ional exposure	Up to 1 Hz	40	-	-	-
	(1-4) Hz	40/f	-	-	-
	(4Hz-1kHz)	10	-	-	-
	(1-100) kHz	f/100	-	-	-
	(0.1-10)MHz	f/100	0.4	10	20
	10MHz-10GHz	-	**0.4**	**10**	**20**
General public exposure	Up to 1 Hz	8	**-**	**-**	**-**
	(1-4) Hz	8/f	**-**	**-**	**-**
	(4Hz-1kHz)	2	**-**	**-**	**-**
	(1-100) kHz	f/500	**-**	**-**	**-**
	(0.1-10)MHz	f/500	0.08	2	4
	10MHz-10GHz	-	**0.08**	**2**	**4**

Note that f is the frequency in hertz and SAR values all are averaged over any period of 6 minutes.

Table 3.The reference levels for MPE adopted by ICNIRP

A) Limits for controlled exposure

Frequency range	E-field strength (V/m)	H-field strength (A/m)	Equivalent plane wave power density S (W/m^2)
Up to 1 Hz	-	1.63×10^5	-
(1-8) Hz	20000	$1.63 \times 10^5/f^2$	-
(8-25) Hz	20000	$2 \times 10^4/f$	-
(0.025-0.82) kHz	500/f	20/f	-
(0.82-65) kHz	610	24.4	-
(0.065-1) MHz	610	1.6/f	-
(1-10) MHz	610/f	1.6/f	-
(10-400) MHz	61	0.16	10
(400-2000) MHz	$3f^{1/2}$	$0.008f^{1/2}$	**f/40**
(2-300) GHz	137	0.36	50

B) Limits for general exposure

Frequency range	E-field strength (V/m)	H-field strength (A/m)	Equivalent plane wave power density S (W/m^2)
Up to 1 Hz	-	3.2×10^4	-
(1-8) Hz	10000	3.2×10^4	-
(8-25) Hz	10000	4000/ f	-
(0.025-0.8) kHz	250/f	4/f	-
(0.8-3) kHz	250/f	5	-
(3-150) kHz	87	5	-
(0.15-1) MHz	87	0.73/f	-
(1-10) MHz	$87/f^{1/2}$	0.73/f	-
(10-400) MHz	28	0.073	2
(400-2000) GHz	$1.375 f^{1/2}$	$0.0037 f^{1/2}$	**f/200**
(2-300) GHz	61	0.16	10

Note that f is the frequency as indicated in the column of frequency range. It is obvious from these limits that the MPE is frequency dependent. Therefore, MPE for both GSM 900 and 1800 will be (4.5 W/m^2)for general public exposure and (22.5 W/m^2) for occupational exposure.

Throughout the world most countries in adopting legislation for EMF exposure do the following: 1) directly/ indirectly / or with certain precautions include the ICNIRP guidelines. 2) develop their own

ISSN 2229-5518

national standard. 3) adopt standard from other countries and 4) issue precautionary environmental guidelines. Most European countries adopted indirectly the ICNIRP guidelines through the European Council and Parliament documents [19].

2. MATERIALS AND METHODS:

The field work on power density measurement has been done using TEMS investigation software. This software is a real-time diagnostic test tool air interface. It is equipped with advanced testing functions, powerful analysis and useful post-processing features. Data is presented either in real time throughout or saved in logfiles for post processing purposes. Information about every individual cell in the dedicated GSM network can be presented by this software. Particularly, drawing cells on maps and displaying them by names in various windows. The scanning is performed either by TEMS mobile station or TEMS scanner (a dedicated frequency scanner mobile). The TEMS mobile is connected to the personal computer by USB connector. When TEMS mobile is scanning it cannot be used as an ordinary GSM mobile (cannot engage in data transfer or voice call). This software has the ability to identify geographically base station locations and the measurement points in terms of longitude and latitude.

The TEMS drive testing mobile was used to observe and record the network performance. The network quality reports of the site were studied. The location and specifications of the antennas of the site are stated in Table 4.

Table4: The site specifications

Longitude	44.373683°
Latitude	35.441903°
Height	23.8 m
GSM 900	3 transmitters
GSM 1800	3 transmitters

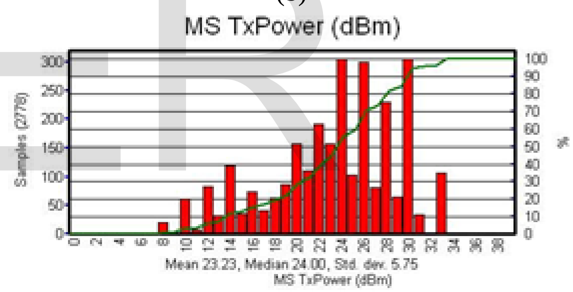
3. RESULTS AND DISCUSSION:

The measurements of EMR are usually done by a broadband meter or a narrowband meter(spectrum analyzer). For the estimation of the total contribution of all RF sources in a designated band, the broadband meter is used, while the spectrum analyzer is used to identify an RF source.

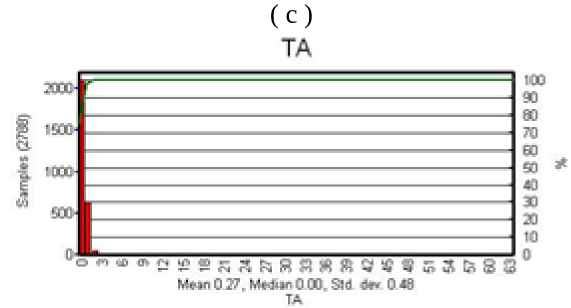
In this study, the TEMS software was used. This software was sensitive to the power density emitted from ASIACELL sites with ARFCNs (80-124) for GSM 900 and (712-774) for GSM 1800. Most of the antennas used by this service provider are Kathrein models. Kathrein antennas are of panel types which divide the entire area around the base station site into three sectors. Figure (3-a) shows the Google map GSM site, figure (3-b) represent coverage prediction of the selected site, for the values (x => -69 dBm) in dense urban (indoor) in red color, for the values (-73 < = x < -69) dBm in urban (indoor) in orange color, for the values (-79 < = x < -73) dBm in suburban (indoor) in yellow color, for the values (-89 < = x < -79) dBm in rural/highway (in car) in green color, and for the values (-95 < = x < -89) dBm in rural/highway (outdoor) in dark blue color, figures (3-c) and (3-d) represent the power density transmitted from (2778) mobile stations to the base station (uplink) for approximately two timing advance (TA) and one TA represent a distance of 550 meters from the foot of the base station, and figure (3-e) shows the received signal strength of the (2778) users around the base station from neighbor cells measured in dBm. Considering the power density shown in Table 3, the power density for both 900 MHz and 1800 MHz should be under (4.5 W/ m^2) and all the measured values are under (4.5 W/ m^2). The results of the electromagnetic power density measurements are demonstrated in Table (4).

(a)

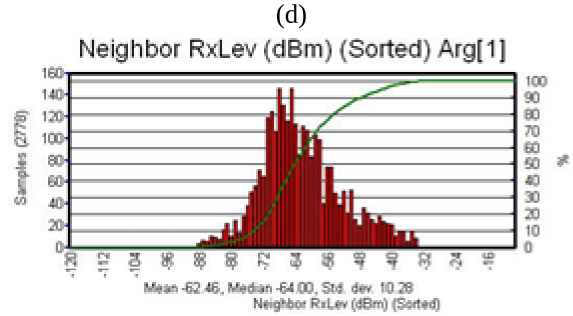

(b)



(c)



(d)



(e)

Figure (3-a) Google map GSM site, figure (3-b) coverage prediction on Google map, figure (3-c) mobile station received power, figure (3-d) timing advance of the site, and figure (3-e) the received power density from neighbor cells.

Table4 : Measured power density

Directionin Degree	Measured Power Density in dBm	Direction in Degree	Measured Power Density in dBm
5	-58	196	-62
14	-66	207	-65
23	-55	211	-59
35	-51	220	-83
44	-53	229	-80
60	-61	233	-83
67	-65	248	-81
74	-61	257	-62
83	-66	261	-70
89	-67	270	-72
98	-77	284	-49
104	-80	289	-46
112	-77	295	-50
118	-59	299	-71
128	-62	307	-78
135	-72	313	-81
147	-71	318	-73
152	-69	330	-79
158	-66	338	-82
164	-72	344	-86
170	-59	350	-73
180	-63	353	-55
187	-56	360	-61

4. CONCLUSIONS

In this study, measurements of the electromagnetic power density have been carried out in different places around a base station inside a dense populated area in Kirkuk-Iraq. The numbers of subscribers who are making calls at same time affect the radiated power from mobile base stations. Therefore, the radiated power varies among the sites; each has its own fluctuations depending on time, place, and season.

In general RF field intensity at any point of measurement will fluctuate with time. This fluctuation is due to fluctuations in propagation losses between the point of measurement and the source, and in the source transmission power.

ACKNOWLEDGEMENT

The researcher would like to thank Mr. Faraidon Abdulla Muhammad Senior NOC Manager, Mr. Harith Zidan Khalaf the RF Planning Engineer Team Leader, and staff members of ASIACELL/ Kirkuk branch for their assistance, valuable information and data collection in their respect fields.

REFERENCES

[1] SC6, " Limits of Human Exposure to Radiofrequency Electromagnetic Energy in the Frequency Range from 3 kHz to 300 GHz", Environmental Health Directorate, Healthy Environments and Consumer Safety Branch, Safety Code 6. Ottawa: Health Canada, 2009.

[2] A. Mousa, "Electromagnetic Radiation Measurements and Safety Issues of some Cellular Base Stations in Nablus", Journal of Engineering Science and Technology Review, Vol. 4, No, 1, pp. 35-42, 2011.

[3] T. S. Rappaport, "Wireless Communications, Principles &Practice", 2nd edition, Prentice Hall, 2002.

[4] F. A. Al-Emam, A. B. Mustafa, and A. I. Mohamed, "The Impact of Electromagnetic Radiations from Mobile Base Stations & Mobile Phones on Human Body", International Journal of Engineering Sciences Paradigms and Researches, Vol. 24 , Issue 01, 2015.

[5] World Health Organization (WHO) Media center, "Electromagnetic fields and public health: mobile phones", Fact sheet No. 193, 2014.

[6] P. Baltrenas and R. Buckus,"Indoor Measurements of the Power Density Close to Mobile Station Antenna", the 8th International Conference on Environmental Engineering, Vilnius, Lithuania, (19-20) May, 2011.

[7] IEEE Standards Coordinating Committee 28 on Non-Ionizing Radiation Hazards, "IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz", IEEE Std. C95.1, 1999.

[8] K. Chan, R. F. Cleveland, and Jr. D. Means, "Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields", Issued by Federal Communications Commission Office of Engineering & Technology, 1997.

[9] S. M. Mann, T. G. Cooper, S. G. Allen, R. P. Blackwell and A. J. Lowe, "Exposure to Radio Waves near Mobile Phone Base Stations", NRPB-R321, pp.1-59, 2000.

[10] International Commission on Non-Ionizing Radiation Protection (ICNIRP), " ICNIRP Guidelines for limiting Exposure to Time-Varying Electric, Magnetic and Electromagnetic Fields (up to 300 GHz)", Journal of Health Physics, Vol.74, No. 4, pp. 494-522, 1998.

[11] P. Iine, W. A. Cornelius, M. J. Bangay and M. Grollo, "Levels of Radiofrequency Radiation from GSM Mobile Telephone Base Stations", Published by Australian Radiation Protection and Nuclear Safety Agency (ARPNSA), Technical Report 129, 2000.

[12] R. K. Singh, "Assessment of Electromagnetic Radiation from Base Station Antenna", Indian Journal of Radio & Space Physics, Vol. 41, pp. 557-565, 2012.

[13] A. D. Asiegbu and O. O. Ogunlaja, "Preliminary Investigation of Exposure Levels from Mobile Telephone Base Stations in Abia, South East Nigeria", International Journal of Current Research, Vol. 11, pp. 47-53, 2010.

[14] E. Hamiti, M. Ibrani, L. Ahma, V. Shala, and R. Halili, "Comparative Analysis of Electromagnetic Field Exposure Levels and Determination of the Minimum Safe Distance from Mobile-Phone Base Stations in Urban Areas", Journal of Progress in Electromagnetics Research M, Vol. 50, pp. 117-128, 2016.

[15] J. Eberspächer, H. Vögel, and C. Bettstetter, "GSM Switching, Services and Protocols", John Wiley & Sons Ltd., 2nd edition, 2001.

[16] G. J. Mullett, "Wireless Telecommunications Systems and Networks", Thomson Delmar Learning, 2006.

[17] M. M. Dawoud, "High Frequency Radiation and Human Exposure", Proceedings of the International Conference on Non-Ionizing Radiation at UNITEN, Electromagnetic Fields and our Health, 2003.

[18] R. F. Cleveland and J. L. Uleck, "Questions and Answers about Biological Effects and Potential Hazards of Radiofrequency Electromagnetic Fields", Issued by Federal Communications Commission Office of Engineering & Technology, August 1999.

[19] D. Šimunić, "Non-Ionising Radiation Human Exposure Assessment near Telecommunication Devices in Croatia", Preliminary report presented at the 6th Symposium of the Croatian Radiation Protection Association with international participation, Stubičke Toplice, Croatia, (18-20) April 2005.