A Study on the Effects of Cellular Mobile Networks on People in Tikrit City Based on Power Density Measurements and Calculations

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***Abstract*—In this paper, the emitted electromagnetic waves (EMW) from different cellular mobile base stations (BSs) have been measured and calculated in order to study their effects on public health. Moreover, a comparison between the effect of radiated power from the BSs on people who live near them and those who live away has been made by using OpenSignal software and calculated theoretically. The values of power density for different cells were also calculated to compare them with the maximum permissible exposure limit-the acceptable range values of power density. The measurements were done in Tikrit City considering ten cells and various locations and distances. The results show that most of the power density and EMV for the tested cells are within the acceptable range. However, power density and EMV for two of tested cells have hurtful effects in the long term for people who live near the BSs.**

Keywords-mobile effect (ME); electromagnetic waves (EMW); radiation; power density (PD)

I. INTRODUCTION

The percentage of people in Iraq who use mobile phones has been increasing exponentially, and the communication between people via mobile phones has become a commodity [1]. Since mobile devices or networks are considered essential means in the modern way of life, it is important to study the effects of mobile networks on humans. Some reports submitted by World Health Organization (WHO) reported that the emissions from the cell phones and BSs placed on house rooftops and in populated zones are causing some severe health risks [2] and the effects of EMW emitted by mobile phones and BSs depend on the time of mobile phone use. Before studying the effect of transmitted power by telecommunication towers on humans, we should know the range of the used frequencies. In general, 800MHz, 900MHz, 1800MHz, and 2450MHz represent the frequencies of EMW used for wireless mobile connections. The range of frequencies for Global System for Mobile Communications (GSM) is between 890 and 960MHz, these frequencies are divided into two groups: the frequencies from 890MHz to 915MHz are used for uplink while the frequencies from 935MHz to 960MHz are used for downlink as shown in Table I. There is also an Extended GSM (EGSM), the range of the uplink frequency for EGSM technology is between 880 and 890MHz [2] while the downlink of this technology is between 925 and 935MHz). The bandwidth in GSM is 25MHz. Three main wireless mobile telecommunication providers are available in Iraq: Asiacell, Korek, and Zain. In this research, we focused only on GSM technology used by Asiacell in Tikrit (a city in the north of Iraq), and the test was done for towers of this company and in this city. The signals of telecommunication towers must spread on to cover the mobile devices. These towers, as a part of a wireless mobile communication network, are required to create a connection between phone devices and the network. Therefore, the commutation towers are distributed in all areas of Tikrit City to ensure providing services for all users as shown in Figure 1.

TABLE I. FREQUENCY SPECTRUM FOR TELECOMMUNICATION COMPANIES IN IRAQ.

System	Frequency		Bandwidth	Channel number
	Uplink	Downlink		
EGSM	880-890	925-935	10 MHz	50
GSM	890-915	935-960	25 MHz	125
GSM 1800	1710-1785	1805-1880	75 MHz	375
GSM 1900	1850-1910	1930-1990	60 MHz	300
Korek	880.2-891.8	925.2-936.8	11.6 MHz	58
Zen	891.8-903.4	936.8-948.4	11.6 MHz	58
Asiacell	903.4 -915	948.4-960	11.6 MHz	58

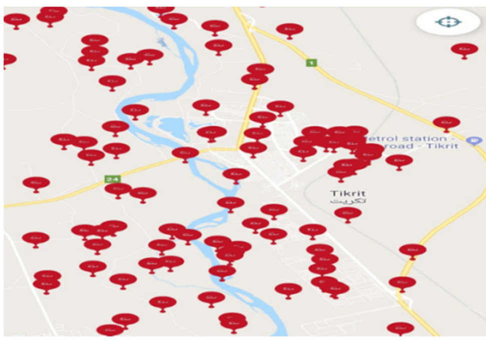

Fig. 1. Asiacell's communication towers in Tikrit by Open Signal Program

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The increase in the number of towers (base stations, Node B) leads to an increase in the population who are exposed to the EMW that are radiated from these towers. The EMW radiation is defined as a stream of photons in a given space, each photon having a quantity of energy, and this energy creates different types of radiation. These radiations produce the electromagnetic (EM) spectrum. EM radiation is divided into two types:

- Ionizing radiation: The wave is a container of high energy that is stronger than the energy of the bonding of the electrons within atoms/molecules and the formation of ions, such as cosmic rays and gamma.
- Non-ionizing radiation: These radiations do not have enough energy to form ions from atoms or particles of matter, such as radio waves and infrared radiation [3].

The density of EM radiation effect depends on 5 factors:

- The frequency/wavelength of radio frequency (RF) transferred signal.
- RF power radiated from the tower.
- Time of intake of RF signal at a given space from the tower. Time/ frequency of recurring exposure.
- Temperature degree, and level of wetness.

Radiation ratio changes from one place to another. It depends on the person's distance from the BS, the rate of mobile daily use, and the power of the received signal. Tissues in the body are exposed to the EMW radiation emitted from mobile phones or communications towers, especially if these frequencies are high. The intensity of this effect depends on the location of the person, and the characteristics of the cell's physiology [4]. In order to study the impacts of RF radiation on humans, it is essential to define the specific absorption rate (SAR). SAR is the quantity of RF energy absorbed per mass and time. Many governments and international agencies have been standardized the accepted range values of SAR, so if the value goes beyond this range, it will be considered unhealthy.

$$\text{SAR} = \frac{\sigma |E\ 2\ |}{\rho} \qquad (1)$$

Equation (1) is the main equation of SAR. $|E\ 2\ |$ is the root mean square of the intensity of the electrical field, σ is conductivity, and ρ is the mass density of tissue. Power density (PD), magnetic field strength B, and electric field strength E are the main factors of the EM field. In this paper, PDs for different BS cells have been studied and measured. Then a comparison between those values with the maximum permissible exposure limit was conducted and discussed.

II. LITERATURE REVIEW

EMF radiation on the human body causes biological changes and health effects. The biological changes are divided into two types: thermic effects and non-thermic effects. Thermic effects are caused by the absorption of EMW transmitted from towers while non-thermic effects are those that occur within the cells of the body and are possibly harmful. Health effects are any changes that take place in the cells of the body. Whether in a long time or for a short time, every person reacts in a different way in different levels of EM radiation. There are short-term and long-term effects from phone radiation. The earliest effects are snooze diseases, headaches, gloominess, etc., while long-time effects can be brain tumours, cancer, DNA corruption, memory weakness, etc. (Figure 2) [7]. Cancer is one of the most common diseases in the world, with no specific treatment, so, often studies avoid dealing with it. In [3], the researchers found that the diagnosed cancer rate for persons who live in range of 500m from a mobile BS is three times higher than of the persons that live outside this range. Breast, prostate, liver, stomach, and blood cancer also increase near BSs [8]. Since the radiation effects on the body are cumulative, a handheld broadband radiation monitor (frequency range of 800MHz-2500MHz) has been established to measure total received power. Radiation measurements were carried out in a lady's apartment, who had developed cancer within one year of the installation of a cell tower. The layout of the apartment and the measured readings are shown in Figure 3. It may be noted that the emission level is very high and it is between -4 to -10dBm at 900MHz, when -10dBm received power is equivalent to 7,068μW/m^2, which is higher than the accepted value in India, which is 4.7W/m^2=4,700,000μW/m^2 [9]. Hormones are affected by EM emissions [10]. People from both genders were exposed to larger levels of EM emissions for an evening in the lab. Serum estrogen levels in women were grown. On the other hand, testosterone serum in men decreased. The increase in the levels of estrogen augmented the risk of cancer and the decreased level of testosterone has been correlated to the growth of prostate and testicular diseases [11].

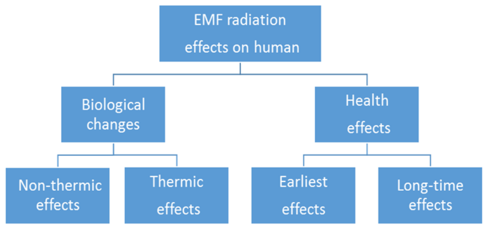

Fig. 2. EMF radiation effects

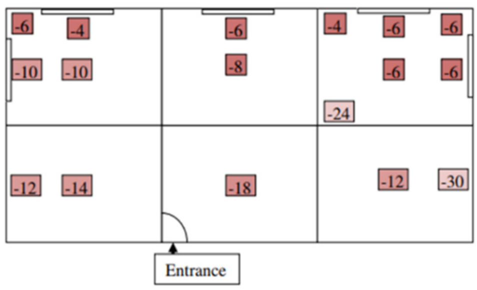

Fig. 3. Measured power at a cancer patient's residence.

As a direct response to public concern, some significant studies with multiple contributors and diverse expertise have been published recently on the health effects of low frequency EM fields. The mobile phone frequencies have effects such as psychiatric, muscle weakness diseases, and others. In [12] some steps to avoid the effects of cell phone exposure are proposed:

- Using PSTN phone when it is available.
- Reducing call times as much as possible.
- Stay away from a call in case of bad coverage.
- Switching off mobile when sleeping.
- Holding a cell phone away from the heart and head during charging.

The authors in[12] found that low-level EMF motivates the calcium to release ions from the cell wall. Infiltrate of calcium ions in the cytosol seems as a metabolic stimulant. This effects growth and healing, but also it supports the emergence of tumors. Loss of calcium ions makes leaks in the wall of lysosomes releasing DNA thus generating DNA corruption. Another probability of DNA corruption can be in growing free radical formation inside the cells, which further causes cellular damage in the mitochondria [13]. EM radiation increases heartbeat rate, changes body temperature, rises blood pressure, and causes breathing difficulties. In [14], a study was done on 20 people (10 men and 10 women), aged between 20 and 60 years. When the mobile was working in calling mode, rapid and arrhythmic heartbeat rate and changing in breathing time was recorded in 5% of the men in a group of 20–40 years after 30 minutes of exposure, during which the handset was installed in the ear end to the brain. In [15], a study on the effects of EM radiation on sperm movement in men was presented. The study was based on a test of 27 men. Some of them were exposed to EM radiation. Samples were taken and then were classified into two groups. The first group was taken from people who were exposed to EMR (900MHz) while the second group included samples of non-exposed people. The results showed that EMR released by the antenna had effects on the sperm movement. In addition it lead to behavioral or architectural changes of the germ cell [16].

International Commission on Non-Ionizing Radiation Protection (ICNIRP), World Health Organization (WHO), and other public interest organizations have not mentioned harmless radiation procedures [17]. There are many countries that accept radiation standards and guidelines, and define a limitation to the power released from towers and the time of healthy mobile use. On the other hand, the radiation limit is not strictly fixed, many countries are adopting their own radiation limits. Federal Communications Commission (FCC) and many other international communication organizations such as IEEE have published guidelines of acceptable power density range in a frequency range of 300MHz-1500MHz. Based on the maximum permissible exposure limit, the value of safe health PD is 0.6W/m^2 for general (900MHz) while 0.1W/m^2 for frequencies more than 1500MHz (same as FCC guideline). However, some countries like Australia are very much stricter in terms of maximum radiation density values with a limit of 0.000005W/m^2 [5, 6].

III. POWER MEASUREMENTS AND CALCULATIONS

The procedure was divided in two stages: the first stage was measuring the received power and finding the frequencies of Asiacell company by using specific software, and the second was conducting mathematical calculations.

A. Software Results

Two mobile software applications were used: CellMapper 5.1.7 and OpenSignal 5.37. The first was used to acquire the frequencies of the tested cell ID and the received power, while the other one was used to show the BS towers' location (Figure 4). Received power, frequencies, and the running protocol for tested cell IDs were measured. In order to cover different environments, several cells with different protocols (GSM, UMTS, DCS 1800, etc.), frequencies, and distances were tested. The tested cell IDs were 50828, 52295, and 51515 at a distance of 100m, 51515 at 1000m, 50826, 52297, and 51511 at 200m, and 51511 at 800m (Figures 5-7). The summary of the test results is presented in Table II.

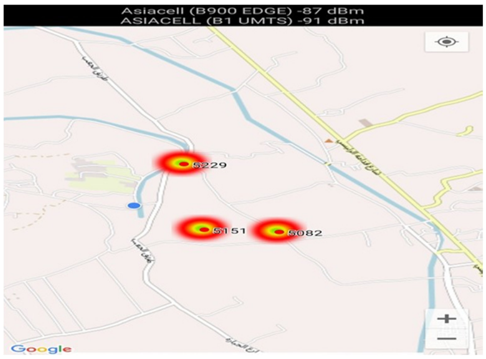

Fig. 4. Locations and ID of the tested cells by OpenSignal

Fig. 5. Results of 5082 and 51511 cell IDs

Fig. 6. Results of 52295 and 51511 cells

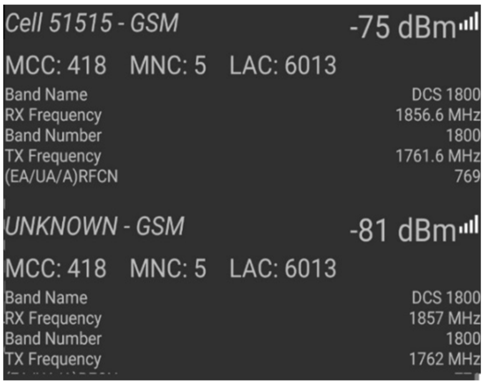

Fig. 7. Results of cell ID 51515

TABLE II. TEST RESULTS SUMMARY

Cell ID	Technique	Frequency (MHz)	Distance	Power (dBm)
50828	UMTS	2137.4	100	-59
52295	UMTS	2132.4	50	-55
51515	DCS 1800	1856.6	100	-55
51515	DCS 1800	1856.6	1000	-75
50826	DCS 1800	1853.8	100	-55
52297	DCS 1800	1853.4	50	-53
51511	UMTS	957.6	200	-53
51511	UMTS	957.6	800	-83

B. Mathematical Calculations

In order to calculate the received signal (*Pr*) transmitted from a specific antenna BS, we will depend on (2):

$$Pr = Pt * Gt * Gr * \{\frac{\lambda}{4\pi D}\}^2 \quad (2)$$

where *Pt* is the transmitted power, *Pr* the received power, *D* represents the distance between the transmit power source and the receiver, Gt is the transmit antenna gain, and Gr the received antenna gain.

Equation (2) is usually written in dBm instead of Watts in the below form:

$$P_r = P_t + G_t + G_r + 20log_{10}(\frac{\lambda}{4\pi D})$$

The theoretical calculation is done based on (2) and (4), then a comparison of those values with the practical power values (measured power) is made.

$$Pd = \frac{P_r * 4\pi}{Gm * \lambda^2} \quad (3)$$

where *Pd* is power density, *Gm* the mobile gain, λ the wavelength which is equal to $\frac{c}{f}$, *c* the speed of light=3×10^8m/s, and *f* is the frequency. Therefore, (3) becomes:

$$\text{Power Density} = \frac{P_r * 4\pi * f^2}{Gm * c^2} \quad (4)$$

For all cells, the below values are used to find the power: *Gt*=0, *Gr*=0, *Pt*=30dBm for UMTS and 33 dBm for DCS 1800.

1) Cell ID 50828

At 100m distance, frequency of 2137.4MHz, UMTS.

$$P_t = 30\ dBm, P_r = P_t + G_t + G_r + 20log_{10}(\frac{\lambda}{4\pi D}), \lambda = \frac{c}{f}$$

$$P_r = 30 + 0 + 0 + 20log_{10}(\frac{\frac{3*10^8}{2137.4*10^6}}{4\pi*100}) = \text{-49.05dBm}$$

$=12.45\times10^{-9}$W

$$Power\ Density = \frac{12.45*10^{-9}*4\pi*(\mathbf{2137.4}*10^6)^2}{1*(3*10^8)^2} = \frac{156.372(\ 4568478.76)*1000}{9*10^{16}} = 0.793\text{mW/m}^2$$

2) Cell ID 52295

At a distance of 50m, frequency=2132.4MHz, UMTS

$$P_t = 30\ dBm, P_r = 30 + 0 + 0 + 20log_{10}(\frac{\frac{3*10^8}{2132.4*10^6}}{4\pi*50})$$

$=$-43dBm$=50.119\times10^{-9}$W

$$Pd = \frac{50.119*10^{-9}*4\pi*(2132.4*10^6)^2}{1*(3*10^8)^2} = \frac{50.119*10^{-9}*4\pi*4547129.76*10^{12}}{9*10^{16}} = 31.8\mu\text{W/m}^2.$$

3) Cell ID 51515

Frequency=1856.6MHz, DCS 1800, *Pt*=33dBm

- At 100m

$$P_r = 33 + 0 + 0 + 20\log_{10}(\frac{\frac{3*10^8}{1856.6*10^6}}{4\pi*100}) = -44.82$$

$=32.961\times10^{-9}$W

$$Pd = \frac{32.961*10^{-9}*4\pi*(\mathbf{1856.6}*10^6)^2}{1*(3*10^8)^2} = \frac{32.961*10^{-9}*4\pi*3446963.56*10^{12}}{9*10^{16}} = 15.853\mu\text{W/m}^2$$

- At 1000 m

$$P_r = 33 + 0 + 0 + 20log_{10}(\frac{\frac{3*10^8}{1856.6*10^6}}{4\pi*1000}) = \text{-64.82dBm}$$

Pd=329.610x10^{-12}W

$$\frac{329.610*10^{-12}*4\pi*3446963.56*10^{12}}{9*10^{16}} = 0.158\ \mu\text{W/m}^2$$

4) Cell ID 50826

At 100m, *f*=1853.8MHz, DCS1800, *Pt*=33dBm

$$P_r = 33 + 0 + 0 + 20log_{10}\left(\frac{\frac{3*10^8}{1853.8*10^6}}{4\pi*100}\right) =$$

$-44.81=33.037\times10^{-9}$W

$$Pd = \frac{33.037*10^{-9}*4\pi*3436574.44*10^{12}}{9*10^{16}} = 15.843\mu\text{W/m}^2$$

5) Cell ID 52297

At 50m, *f*=1853.4MHz, DCS1800, *Pt*=33dBm

$$P_r = 33 + 0 + 0 + 20log_{10}(\frac{\frac{3*10^8}{1853.4*10^6}}{4\pi*50}) = \text{-38.79dbm}$$

$=132.130\times10^{-9}$W

$$Pd = \frac{132.130*10^{-9}*4\pi*3436574.44*10^{12}}{9*10^{16}} = 63.368\mu W/m^2$$

6) Cell ID 51511

Frequency=957.6MHz, UMTS, *Pt*=30dBm.

- At a distance of 200m

$$P_r = 30 + 0 + 0 + 20log_{10}\left(\frac{\frac{3*10^8}{957.6*10^6}}{4\pi*200}\right) = -45.09$$

$=30.974\times10^{-9}$W

$$Pd = \frac{30.974*10^{-9}*4\pi*916997.76*10^{12}}{9*10^{16}} = 3.963\mu W/m^2$$

- At a distance of 800m

$$P_r = 30 + 0 + 0 + 20log_{10}\left(\frac{\frac{3*10^8}{957.6*10^6}}{4\pi*800}\right) =$$

$-57.31=1.858\times10^{-9}$W

$$Pd = \frac{1.858*10^{-9}*4\pi*916997.76*10^{12}}{9*10^{16}} = 0.2377\mu W/m^2$$

IV. Results and Discussion

Figure 8 shows the comparison between the measured and the theoretical received power values. It is obvious that there is a difference between the measured and the theoretical values. For instance, the calculated power for cell ID (50828) was -49.05dBm while the measured power for the same cell ID was -59dBm.

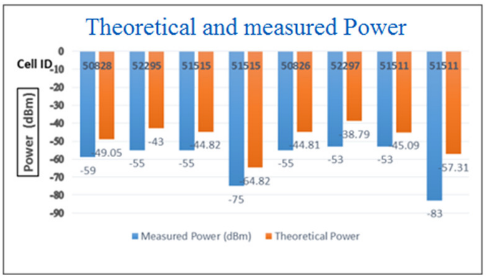

Fig. 8. Measured and theoretical power for tested cell

It can be noticed from the chart that 10dBm is the average difference between the calculated and the measured power for almost all cell IDs. This difference could have occurred due to neglecting the loss values in connectors and feeders when we calculated the power theoretically. Table III presents detailed information about the parameters of the tested cells and results in values of power. Those parameters are cell IDs, distance, amount of frequency for each cell, measured received power form each cell, theoretical calculation, and power density. It is clear that the received power depends on the distance from the transmitter, and the frequency. For cell ID 51515, there were two values of power measured, the power reduced from -55 to -75 because the first one was measured at a distance of 100m while the second measurement was at a distance of 1000m. However, the values of power also change if the value of frequency is changed even in the same distance as shown in the Table for cell ID 50826 and 50828.

TABLE III. CELL ID, POWER AND POWER DENSITY VALUES

Cell ID	Protocol	*f* (MHz)	Distance	Measured Power (dBm)	Theoretical Power (dBm)	Power Density ($\mu W/m^2$)
50828	UMTS	2137.4	100	-59	-49.05	0.000793
52295	UMTS	2132.4	50	-55	-43.00	31.8
51515	DCS 1800	1856.6	100	-55	-44.82	15.853
51515	DCS 1800	1856.6	1000	-75	-64.82	0.158
50826	DCS 1800	1853.8	100	-55	-44.81	15.843
52297	DCS 1800	1853.4	50	-53	-38.79	63.368
51511	UMTS	957.6	200	-53	-45.09	3.963
51511	UMTS	957.6	800	-83	-57.31	0.2377

The range of power density values for the tested cells is between 0.000793 and 63.368μW/m^2 as shown in Table III. The highest power density value was 63.368μW/m^2 at a distance of 50m for Cell ID 52297 which used DCS 1800 and *f*=1853.4MHz while the value of power density for the same cell reduced to 15.843μW/m^2 when the test was done at a distance of 100m. This means that the value of power density reduced by 75% when the distance changed from 50m to 100m whereas the lowest value of power density was 0.000793μW/m^2 at 100m distance for Cell ID 50828 which used UMTS protocol and 2137.4MHz frequency. The reason for that was that the telecommunication company uses lower power to transmit the signal in case of UMTS since it is rather designed to provide data than calls. So, when the transmitted power reduced, the power density decreased. The results also show the range of power density values for the tested cells is within the acceptable limits according to the maximum permissible exposure limit issued by the FCC and the IEEE. The values were below 0.6W/m^2 for the general frequency 900MHz and 0.1W/m^2 for frequencies more than 1500MHz. However, some power density values for the tested cells such as 31.8, 15.853, 15.843, and 63.368μW/m^2 for Cell IDs 52295, 51515, 50826, and 52297 are considered unacceptable and harmful according to government agencies in Australia because they are higher than the Australian acceptable value of 0.000005W/m^2 [6].

V. Conclusion

In this research, the received power for eight cells has been theoretically calculated and practically measured. A comparison between the theoretical and the measured received power was conducted. Power density values were calculated in order to decide if they are harmful or not based on safe range values issued by FCC, IEEE, and Australian agencies. The results demonstrate that the distance between the tower (BTS/Node B) and the receiver, and the used frequency have a major impact on power density. *Pd* was reduced by 75% when the distance between the transmitter and the receiver doubled. The highest *Pd* value was 63.368μW/m^2 at a distance of 50m for DCS 1800 protocol, and frequency of 1853.4MHz while it reduced to 15.843μW/m^2 when the test was done at a distance of 100m. The results show the range of power density values for the tested cells is within acceptable limits according to the guidelines and reports issued by FCC and IEEE. However, some power density values are considered unacceptable and harmful according to the Australian government agencies.

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