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MEASUREMENT OF LEVELS OF ELECTROMAGNETIC ENERGY DENSITY EMITTED BY MOBILE PHONE TOWERS IN THE CITY OF MOSUL, IRAQ

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Abstract

This research deals with measuring the energy density levels of the mobile phone towers for the downlink of the GSM 900 and GSM 1800 frequency range signals for the Asiacell and Korek companies in the city of Mosul and comparing them with the national and international standards for radiation protection. This research used SRM-3006 to measure the energy density of electromagnetic radiation. Measurements were taken from mobile phone towers in the municipal humpback sector with the positioning of the towers using GPS. The results presented show that the radio frequency radiation levels of the constellation antennas do not exceed the permissible limits for different radio frequency signals. The average energy density (PD) in the frequency range of (900 MHZ) were 0.0872399 W/m^2 for Asiacell and 0.0313094 W/m^2 for Korek. Whereas, the average energy density (PD) in the frequency range of (MHZ 1800) were 0.16183177 W/m^2 for Asiacell and 0.0607802 W/m^2 for Korek. The highest total mean density was 0.17914139 W/m^2, but many sites in this study are exposed in the two levels above 0.1 W/m^2, which is the Russian border. The results of the energy density values obtained were higher when compared to other countries' research this is due to some differences in measuring devices, measurement site standards, measurement equipment settings, survey methodology and urban planning. The use of GIS to draw maps of the distribution of radio towers and the level of radiation.

Key words: Radiofrequency (RF) Radiation, Electromagnetic Radiation (EMR), Power density, Non-Ionizing Electromagnetic Radiation, GSM, Mobile tower.

Introduction

Our contemporary world is witnessing a huge revolution in information and communication technologies and this revolution is accompanied by a rapid expansion in the use of technological systems that emit electromagnetic radiation, especially in recent years, such as; Radio, television and radar transmission stations, satellite broadcasting, industrial, medical and home applications; Like microwave ovens and last but not least the mobile phone that has invaded the lives of millions in a way that has no longer had to be dealt with (Hayawi and Quboa, 2007; Beekhuizen *et al*., 2014; Zeleke *et al*., 2018). This development has led to the advancement of systems of this type of communication widely in all countries of the world including Iraq, where it entered after 2003 and became accessible to all. This led to increase installation of mobile phone towers spread randomly within cities and in various regions (industrial, agricultural, commercial and residential) and even near hospitals, schools, kindergartens and inside campuses. The public became constantly and increasingly exposed to the electromagnetic fields of radio frequencies, which raised the concern of specialists about the effect of electromagnetic radiation on human health. Many different and diverse opinions emerged about the environmental effects of these radiations (Sivani and Sudarsanam, 2012; Nyakyi *et al*., 2013).

Cellular mobile systems for mobile phones can be divided into three generations, the first generation works in the range of (450-900) MHz, the second generation (GSM) are the digital generation that works in the range of 900 MHz, 1800 MHz or 1900 MHz and the third generation in the range of 2000 MHz. In the GSM 900 system, there are two frequency bands, uplink 890-915MHz (transmitted from mobile phone to the base

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stations (towers) and 935-960 MHz downlink (transmitted from base stations to mobile phones). The GSM 1800 system uses the frequency bands from 1710-1785 for the uplink and 1805-1880 MHz for the downlink (Cansiz *et al.*, 2016).

Several previous studies on the measurement of downlink electromagnetic radiation have been conducted in several countries, including Sweden (Hardell *et al.*, 2016; Carlberg *et al.*, 2019) and (Ramirez-Vazquez *et al.*, 2019) Spain.

In Iraq, there are many telecommunications companies that provide mobile phone service, including Asia Cell and Korek. The work of the mobile phone in the cities depends on dividing the geographical area of the city into small cells, each with a number of transmitting and receiving antennas. These antennas are placed on the roofs of buildings, houses, ground, in addition to the mobile towers with a height of (15-170) meters (Ali, 2013).

Materials and Methods

Research, plan and study site

It is noticed that there are three telecom networks in the city of Mosul, which are Asia Cell, Korek and Zain. This study focused on the level of electromagnetic energy density emitted by the Asia cell and Korek towers, as they are the most commonly used in the city of Mosul.

Because of the large numbers of towers, the humpback sector located in the northeast on the left side of the city was chosen to record the measurements. The area of the sector is 23,346 km^2 (Mosul municipality). This sector is distinguished by the fact that it includes 19 residential neighbourhoods, commercial areas, cultural group area, markets and commercial malls, as well as the university of Mosul, private and governmental hospitals, health centers, schools, kindergartens, hotels and a green area (tourist forest area).

The work focused on investigating the radiation emitted from constellations in the frequencies (GSM 900 and GSM 1800). The number of towers measured for Asiacell Company was 46 and for Korek Company was 33. After obtaining the results, they were compared with international and national standards.

Fig. 1: SRM-3006.

Measuring device used in the project

The SRM-3006 (selective radiation scale) meter (Fig. 1) provided by the German company Narda measurements of safety was used in the high-frequency electromagnetic fields in the frequency range of 9 kHz to 6 GHz. The device evaluates the field strengths that it measures from mobile, radio, television, internet and radar towers, according to the applicable regulations (Hammash, 2009).

Several operating modes can be identified in the device. In this study the Measurement routines method approved by the Iraqi Ministry of Health and Environment has been applied. Settings have been established on the basic unit (device) SRM-3006 where company-specific frequencies have been entered as two programs for each company for 900 GSM frequencies and for 1800 GSM frequencies. To install the settings, the devise was connected to the computer and (SRM-3006 Tools) program was opened to configure the measurement software. We first transferred data from the device to the computer, then the setting of each company was merged and assigned a specific name and then re-downloaded to the device.

After these steps, the instrument was ready for measurement.

• Software used in the Project:

1. The MAPS.ME program
2. Arc GIS 6.2
3. PC SRM-3006 Tools

Methods

The field measurement process was carried out for a period of five months (October 2019 - February 2020) and took about 4 to 5 hours per day and at an average of

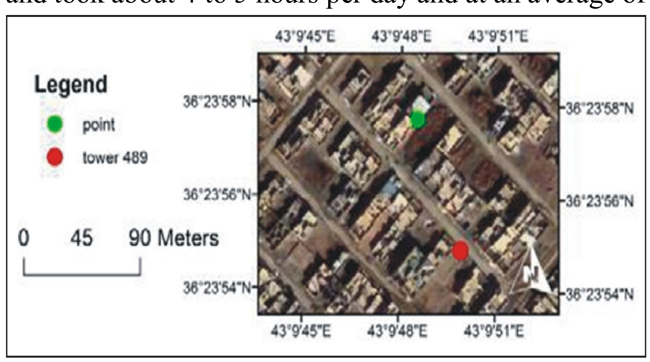


Fig. 2: The location of the *Korek Tower* and the point measured from it for several hours of the day.

Fig. 3: Shows different types of antenna structures found in the survey.

3 days a week during the morning rush period from 8:30 AM until 1:30 PM.

Information about the various sites chosen for observation was collected accordingly and then the name and information of the constellations was verified after access. The main objective was to find the density levels of electromagnetic energy by measuring the electric field strength (dBμV / m unit); where SRM-3006 was used at an angle of 45°C and at a height of about 1.2-1.5 m above the ground, the height of an average human body toward the antenna on the tower as used in previous studies (Ismail *et al.*, 2010; Nwankwo *et al.*, 2012; Ayinmode and Farai, 2013; Awad and Habeeballah, 2014; Parajuli *et al.*, 2015; Deatanyah *et al.*, 2018; Jibiri *et al.*, 2019).

In order to reach a better estimate of the site exposure, three or four measurements were taken for each tower and by two programs per downlink measurement (DOWNLINK) for GSM frequencies in which mobile phones operate within the second generation, which are 900 MHZ and 1800 MHZ and for different and random distances between towers and antennas as in many previous research (Ahmed *et al.*, 2016; Marinescu and Poparlan, 2016; Madžarević *et al.*, 2018; Abdulsalam *et al.*, 2020).

Most of the measurements were made on the surface of a flat ground around the towers, whether it was ground or on the roofs of buildings. More than one point of measurement was obtained from the roof of each building. The measurement method was as follows: waiting for three minutes for the stability of the reading, then recording the first reading of GSM 900 and stored, the same was done with reading GSM 1800 as it was applied in previous studies (Dhami, 2012; Nwankwo *et al.*, 2012; Urbinello *et al.*, 2014; Deatanyah *et al.*, 2018). Thus, the time for recording each measurement took approximately thirty minutes for each tower and for each point the measurement process took approximately ten minutes. The frequency of this process was in all direction opposite to the antennas according to the instructions of the Iraqi Ministry of Health and Environment, so that different measurements were obtained at several distances and directions.

Screenshots were then taken for each measured step and all measurements and screenshots are stored and downloaded at a later time for processing and analysis.

The energy density levels of radiation from mobile phone towers were determined after official business hours and during holidays. Cork Tower was chosen by Al-Siddiq neighborhood and a point was chosen 90 meters from the roof of the house as shown in fig. 2 and fixed with coordinates. To take multiple readings throughout the day.

During the period of fieldwork, different structures are found in the towers (Fig. 3), on the ground or on the roofs of residential or commercial buildings and all antennas are installed on top of the tower whose height ranges from 15 to 50 meters. It was also observed in some locations that the antennas are not installed on one tower instead distributed over the structure and building and the height ranges from 3 to 15 meters (Nahas and Simsim, 2011; Parajuli, 2014).

The information and coordinates available at the Nineveh Environment Directorate were used to identify the locations of the towers which are stored in the database, as well as field work and MAPS. ME and Google Earth programs which were used to verify the locations of the towers on the ground and their compatibility with the information provided. The geographical locations of the measurement points around the towers, measured through the use of a dedicated energy density meter that contains GPS technology among the functions of the device. And then the measured data were entered into the device using ArcMap 10.3 to prepare a map (KRITING) to show the distribution and density of energy within the study areas and the horoscope locations were shown geographically as shown in fig. 4.

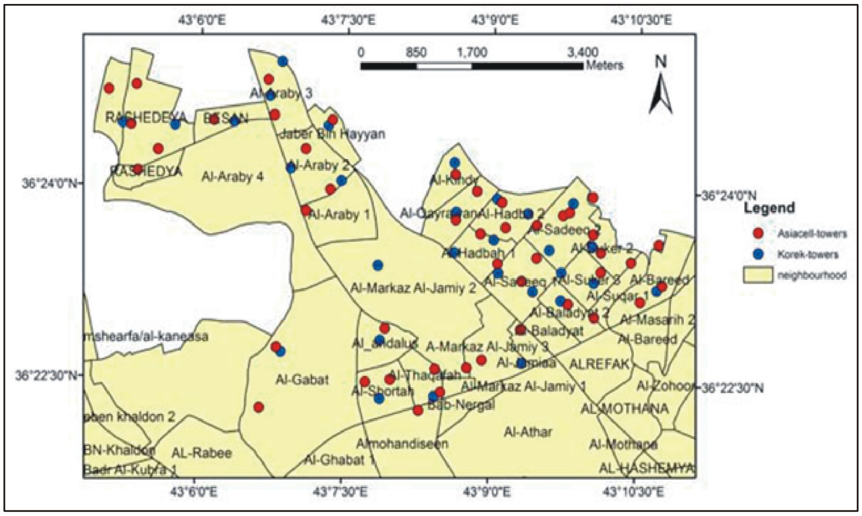


Fig. 4: A Map showing the locations for the constellations in the study area.

Data analysis

After completing the field work, the device was connected to the laptop computer to use PC SRM-3006 Tools software applications and save the measurements in the format of Excel files and screenshots in PNG format. It also included extracting data from the device's memory by operating it and manually extracting readings from the locations of interference and adopting four records at each point for GSM 900 and GSM 1800.

The program provides information such as (date, time, latitude, longitude and electric field strength values from SRM-3006 (Cansiz *et al.*, 2016). After recording the readings, it was entered into the Excel program approved by the Iraqi Ministry of Health and Environment.

Results and Discussion

This study analyzed the data obtained from fieldwork measurements as follows:

Asiacell company

The measurements were made for (46) different sites, including towers for Asiacell and the readings ranged between (0.000068 - 0.25558508 W/m^2). The highest average for GSM900 was 0.0872399 W/m^2 for tower (A16) which was lower than the Iraqi marker, the ICNIRP, the FCC and the Russian limit (97.82%, 98.06%, 98.55%, 12.76%, respectively. The rest of the readings for intermediate values were within the Iraqi and international determinants. It turns out that the energy density levels for the GSM frequencies 1800 (W/m^2) ranged between (0.0000327 - 0.442337 W/m^2). The highest average was 0.16183177 W/m^2 in the tower (A2) which is less than the Iraqi determinant, ICNIRP and FCC with a percentage of (95.95%), (98.2%) and (98.38%), respectively, but exceeding the Russian limit by (162%). Some values of average density appeared beyond the Russian limit, which are (161.83%, 136.62%, 147.61%, 119.46%) and return to the constellations (A2. A9, A11 and A23) respectively. The average of the tower (A11) gave the second highest average due to the fact that two readings were measured from the roof of a building where the antenna was at a heights of 2m and 4m and thus gave higher values than the values taken from the surface of the earth. As it was mentioned, people who work near base stations, especially on the surface, may be exposed to the strength of the electromagnetic field, several times more than people working away from the base stations (Buckus *et al.*, 2017).

Table 1: The highest average values for the Asiacell GSM 1800 frequency.

Percentage of determinants				The average	Symbol	Tower No.	Region
Russia 0.1	FCC 10	ICNIRP 9	IRAQ 4				
161.83%	1.62%	1.80%	4.05%	0.1618318	A2	4131	AL-Araby
136.62%	1.37%	1.52%	3.42%	0.1366194	A9	4194	Mosul Un.
147.61%	1.48%	1.64%	3.69%	0.1476134	A11	4009	Technical Un.
119.46%	1.19%	1.33%	2.99%	0.1194628	A23	4662	Al-Hadbah

Korek Company

The measurements were made for (33) different locations, where the Korek towers had been installed and calculating the average levels of energy density for the GSM 900 frequencies in W/m^2. The readings ranged between (0.0012975 - 0.0511141 W/m^2) and the highest average density was 0.0313094 W/m^2 for the tower (K22) which is lower than the Iraqi mark, the ICNIRP, the FCC and the Russian limit by (99.22%, 99.3%, 99.48%, 68.69%) respectively. All readings for intermediate values were within the Iraqi and international determinants. The average power density levels for the GSM frequencies 1800 (W/m^2), readings ranged between (0.00055001 - 0.1344128 W/m^2). The highest average density was 0.0607802 W/m^2 for the tower (K11) which is less than the Iraqi determinant, the ICNIRP, the FCC and the Russian marker (98.48%, 99.32%, 99.39%, 39.22%) respectively. And the rest of the readings for the average energy density fall within the Iraqi and international determinants.

Peak times

From the note of table 2 and fig. 5, it could be noted that the energy density levels of the rays emitted by the mobile

Table 2: Energy density readings for different hours.

GSM 900W/m²	Time
0.004923	2:00 PM
0.005169	3:00 PM
0.008576	4:00 PM
0.02976	5:00 PM
0.006377	6:00 PM
0.001554	7:00 PM
0.000641	8:00 PM
0.001649	9:00 PM
0.002597	10:00 PM
0.001162	11:00 PM

phone towers in a specific area and for several hours for a tower belonging to the Korek Company in the Al-Siddiq neighborhood, choosing a point 90 meters away and taking the readings from the roof of the house over a day at a rate of one reading per hour (During the winter season), from 2:00 p.m. to 11:00 p.m.

Total exposure

From the measurements of (79) different locations in the towers of the Asiacell and Korek companies, the average total energy density was calculated for the energy density levels for the GSM 900 + GSM 1800 b (W/m²).

From the total average power density to GSM 900 + GSM 1800 b (W/m²) power density levels, the highest total mean density was 0.18114139 W/m² for tower (A2), which is less than the Iraqi limiter, ICNIRP and FCC by (95.52%, 96.02%, 97.01%) respectively and exceeding the Russian limit by (179.14%). In addition to the emergence of many high and exceeding the Russian borders with ratios (170.19%, 169.61%, 139.20%) related to the constellations (A9, A16, A23) respectively. As shown in table 3. And the rest of the measurements are within the Iraqi and international determinants. Among the results presented, we note that the highest average values are for Asiacell.

The highest total average score was (0.17914139 W / m²) which is much lower than the national parameters, ICNIRP and FCC, but it exceeds the Russian limit. This value is more than the values that appeared in previous studies from different countries, such as the study of (Hardell *et al.*, 2016) that was done during the measurement procedure at the Stockholm Central Railway Station in Sweden for exposure to radio frequency RF at the average of high measurements of the GSM + UMTS downlink 900 ranges from 1165 to 2075 μW/m² (equivalent to 0.001165 0.001632 W/m²) and (Carlberg *et al.*, 2019) conducted a radio frequency radiation (RF) measurement in the central parts of Stockholm, Sweden and the average overall level were 5494 μW / m² (equivalent 0.005494 (W/m²). The study of (Ramirez-Vazquez *et al.*, 2019) presented a recording exposure to electromagnetic fields of RF-EMF from mobile base stations (downlink) installed at Albacete, 2017 (Spain). The average exposure recorded to RF-EMF from base stations (downlink) on exhibition opening days (morning, afternoon and night) for the studied areas was 791.8 μW/m² (equivalent to 0.0007918 W/m²), the highest average exposure for the weekend was recorded as 1494.1 and 848.1 μW/m² (equivalent to 0.0014941 and 0.0008481 W/m²), respectively. Recorded measurements were less than statutory limits.

Although the energy density emitted by the constellations is less than the permitted national levels, ICNIRP and FCC, but it is still very important to measure the energy radiated by the mobile station itself. This power is believed to be more than the power

Table 3: Highest average values for total exposure to the GSM900 and GSM 1800 frequency averages for Asiacell and Korek.

Percentage of determinants				Savg	Symbol	Tower No.	Region
Russia 0.1	FCC 10	ICNIRP 4.5	IRAQ 4	(Savg 900 + savg 1800)			
179.14%	2.99%	3.98%	4.48%	0.179141	A2	4131	AL-Araby
170.19%	2.84%	3.78%	4.25%	0.170191	A9	4194	Mosul Uni.
169.61%	2.83%	3.77%	4.24%	0.169614	A16	4265	Al-shortah
139.20%	2.32%	3.09%	3.48%	0.139205	A23	4662	Al-hadbah

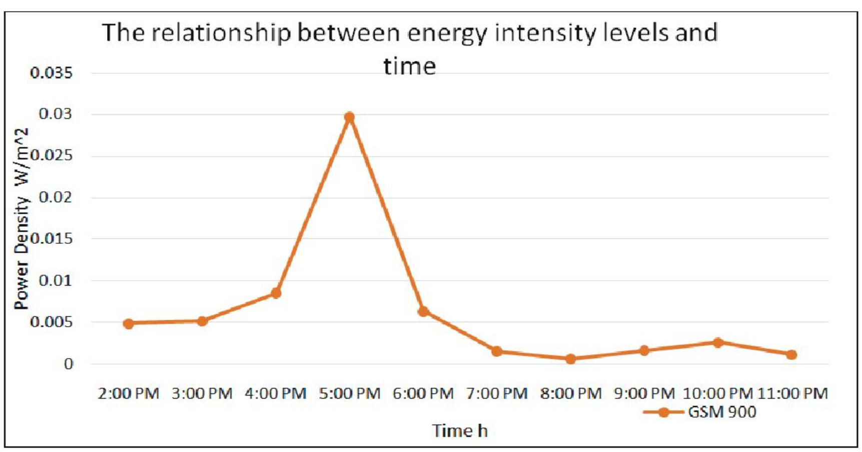
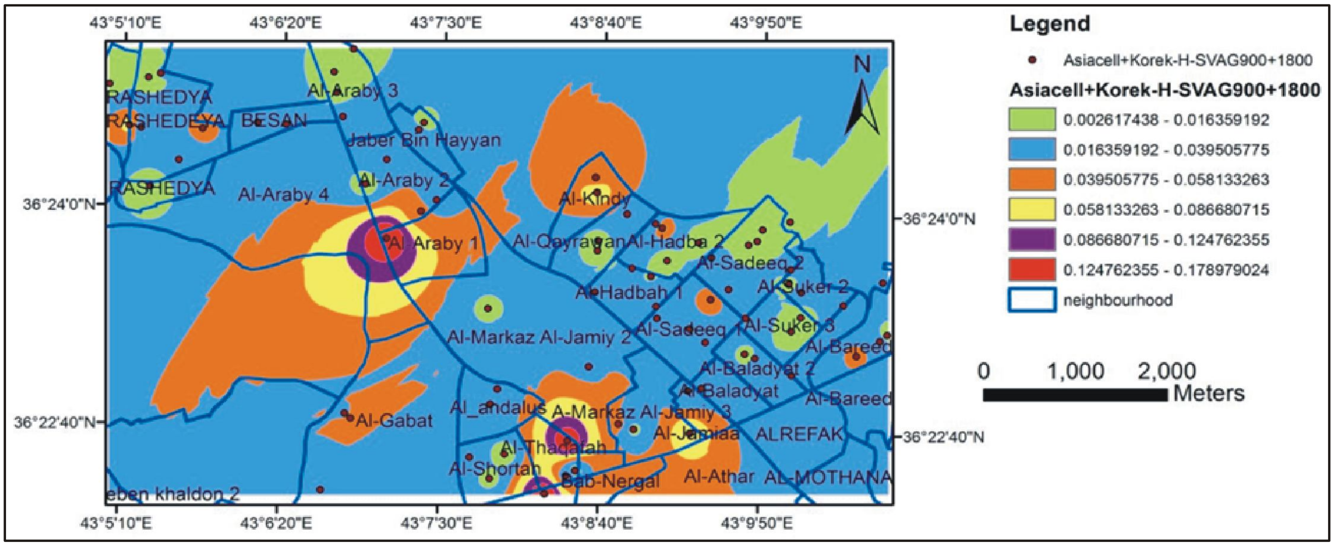


Fig. 5: The differences in energy intensity levels by increasing the energy density from after two o'clock in the afternoon to reach the peak at five o'clock in the afternoon and then begins to decrease, especially after six o'clock in the evening.



received from the base station. Moreover, there are some other sources of electromagnetic radiation in the region; This includes WLAN. Hence, it is important to investigate radiation from these sources (Mousa, 2011) as the study presented here indicates that exposure in the studied sector can be considered within a safe limit. However, communication networks are dynamic systems that continuously evolve and grow due to competitive conditions and the need for a better response to increased customer demand. This development is accomplished by replacing the classic antennas with new antennas or creating new bases or mobile towers in the target areas. Therefore, efforts should be made to control and regulate the random location of the towers to ensure that the public is not exposed (Jibiri *et al.*, 2019). Excessive exposure to electromagnetic fields can be avoided by determining the correct location of base station antennas (Rowley and Joyner, 2012).

Conclusion

This study provided power density measurements for the GSM 900 and GSM 1800 frequency range signals. The results presented showed that the radio frequency radiation levels of the horoscope antennas do not exceed the permissible limits for different radio frequency signals set by international organizations such as FCC and ICNIRP. The permitted limit stipulated in the instructions of the Iraqi Ministry of Health and Environment. The average energy density (PD) in the frequency range (900 MHZ) was 0.0872399 W/m^2 for Asiacell and W/m^2 0.0313094 for Korek. While the average energy density (PD) in the frequency range (MHZ 1800) was 0.16183177 for Asiacell and 0.0607802 W/m^2 for Korek. The highest total mean density was 0.17914139 W/m^2, but many sites in this study are exposed in the long run to levels above 0.01 W/m^2, which is the Russian border, which is an average threshold value for non-thermal biological effects.

Comparing the results of the energy intensity values obtained with other countries increased it. This is due to some differences in measuring devices, measurement site standards, measurement equipment settings, survey methodology and urban planning.

Attempting to achieve the total ambient energy density levels in sensitive locations such as schools and hospitals will need to be addressed to address some of the concerns faced by specialists.

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