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Discovering the spatial locations of the radio frequency radiations effects around mobile towers

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ABSTRACT

Nowadays, smart devices have become a major part of human life, and this need has led to an increase in the demand for these devices, prompting major telecommunications companies to compete with each other to acquire the bulk of this market. This competition led to a significant increase in the number of mobile towers, to expand the coverage area. Each communication tower has transmitters and receivers to connect subscribers within the mobile network and other networks. The receivers and transmitters of each mobile tower operate on radio frequency waves. These waves can cause harm to humans if the body tissues absorb the radiation resulting from these waves. Headache, discomfort, and some other diseases are among the effects resulting from the spatial proximity to the mobile towers. In this paper, a model based on geographic information systems (GIS) software is proposed for the purpose of discovering the area of exposure to radio frequency radiation. This model can assists mitigate the opportunities of exposure to these radiations, thus reducing its danger. Real data of the levels of electromagnetic pollution resulting from mobile towers were analyzed during this study and compared with international safety standards.

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1. INTRODUCTION

At this time, there is a wide and tremendous development in the field of smart devices and technology, as this leads to making most users spend a lot of time in these areas. As smart devices have become a large part of daily life, which prompted most communications companies to develop a more sophisticated transmission system so that it can contain and cover all these large requirements [1]. The mobile towers represent the transmission medium which have the basic antennas of transmitting and receiving the stations that are used in radio frequency to generate a new communication channels to all users [2], [3]. Marketing reasons made substantial companies compete together to install mobile towers in large urban cities that contain numerous shopping centers, numerous companies, universities, and government offices [1]. This expansion requires in most cases a high level of communication services to combine the increasing demand for communication from thousands of companies and users. In the city of Najaf, there are three major mobile companies competing to offer these services: Asiacell, Zain, and Korak. Like the other companies in all world, all of the service providers mentioned are looking forward to provide better services and compete with each other to acquire and maintain new customers. One of the most crucial ways that the subscriber needs and that service providers can work to provide and gain more customers is the constant signal strength and the continuous wide coverage, and in order to guarantee what we mentioned, companies must build numerous towers and they are distributed over different areas. Each tower has a known and specific distance and constant signal strength according to the type of antennas placed on the tower and the transmitting base [4], [5]. There are numerous types of models that are used for covering, such as 2G model (UMTS 800) while 3G model (G1800) that is consider stronger signal compared to the models mentioned previously. The type 3G (2100) contain a very acceptable signal strength. The newer systems that are called 4G models such as (LTET, L2100, LTE FDD, and L 2300) has numerous features, however it is more complex. To take advantage of these features, the user's phone must be compatible with this system in terms of sophistication. The last type (L 2300) used in indoor as the shopping malls and football areas. The radio frequency (RF) is used in all models to configure the communication channels [6]–[8]. The radio frequency is advantageous for establishing communication channels, but the radiation that emits from it will absorbed by human tissues, caused serious diseases [1]. The strength of the radiation depends on two crucial factors which are the frequency and distance of the antenna. In this work, a high frequency measuring device called Narda-SRM-3006 selective radiation meter has been used in the survey which consider perfect for electromagnetic field measurements of a microwave leakage and base transceiver stations.

The ever-increasing number of base transceivers in densely populated cities has increased concerns in societies around effects of RF radiation sources on human health [5]–[9]. To this reason, interest has become very crucial in studying the health effects resulting from direct and indirect exposure to radiation from the cellular base transceiver to mitigate these negative effects [10]–[12]. The radio frequency determinants established by the International Committee for Non-Ionizing Radiation Protection (ICNIRP) are to ensure that exposure to radio frequencies is kept below the harmful level [11]. This organization is concerned with providing advice and guidance on the health and environmental impacts resulting from excessive exposure to non-ionizing radiation in order to protect humans and the environment from the harmful effects of such radiation. This organization is considered an independent organization. In general, most countries of the world adopt the guide set by the organization to determine the values of exposure to magnetic, electromagnetic and electrical fields, which reach (up to 300 GHz) [11]. The guidelines prepared by ICNIRP determine the highest acceptable values of power density (energy per unit area) and the specified absorption rate (SAR), in other words, they determine the amount of radio frequency energy absorbed per-unit. The thermal effect of RF energy determines these physical quantities. In [13], [14], the electromagnetic radiation effect of multiple systems was studied by creating a predictive model. The model dealt with the influence of the transmitting antenna parameters on the power density of multiple connections. The incident power density of open objects was assessed and analyzed for different locations in the United Kingdom using technical data for antennas and free-space propagation. In [15], [16], exposure levels to electromagnetic radiation (EMR) were measured in elementary schools close to cellular base transceivers in the classroom and outside the classroom. After analyzing and inspecting the data, it was obtained that the level of exposure to radio frequencies is much lower than the safety limits stipulated in the regulations of the ICNIRP. In India, EMR from different radio frequency sources has been monitored using a specially designed monitoring system to continuously measure near and far field RF radiations in urban and rural areas [17], [18]. Through the results, it was found that the radiation level exceeded the minimum safety conditions on the high-density base transceiver site [17]. In [19], a study has been made to identify the contamination caused by the RF base transceiver (BTS) of mobile network. The study has practical and theoretical approach. The effect of distance and level of exposure was discussed in theoretical approach while in practical approach the power density of mobile tower in Kufa-Iraq has been measured. In [20], [21], a system has been developed based on a model built with GIS program and a specific application to find safe zones from the effect of RF radiation.

2. RF RADIATION

The area to be covered by the cell phone network is divided into spatial units called (the cell) and each cell contains a fixed BTS. To cover an entire area, this requires finding a number of cells, since each cell has the ability to accommodate a specified number of participants in addition to the possibility of interruption or inter-cell interference. The radio frequencies of electromagnetic waves resulting from communication between phones and the base transceiver are non-ionizing electromagnetic radiations, and this classification is due to their lack of sufficient energy to produce ions that damage the human tissues [22]–[24]. The effects caused by radiofrequency radiation are classified into thermal and non-thermal effects. Raising the body temperature to high levels is the only health effect, which is moreover called the thermal effect. Direct exposure to high levels of electromagnetic radiation leads to increase the temperature of the human body, which leads to damage the body tissues in case of disability to dissipate the excess heat well [23]. The non-thermal effects are classified as more harmful effects on humans than the thermal effects because they cause memory problems, sleep disturbance and headache [23], [25]–[27]. Tissues exposed to radiofrequency radiation absorb quantities of strand measured per unit mass, which is moreover known as the SAR, exposure guidelines are defined by the power density as they represent the physical values for determining those guidelines [26]. Skin depth can be defined as the depth at which the density of the incident power decreases to an amount of regarding (0.135) compared to the amount on the surface of human skin. Down below equations define all parameters related to the incident power density on human skin, the skin depth and the SAR [25], [28].

$$E_i = E_0 e^{-z/\delta} \tag{1}$$

where E_i is the induced electric field intensity, Z is the depth distance, E_0 is the incident field and δ is the skin depth.

$$\delta = \frac{1}{\omega}\sqrt{\frac{2}{\mu\varepsilon}}\left[\sqrt{1+\left(\frac{\sigma}{\mu\varepsilon}\right)^2} - 1\right]^{-0.5} \tag{2}$$

where, tissue dielectric constant, μ is biological tissue magnetic permeability, σ is tissue conductivity (S/m) and ω is angular frequency of the RF source (rad/sec).

$$S = \frac{P_t G_t(\theta,\emptyset)}{4\pi r^2} = \frac{E^2}{Z_0} \tag{3}$$

where S is the power density, P_t is the transmitting power of the antenna, G_t is the antenna gain, E is the electric field (V/m) and Z_0 is the free-space impedance (120πohms).

$$SAR = \frac{\sigma E_i^2}{2\rho} \tag{4}$$

where E_i is induced field in the human tissue (V/m) and the tissue density (kg/m3). Figure 1 illustrate the inverse relationship between the power density and the distance whereas the distance increases, the recorded value of the power density decreases.

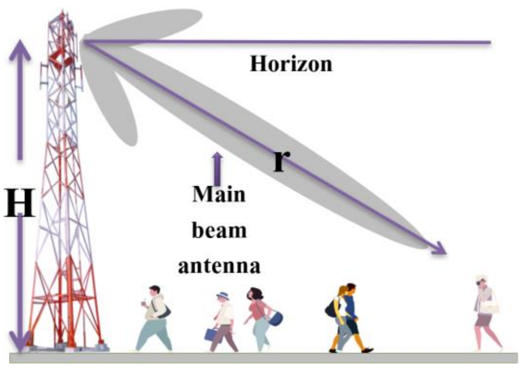

Figure 1. Power density calculation diagram

3. THE PROPOSED WORK

Figure 2 provides a complete idea of the study mechanism. The work includes three main phases, which are: (preparation of geographical databases, data collection and data evaluation). The collected data on the amount of radiation exposure will determine the dangerous zone and diagnose the potential diseases.

3.1. GeoData base preparation

A specific area of the city of Najaf was targeted for the purpose of studying the effect of radio frequency radiation on it. Figure 3 elucidates the complete map of Najaf and the part that was targeted by us. The map was prepared in advance using geographic information system (GIS) software.

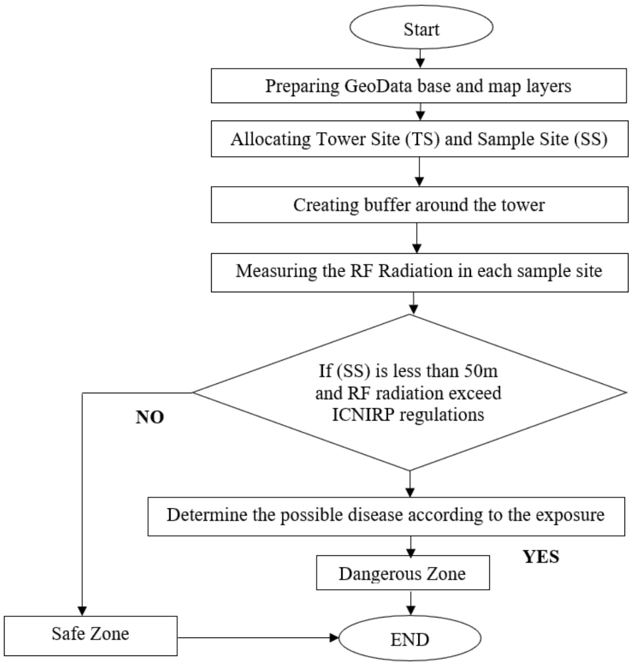

Figure 2. The proposed work flowchart

Figure 3. The entire map of Najaf city and the targeted region

The used dataset in this research has two main databases and each database will be generated using AcrCalalog program. The initially database represents the environment that includes the mobile tower in terms of the geographical location of the tower, the houses surrounding the tower, the places of sampling and the recorded values of radiation by Narda-SRM-3006 selective radiation meter device which illustrated in Figure 4. All these data are organized in the form of a table inside the point that represents the tower on the map. This table is generated using the ArcMap GIS. Each tower has a specific location (a specific coordinate) that the mobile company carefully chooses to cover a fixed plot. Using a global position system (GPS) device, the coordinates of each tower were accurately recorded. After completing the positioning process for each tower, the GIS program is used to install the sites of the towers for the three mobile companies which mentioned previously over the map within the targeted area as elucidated in Figure 5.

The second database represents diseases resulting from exposure to radiofrequency radiation. This database used like a reference to the purpose of comparison the obtained data and diagnose potential disease based on the amount of exposure to radiation. This database was built according to the standards mentioned in ICNIRP.

Figure 4. Narda-SRM-3006 selective radiation meter device

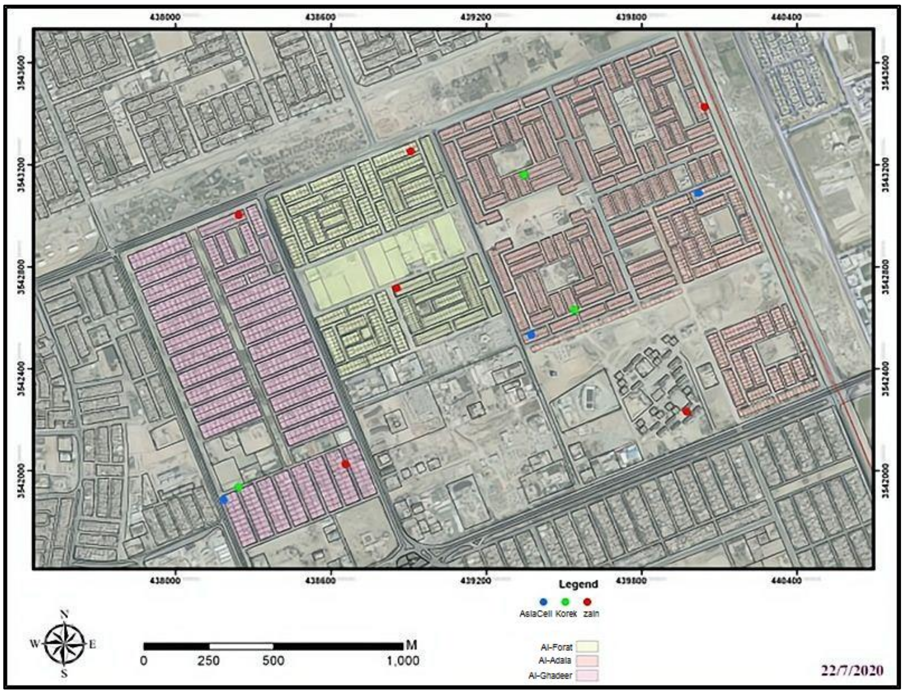

Figure 5. Distribution of mobile towers within the target area

3.2. Data collection

At this stage, in general, the amount of radiation around the tower within a specific area is determined. Using ArcMap and specifically the buffering tool, a buffer was generated based on the location data of each tower. The buffer covers the area of a circle with a radius equal to 50 m, where the tower represents the center of this circle. This buffer provides an idea of the area contaminated by radio frequency radiation within the tower influence circuit and outside it as well. A measurement point is selected within the limits of the buffer circuit and the radiation value at this point is recorded. This buffer provides a complete visualization of the radiation density in the area surrounding the tower. Figure 6 illustrates the tower location and the buffer area while the black pluses represent the sampling points. Table 1 represents the recorded power density values for samples located within the buffer circuit.

Figure 6. The buffer area and samples sites

Table 1. Recorded power density value for each mobile tower

Samples site in (Degree, Minute, Second)		Recorded power density in (µW/Cm2)			Mobile network company name
Latitude	Longitude	Sector A	Sector B	Sector C	
32 00 45.8	44 21 01.8	1.238	0.530	0.225	Zain
32 00 42.7	44 20 45.8	1.31	5.8	0.73	Korek
32 00 41.0	44 20 43.8	0.34	0.88	2.34	Korek
32 01 18.0	44 20 45.3	0.105	1.3	0.5	Zain
32 01 08.5	44 21 08.0	0.35	0.86	0.256	Zain
32 01 0 2.5	44 21 28.7	0.25	1.45	0.3	Asiacell
32 01 05.2	44 21 35.4	0.5	0.55	0.51	Asiacell
32 00 52.8	44 21 51.8	0.4547	0.4	0.38	Zain
32 01 05.5	44 22 03.8	0.52	0.64	0.95	Korek
32 01 20.9	44 21 52.7	0.16	0.24	0.19	Asiacell
32 01 31.6	44 21 54.7	0.96	0.9	0.35	Zain
32 01 22.8	44 21 27.9	1.3	1.27	0.388	Korek
32 01 25.6	44 21 10.8	3	0.6	1	Zain

3.3. Data evaluation

At this stage, the previously collected data within the buffer space is compared with “the International Reported Biological Effects from radiofrequency radiation at low-intensity exposure reference Table 2”. Each radiation value recorded within the buffer range is compared with the numbers recorded within the Table 2 to determine the percentage of potential impact and disease. If the recorded value less than a minimum permissible limit or not founded in the Table 2, then the area is considered safe. Otherwise, the Table 2 provides the potential effect of radiation. Work begins with determining whether the sample is inside or outside the range of the buffer. If the sample is within the buffer range, the program will start calculating and evaluating the data (the distance of the sample from the tower and the recorded radiation value). After processing the data is stored at the point representing the tower on the map. In open spaces, the radiation effect can travel farther distances than specified by the warehouse, causing symptoms ranging from annoyance to some serious diseases.

Table 2. Reported biological effects come from radiofrequency radiation at low-intensity exposure (cell tower, wireless laptop, Wi-Fi, and "smart" meter RF intensities) [10]

The Power Density Microwatts/centimeter^2 uW/cm^2	Note
0.01-0.05	Adults (from 18 to 91 years) with the short-term exposure to GSM cell phone radiation reported neurological problems and headache.
0.005-0.04	Adults exposed to the short-term cell phone radiation reported headache and concentration difficulties.
0.015-0.21	Adults exposed to the short-term GSM 900 radiation reported changes in mental state.
0.05-0.1	RFR regarded to the adverse neurological, cancer risk and cardio symptoms.
0.05-0.1	RFR related to the headache, sleeping problems and concentration.
0.07-0.1	Abnormalities that occur in the head of the sperm of mice for six months to the base station level RF/MW, where there is an increase in the incidence of malformations on the reproductive health of people who live near GSM stations.
0.38	In heart cells, RFR affected calcium metabolism.
0.8- 10	RFR reason the emotional behavior changes by some weak Microwaves.
0.13	RFR come from the 3G towers decreased cognition.
0.16	Memory, motor function and attention of children affected (Latvia).
0.168-1.053	Definitive sterility in mice after five generations of detect to RFR from antenna park.
0.2-8	RFR caused a 2-fold that increasing in the leukemia in children.
0.2-8	RFR decreasing the survival in the children (with leukemia).
0.21-1.28	An increase in headaches occurred in adults and adolescents after 45 minutes of exposure to universal global telecommunications system (UMTS) cell phone radiation.

4. RESULTS AND DISCUSSION

The results go through three stages, the initially stage is to determine the mobile towers and the device used to measure the amount of radiation produced by it. All data is transferred using the ArcMap program to the links placed on the map that represent the tower and its information, and this stage is considered the second stage. Analyzing and comparing data with the ICNIRP boundaries is the final stage.

Stage-1: The electromagnetic frequencies between 3 kHz and 6 GHz are considered the best for measuring the radio frequency radiation produced by the mobile towers. One of the towers was chosen randomly to discuss the results, as this tower is located on the roof of one of the residential buildings within the target area of the study. Each tower has three antennas, each of which is transmitted at an angle of 120 degrees to cover a specific area in a specific direction, as the tower's coverage has been divided into three sections (section A, section B and section C) as elucidated in the Figure 7. At this stage, a database of the tower is moreover built, depending on its geographical location, represented by the X and Y coordinates. The database prepared at this stage contains the geographical coordinates of the tower (world geodetic system (WGS) 1984 coordination system), the location of samples around the tower, and the different values of the measured radiation.

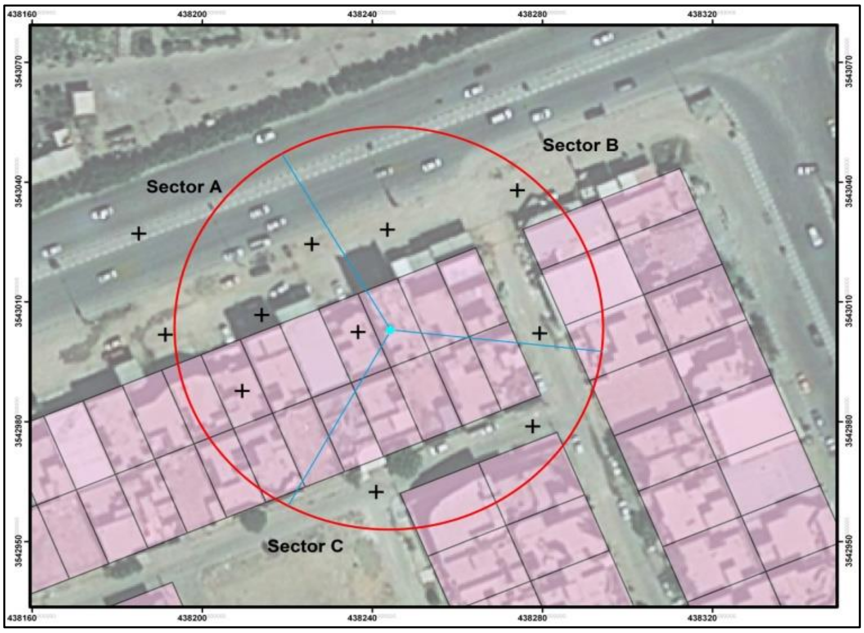

Figure 7. The three transmission sectors

Stage-2: After feeding the points on the map, which are the links between the database and the geographic location of the tower with the previously obtained data, the points are reclassified using the ArcMap program by selecting the points properties, then choosing the symbology option to reclassify each point depending on the distance that separate it from the mobile tower and its own recorded RF radiation value.

Stage-3: At this stage, all available resources are analyzed within the database prepared by the ArcCatalog program, and the spatial location of the tower is saved in the database. Record readings of radiation values are moreover stored for each point in the database after analyzing and comparing them with the ICNIRP boundaries. This data provides the entire perception regarding the location of the radiation impact and the distance separating it from the mobile tower. After this step, places where a person is likely to be exposed to tissue damage can be located. Figure 8 illustrate the safe and dangerous places where the green signs represent places where radiation levels did not exceed the permissible limits, while the red signs represent places of high radiation that could cause harm to humans. It can be seen from the Figure 8 that one of the three antennas on the mobile tower, specifically section A, exceeded the permissible limits for exposure to radio frequency radiation, unlike the other two antennas that did not exceed the limits. Table 3 elucidates the diseases diagnosed based on the calculated power density value and the distance between the sample site and the center of the mobile tower.

Figure 8. Dangerous and safe regions of RF radiation

Table 3. Diagnosed diseases of mobile towers

Samples location (Degree, Minutes, Seconds) Latitude	Longitude	Propagation sector	Recorded power density (μW/Cm^2)	Disease	Distance in meters
32 01 08.5	44 21 08.0	Sector B	0.86	RFR caused a 2-fold that increasing in the leukemia in children.	37
32 01 05.2	44 21 35.4	Sector B	0.55	Irreversible infertility in mice after 5 generations of exposure to RFR from an "antenna park"	14
32 01 31.6	44 21 54.7	Sector A	0.96	Caused emotional behavior changes by some weak Microwaves.	40
		Sector B	0.9	Same previous field.	40
32 01 22.8	44 21 27.9	Sector A	1.3	An increase in headaches occurred in adults and adolescents after 45 minutes of exposure to UMTS cell phone radiation.	
		Sector B	1.27	Same previous field.	
32 00 52.8	44 21 51.8	Sector A	0.4547	Calcium metabolism in heart cells	24
32 01 05.5	44 22 03.8	Sector C	0.95	As mentioned above, (Caused emotional behavior changes by some weak Microwaves).	40

5. CONCLUSION

The increase in population growth, urbanization, and the high demand for electronic services will push mobile companies to expand the bandwidth, which requires an increase in the number of mobile towers. This expansion is accompanied by an increase in the population's exposure to the risk of radiofrequency radiation. Therefore, it is very essential to analyze and study the areas surrounding the tower, which are likely to contain the highest rates of radiation impact, to enable residents to know the appropriate work and housing places. This paper mainly aims to study the actual effect of mobile towers in practice by measuring the power density values around each tower within the target area and producing spatial maps elucidating the radiation effect locations for each mobile tower. More than 116 power density readings for three mobile networks were detected during the field survey. A specific area of the city was targeted for the purpose of preparing this study, which included 14 mobile towers. As a future work, producing a mobile application to measure the rates of radio radiation will be very useful for its ease and availability on each user's phone.

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