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Evaluation of electromagnetic field levels generated from mobile communication stations near the University of Karbala

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Abstract

This study systematically measured the density of power levels of electromagnetic fields (EMFs) emitted by mobile base station towers operating in the 900 MHz, 1800 MHz, and 2100 MHz frequency bands in Karbala, Iraq. Using a German-designed Narda SRM 3006 micro spectrum analyzer, we assessed exposure levels in multiple directions around the University of Karbala. We also used GIS software, ArcGIS 10.7.1, to map nearby towers and emission directions. By comparing the measured power densities with national and international safety standards—including those set by the Iraqi Ministry of Health and Environment, the International Commission on Non-Ionizing Radiation Protection (ICNIRP), the Federal Communications Commission (FCC), and the Institute of Electrical and Electronics Engineers (IEEE)—we found that all recorded levels were within permissible exposure limits. Notably, the highest average measured power density was 358.2 nW/cm² at the 2100 MHz frequency band. These results confirm that telecommunications tower emissions in the studied areas comply with global radiation safety standards, providing valuable insights into public health safety from electromagnetic exposure. Our research establishes important foundations for monitoring electromagnetic fields in urban environments, supporting efforts to implement safe radiation limits and guiding future policy decisions.

Keywords: Radiofrequency, the density of power, electromagnetic radiation, International Non-Ionising Radiation Committee (ICNIRP), (FCC), (IEEE).

1. Introduction

Electrical appliances, power lines, transformers, and communication towers are just a few of the sources of electromagnetic fields (EMFs) that the general public is being exposed to more and more [1]. These devices emit electromagnetic radiation at varying levels, and understanding their effects is critical to assessing potential health risks [2] and ensuring compliance with safety standards [3,4].

In recent decades, the rapid expansion of information and communications technologies has greatly increased human exposure to electromagnetic radiation. Sources such as radio and television broadcasting stations, radar systems, satellite communications, industrial and medical equipment, microwave ovens, and, most importantly, mobile phones, have become ubiquitous [5]. Concerns regarding the possible health effects of extended exposure to radiofrequency radiation have been raised by the extensive expansion of mobile phone towers, which are frequently found in residential neighborhoods and metropolitan areas, as well as close to hospitals and educational institutions [6].

Most mobile communications stations operate within specific frequency bands, typically 900 MHz, 1800 MHz, and 2100 MHz [7]. The increasing number of mobile phone towers has raised concerns about potential health risks, particularly in densely populated areas [8]. Therefore, monitoring and evaluating electromagnetic energy levels in areas such as Karbala is essential to ensure compliance with national and international safety regulations. To lower possible health hazards, groups like the International Commission on Non-Ionizing Radiation Protection (ICNIRP) [7,9], the Federal Communications Commission (FCC) [10], and the Institute of Electrical and Electronics Engineers (IEEE) [11] have set exposure limits. However, because these requirements differ by location, local studies are required to evaluate compliance and offer recommendations tailored to a particular area.

We aim to measure the power density levels of electromagnetic radiation emitted by mobile phone towers operating at frequencies of 900, 1800, and 2100 MHz in the city of Karbala. We focused on communication towers located near the University of Karbala, specifically those operated by Asiacell and Zain, the two major mobile phone service providers in the area. The university campus, which houses multiple colleges such as medicine, pharmacy, dentistry, nursing, applied medical sciences, and engineering, was selected due to its high number of students and faculty members. The student parking area, where students wait for transportation, received particular attention due to the potential for prolonged exposure of individuals in this location to radiation from nearby antennas.

This study provides a thorough assessment of the compliance of mobile telecommunications towers with radiation safety standards by systematically measuring power density levels at different locations and comparing them with applicable safety guidelines. The findings will support current debates over the dangers electromagnetic radiation poses to public health and assist legislators in setting safer exposure thresholds.

Methodology

2.1 Devices and equipment used in measuring radiation

Table 1 shows the reference power density limits for general exposure, as defined by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) guidelines [9, 12]. These limits vary by frequency and are expressed in watts per square meter (W/m²). Power density (S) is calculated based on frequency (f, in MHz).

Measurements were conducted during peak hours of the workday to capture the highest possible exposure levels. Following ICNIRP standards, each measurement point was recorded over a 6-minute averaging period, ensuring accurate and standardized data collection.

Table 1. ICNIRP Guidelines for public exposure (mobile phone frequencies).

Frequency range	**Power density (S)[W/m^2]**
400 – 2000 MHz	f/200
2 – 300 GHz	10

We utilized the Narda SRM-3006 spectrum analyzer to measure electromagnetic field levels. Figure 1 illustrates the SRM-3006, produced by Narda Safety Test Solutions (Germany), a high-precision device engineered to measure high-frequency electromagnetic fields ranging from 9 kHz to 6 GHz.

This device accurately evaluates field strength levels emitted from various sources, including mobile phone stations, radio and TV transmission devices, internet communication systems, and radar towers [13]. The SRM-3006 is specifically designed for non-ionizing radiation exposure assessment, ensuring compliance with international safety standards.

Fig. 1: Narda Model SRM-3006 Electric Field Meter.

2.2 Data collection procedures

A customized service table, named Mobile Operators, was created using the SRM-3006 Tools program. This table includes the frequency bands allocated to national mobile phone providers, covering a range from 790 MHz to 3.8 GHz, which is used for various telecommunication services. Table 2 presents the frequency band allocations within the Mobile Operators service table.

Table 2. Mobile Operators' service table created with Narda SRM 3006 Tools**.**

Index	**Service name**	**F min [MHz]**	**F max [MHz]**	**Technology**
1	MOBIL 800 DL	791	821	4G
2	MOBIL 900 DL	925	960	2G, 3G, 4G
3	MOBIL 1800 DL	1805	1880	2G, 4G
4	MOBIL 2100 DL	2110	2170	3G, 4G
5	MOBIL 2600 DL	2570	2690	4G
6	MOBIL 3500-3700	3400	3800	5G

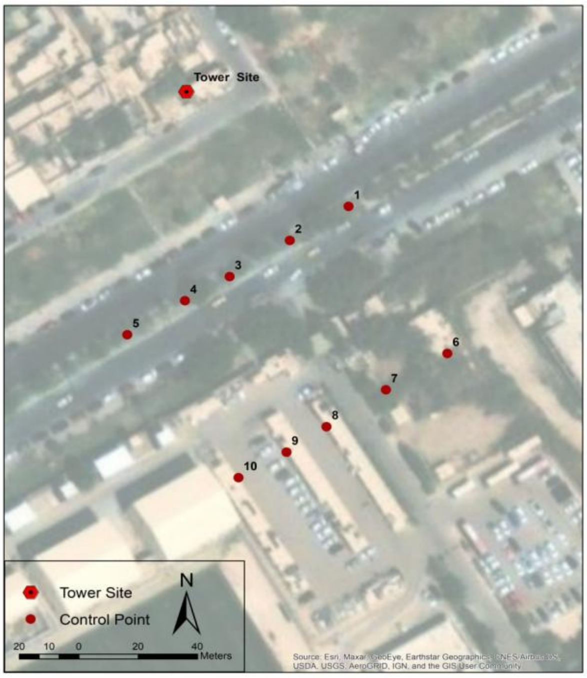
Measurements were performed for the 900 MHz, 1800 MHz, and 2100 MHz frequency bands, within distances ranging from 60 to 140 meters from the mobile phone base station. A calibrated Narda SRM-3006 spectrum analyzer, equipped with both an isotropic probe and an electric field probe, was used to assess the electromagnetic field exposure. The device covers a frequency range from 420 MHz to 6 GHz, encompassing all bands currently used for mobile communication base station transmissions.

Electromagnetic field exposure levels were recorded at the specified location. The analyzer is designed to display average field strength values, enabling the recording of average emission levels over 6 minutes according to the International Commission on Non-Ionizing Radiation Protection (ICNIRP) guidelines. This measure is critical for assessing human exposure to non-ionizing radiation. A schematic representation of the measurement setup is shown in Figure 2.

Fig. 2. Narda SRM 3006 Measuring system and Location of the measuring point.

Evaluations were made at selected locations near the mobile base station following the regulations of the Information and Communications Technology Commission of Iraq, which adopts the standards of ICNIRP, FCC, and IEEE. These organizations provide the regulatory framework for examining and measuring electromagnetic radiation emitted by telecommunications equipment and systems in Iraq. During measurements, clear line-of-sight was maintained between the measurement equipment and the base station antennas, with no physical obstructions present.

A total of ten measurement points were selected: five located within the university campus, and five situated just outside the university perimeter, specifically in areas where students typically gather while waiting for transportation. Measurements were taken in five key directions relative to the base station: east, southeast, south, southwest, and west. Directions that did not contribute significantly to the university's exposure, due to their orientation away from the campus, were excluded from the study. This spatial distribution is illustrated in Figure 3.



Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Fig. 3: The location of the antenna and the points measured from it

2. Results and discussion

3.1 Statistical or analytical methods employed

Upon completion of field measurements, the SRM-3006 was connected to a computer to take advantage of the PC SRM-3006 Tools software suite.. This software facilitated the extraction of measurement data, including screenshots saved in PNG format and data files exported in Excel format.

Data retrieval from the device's internal memory was conducted, including manual readings from locations with high potential for electromagnetic interference. For each measurement point, three types of values were recorded:

- Actual (real-time) values

- Maximum values

- Average values

These records were obtained across the frequency bands corresponding to GSM 900, GSM 1800, and GSM 2100.

The software application also provided location and time metadata, including date, time, geographic coordinates (latitude and longitude), and corresponding electric field intensity values. All collected data were subsequently organized and analyzed using Microsoft Excel, which served as the primary tool for statistical processing and visualization of the results.

3.2 Data Collection and Analysis

The SRM-3006 spectrum analyzer was configured in accordance with established standards and protocols. Specific frequency bands corresponding to mobile communication technologies were entered into the system, namely: GSM 900, GSM 1800, and GSM 2100.

Field measurements were conducted over a period of approximately 6 to 7 hours, during peak daytime activity from 8:30 AM to 3:00 PM, to capture the highest possible electromagnetic field exposure levels. Information related to the mobile base station site was gathered on location, and the tower's identification and technical details were verified upon access.

The primary objective was to measure the strength of the electric field to ascertain the maximum levels of electromagnetic energy power density. By earlier research approaches, the SRM-3006 was positioned at a 45° inclination angle and kept at a height of 1.2 to 1.5 m above ground level, or around the usual height of the human body [14, 15, 16]. To improve the accuracy of exposure assessment, ten measurements were performed at varied and random distances from the antenna. For each location, readings were taken across three downlink measurement programs, covering all relevant generations of mobile networks (2G, 3G, and 4G) operating at the 900 MHz, 1800 MHz, and 2100 MHz frequency bands, in alignment with similar approaches reported in earlier studies [6].

All measurements were conducted on level ground surrounding the base station antenna. The measurement protocol involved selecting multiple points at various distances and directions from the tower, as illustrated in Figure 3. The SRM-3006 device was activated and carefully positioned with its probe aligned directly toward the antenna, as shown in Figure 4, to ensure accurate readings. A brief stabilization period was allowed before recording the data.

At each selected location, measurements were taken sequentially for the GSM 900, GSM 1800, and GSM 2100 bands. The first reading was recorded for GSM 900 at a distance of 65 meters in the eastern direction. For each frequency band, the measurement duration was standardized to 6 minutes, in accordance with ICNIRP guidelines, allowing for the calculation of three values:

Actual (instantaneous) power density

Maximum observed power density

Average power density over the 6-minute interval.

This procedure was repeated systematically for all identified measurement points and for all three frequency bands. The detailed results of these measurements are presented in Tables 3 and 4.

Fig. 4: Placing the device Narda SRM 3006 and directing the probe on the tower to take measurements.

Table 3 presents the measured values of electromagnetic field (EMF) power density for outdoor locations near the University of Kerbala, specifically in areas just outside the university perimeter. The table includes data for the actual, maximum, and average power density levels, measured in watts per square meter or (W/m²), recorded over a 6-minute time interval, following ICNIRP standards. Measurements were taken for GSM 900, GSM 1800, and GSM 2100 frequency bands at five distinct locations around the university.

Table (3) Electromagnetic field power density measured values for location outside the University of Kerbala.

The recorded power density values varied across the different frequencies and directions, ranging from 0.000889 to 0.008885 W/m². The variation reflects the influence of both distance from the base station and antenna orientation. Details for each control point, including the frequency band, direction, distance, and time of measurement, are summarized below.

Table 3: Electromagnetic field power density measured values for location outside the University of Kerbala.

Power density S (W/ m^2)			Time (pm)	Frequency MHZ	Direction	Distance from Tower's Site (m)	N. of control point
Average (W/ m^2)	Max level (W/ m^2)	Actually (W/ m^2)					
0.000889	0.001633	0.001144	12:30	900	East	65	1
0.00366	0.006259	0.003338	12:39	1800	East		
0.00276	0.005133	0.002234	12:53	2100	East		
0.001469	0.002662	0.002396	1:03	900	South-East	60	2
0.002347	0.004762	0.001644	1:10	1800	South-East		
0.001643	0.001003	0.001365	1:18	2100	South-East		
0.001673	0.00339	0.002269	1:26	900	South	70	3
0.002909	0.006048	0.003716	1:35	1800	South		
0.00221	0.005249	0.001586	1:45	2100	South		
0.002642	0.007889	0.003191	1:54	900	South-West	75	4
0.003394	0.008338	0.002181	2:10	1800	South-West		
0.002777	0.008885	0.002589	2:23	2100	South-West		
0.002162	0.003057	0.002461	2:35	900	West	90	5
0.002775	0.006434	0.002176	2:44	1800	West		
0.001268	0.002619	0.00124	2:52	2100	West		

Meanwhile, Table 4 presents the electromagnetic field power density measured inside the University of Kerbala at five control points located in different directions and distances from the base station. Each location was evaluated for GSM 900, 1800, and 2100 MHz frequencies, and measurements include the actual, maximum, and average power density values over a 6-minute interval.

The data shows variations in power density based on distance, direction, and frequency, with values ranging between 0.000584 W/m² and 0.005682 W/m². These values are well within the safety guidelines set by international standards.

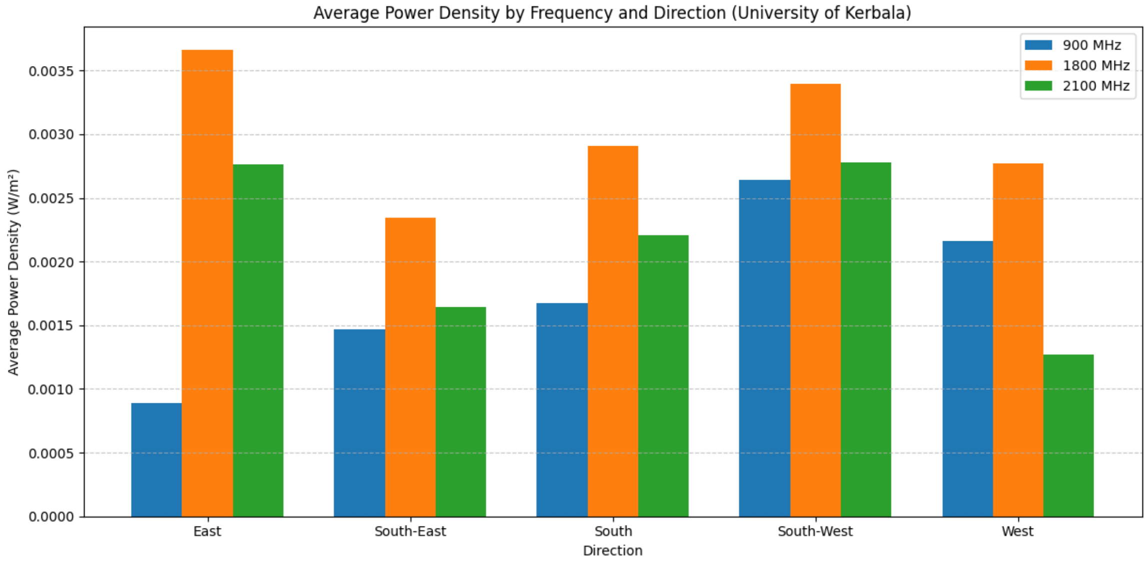


Fig. 5. Average power density by Frequency and Direction outside the University of Kerbala.

Figure 5 shows the average power density (in W/m2) for three GSM frequency bands (900 MHz, 1800 MHz, and 2100 MHz) measured inside and outside the University of Kerbala in five different geographic orientations (East, South-East, South, South-West, and West). The data reveal that the GSM1800 band consistently exhibits the highest average power density in all directions, indicating a higher level of signal transmission or usage at this frequency. Notably, the South-West and East directions show elevated power density values across all bands, likely due to closer proximity to base stations or clearer line-of-sight paths. In contrast, the lowest values were observed for GSM900 in the East direction and GSM2100 in the West direction. These findings highlight the spatial and frequency-dependent variation in electromagnetic field exposure, which is critical for environmental monitoring and the optimization of cellular network deployment.

Table (4) Values of the measured electromagnetic field power density at the University of Kerbala.

Power density S (W/ m^2)			Time (pm)	Frequency MHZ	Direction	Distance from Tower's Site (m)	N. of control point
Average (W/ m^2)	Max level (W/ m^2)	Actually (W/m^2)				(m)	
0.001186	0.001788	0.001133	10:00	900	East	130	6
0.002942	0.005682	0.002169	10:08	1800	East		
0.003582	0.004933	0.003413	10:17	2100	East		
0.00063	0.001101	0.000584	10:35	900	South-East	125	7
0.00104	0.00165	0.001203	10:43	1800	South-East		
0.000893	0.001266	0.000941	10:51	2100	South-East		
0.000936	0.001547	0.000861	11:01	900	South	130	8
0.001582	0.005336	0.001511	11:10	1800	South		
0.001112	0.001641	0.001019	11:18	2100	South		
0.001109	0.001852	0.001288	11:25	900	South-West	135	9
0.002357	0.0033	0.002458	11:33	1800	South-West		
0.00181	0.002512	0.001176	11:42	2100	South-West		
0.000876	0.001587	0.000588	11:50	900	West	140	10
0.001334	0.00177	0.001206	11:57	1800	West		
0.00106	0.001423	0.001169	12:05	2100	West		

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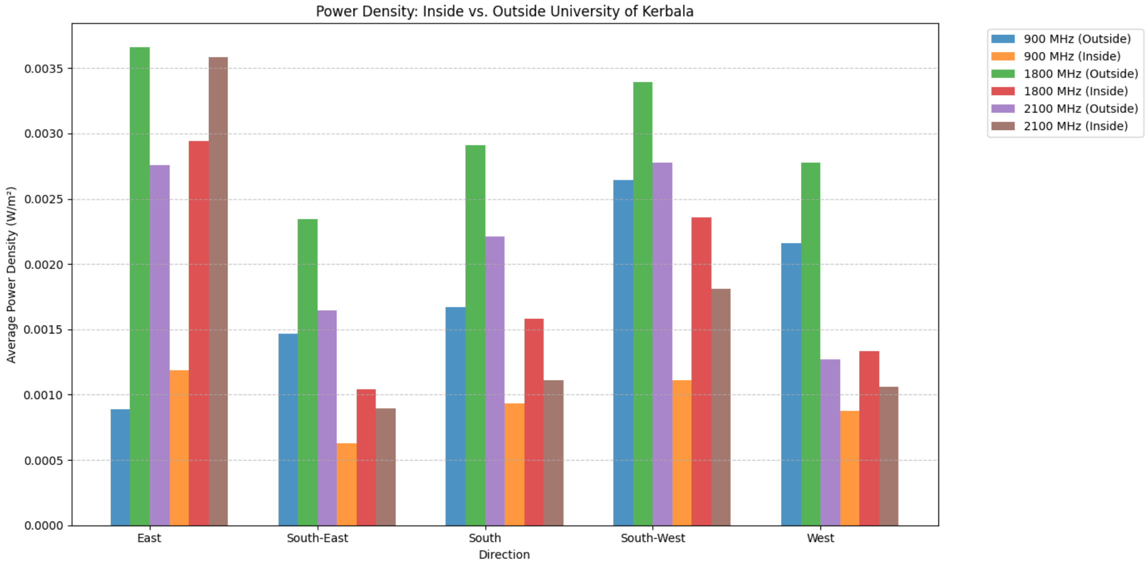

Fig. 6. Average power density by Frequency and Direction inside the University of Kerbala.

The figure 6 presents a comparative analysis of average power density (in W/m²) for GSM frequencies 900 MHz, 1800 MHz, and 2100 MHz measured both inside and outside the University of Kerbala across five directions: East, South-East, South, South-West, and West. Across all frequencies and directions, the power density values are generally higher outdoors compared to indoors, highlighting the attenuating effect of building materials on electromagnetic wave propagation. Notably, the 1800 MHz frequency band consistently records the highest power densities, particularly in the East and South-West directions, suggesting strong signal transmission or closer proximity to base stations. In contrast, the 900 MHz band shows the lowest power densities indoors, especially in the South-East and West directions. The chart underscores the directional and environmental variations in RF exposure, providing essential insights for urban planning, health assessments, and the design of wireless communication systems within academic environments.

The measurements for power density were recorded near and inside the University of Karbala for the GSM900 frequency band in the east direction were (0.000889, 0.001186 $w \backslash m^2$) respectively and in the GSM1800 frequency band for the same direction recorded (0.00366, 0.002942 $w \backslash m^2$) respectively while in the GSM2100 frequency band in the same direction too was (0.00276, 0.003582 $w \backslash m^2$) respectively.

In the southeast direction, the measurements for average power density were recorded near and inside the University of Karbala for the GSM900 frequency band (0.001469, 0.00063 $w\backslash m^2$), respectively. In the GSM1800 frequency band, for the same direction, the values were recorded (0.002347, 0.00104 $w\backslash m^2$), respectively. In the GSM2100 frequency band, for the same direction, the values were recorded (0.001643, 0.000893 $w\backslash m^2$), respectively.

In the south direction, the measurements for average power density were recorded near and inside the University of Karbala for the GSM900 frequency band (0.001673, 0.000936 $w\backslash m^2$), respectively. For the same direction, the values were recorded (0.002909, 0.001582 $w\backslash m^2$), respectively, in the GSM1800 frequency bands. While for the GSM2100 frequency band, the values were recorded as 0.00221, 0.001112 $w\backslash m^2$), respectively for the same direction too.

Average power density measurements were taken in the Southwest direction, next to the University of Karbala, and inside the University of Karbala for the GSM900 frequency band was (0.002642, 0.001109 $w\backslash m^2$). The GSM1800 frequency bands were used to record the values for the same direction (0.003394,0.002357 $w\backslash m^2$) respectively. while for the GSM2100 frequency band, the values were recorded (0.002777, 0.00181 $w\backslash m^2$), respectively for the same direction too.

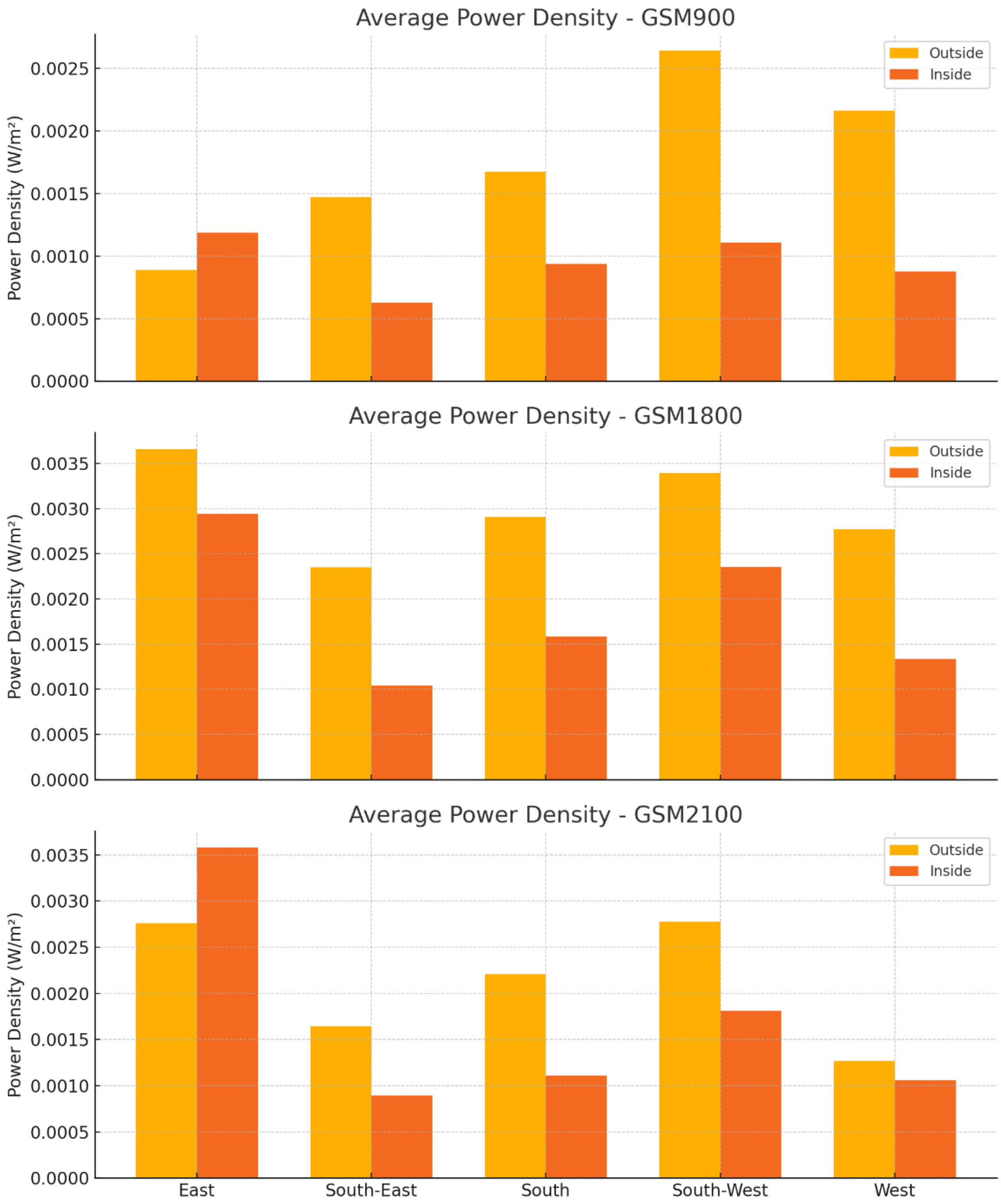

Fig. 7. Average power density by Frequency and Direction inside and outside the University of Kerbala.

The figure 7 comprises three bar charts comparing the average power density (W/m²) of electromagnetic fields for GSM900, GSM1800, and GSM2100 frequency bands, measured inside and outside buildings in five directions (East, South-East, South, South-West, and

West) within the University of Kerbala. In all three frequency bands, outdoor measurements consistently show higher power density values than indoor ones, emphasizing the shielding effect of building structures. For GSM900, the South-West direction exhibits the highest power density outside, while indoor values remain relatively low across all directions. GSM1800 presents the highest overall outdoor power density in the East direction, followed closely by South-West, with a noticeable reduction indoors. Interestingly, for GSM2100, the East direction shows the highest indoor power density, slightly exceeding the outdoor value, possibly due to indoor signal amplifiers or reflections. Finally, in the west direction, the measurements for average power density were recorded near and inside the University of Karbala for the GSM900 frequency band (0.002162, 0.000876$w\backslash m^2$), respectively. In the GSM1800 frequency band, for the same direction, the values were recorded (0.002775,0.001334 $w\backslash m^2$), respectively. In the GSM2100 frequency band, for the same direction, the values were recorded (0.001268, 0.00106 $w\backslash m^2$), respectively.

Table 5 presents the highest average power density values recorded for GSM 900 MHz, GSM 1800 MHz, and GSM 2100 MHz frequency bands, alongside their corresponding percentage levels relative to the international exposure limits set by ICNIRP, FCC, and IEEE. For GSM 900 MHz, the maximum average power density was 0.002642 W/m², observed at point A1 in the southwest direction, representing only 0.0587% of the ICNIRP limit. For GSM 1800 MHz, the highest value was 0.003394 W/m² at point A2, also in the southwest direction, which accounts for 0.0377% of the ICNIRP reference level. The maximum for GSM 2100 MHz was 0.003582 W/m², measured at point A3 in the east direction, constituting 0.0358% of all three standards (ICNIRP, FCC, and IEEE). These values are significantly below the recommended exposure limits, indicating that the electromagnetic field (EMF) radiation levels in the studied areas are within safe limits for human exposure.

Table 5: The greatest average value for the GSM 900MHz, GSM 1800MHz, and GSM 2100 MHz frequencies

The greatest average value for the GSM 900 MHz frequency						
Percentage of determinants			The average	Symbol	Point	Direction
ICNIRP 4.5	FCC 6	IEEE 6				
0.0587%	0.044%	0.044%	0.002642	A1	4	Southwest
The greatest average value for the GSM 1800 MHz frequency						
Percentage of determinants			The average	Symbol	Point	Direction
ICNIRP 9	FCC 10	IEEE 6				
0.0377%	0.03394%	0.0565%	0.003394	A2	4	Southwest
The greatest average value for the GSM 2100 MHz frequency						
Percentage of determinants			The average	Symbol	Point	Direction
ICNIRP 10	FCC 10	IEEE 10				
0.0358%	0.0358%	0.0358%	0.003582	A3	6	East

3. Conclusion

This study systematically investigated the electromagnetic field levels emitted from antenna towers in Karbala City. We collected data on radio frequency levels at mobile phone stations in and around the University of Karbala area, which provided power density measurements for GSM 900, GSM 1800, and GSM 2100 frequency band signals. Then we compared the results with national (Iraqi Ministry of Health and Environment) and international (ICNIRP, FCC, IEEE) standards for radiation exposure.

The findings demonstrated that the horoscope antennas' radio frequency radiation levels fall within acceptable bounds for various radio frequency signals established by the Iraqi Ministry of Health and Environment based on standards provided by ICNIRP and international standards from other organizations, such as the FCC and IEEE for exposure standards.

The GSM900's highest average was (0.002642 $w\backslash m^{2}$), for point 4 at (75 m) in the southwest direction, which was much less than ICNIRP, FCC, and IEEE, with a percentage of (0.0587%) (0.044%) (0.044%) respectively. We also note that the power density levels for the GSM frequencies 1800 ($w\backslash m^{2}$) ranged between (0.003394 – 0.001044 $w\backslash m^{2}$), The highest average was (0.003394 $w\backslash m^{2}$) in point 4 at 75 M in the southwest direction which was much less than the ICNIRP, FCC, and IEEE with a percentage of (0.0377%) (0.03394%) (0.0565%) respectively. Finally, it turns out that the energy density levels for the GSM frequencies 2100 ($w\backslash m^{2}$), varied from (0.003582 – 0.008928 $w\backslash m^{2}$). The highest average was (0.003582 $w\backslash m^{2}$) in point 6 at 130 M in the east direction, which was less than the ICNIRP, FCC, and IEEE with a percentage of (0.0358%) (0.0358%) (0.0358%) respectively. However, some hot spots with slightly elevated values indicate the need for periodic monitoring to ensure that the rapid growth of communications infrastructure does not result in unsafe exposure levels.

Recommendations

The results of this study provide a valuable reference for policymakers and stakeholders in ensuring safe and sustainable communications practices in Karbala City. Implementing such scientific documentation on exposure to electromagnetic fields can further support efforts to alleviate community concerns and promote safety.

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