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Measuring the Emission of Non-Ionizing Radiation from Mobile Phone Transceiver Towers

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Abstract
This study presents an assessment of non-ionizing radio frequency (RF) radiation emitted by mobile phone base stations transceiver (BTSs) in the city of Al-Ajailat, Libya. Using the HF32D broadband electromagnetic field analyzer, measurements were conducted at 40 outdoor locations near four different towers, covering the frequency range of 800 MHz to 2.7 GHz. Additional readings were taken vertically across seven floors of a building adjacent to one of the towers. Measurements were performed hourly over a 13-hour period to capture temporal variations. Results were analyzed with respect to ICNIRP exposure guidelines and international benchmarks. The findings indicate that the measured power density levels were well below the ICNIRP reference limits. While the study confirms compliance with international safety standards, it highlights variations in exposure based on distance, elevation, and time of day. These insights may help inform public safety planning and future studies of RF exposure in urban environments.

Keywords: power density, mobile phone, Electromagnetic radiation, RF exposure.

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قياس الاشعاعات غير المؤينة الصادرة من ابراج استقبال وارسال الهاتف المحمول

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الملخص

تقدم هذه الدراسة تقييماً للإشعاع الكهرومغناطيسي غير المؤين(RF) المنبعث من محطات الإرسال والاستقبال للهاتف المحمول (BTS) في مدينة العجيلات، ليبيا. تم إجراء القياسات باستخدام محلل المجال الكهرومغناطيسي واسع النطاق(HF32D) في 40 موقعًا خارجيًا بالقرب من تسعة أبراج مختلفة، ضمن نطاق تردد يتراوح بين 800 MHz و 2.7 GHz . كما تم أخذ قراءات إضافية رأسيًا عبر سبعة طوابق في مبنى مجاور لأحد الأبراج. كما نُفذت قياسات في نقطة بإحدى الشوارع الرئيسية كل ساعة على مدار13 ساعة لرصد التغيرات قيم الاشعاع مع الزمن. حيث تم تحليل النتائج بالرجوع إلى إرشادات اللجنة الدولية للحماية من الإشعاع غير المؤين (ICNIRP) والمعايير الدولية ذات الصلة. أظهرت النتائج أن مستويات كثافة القدرة المقاسة كانت أقل بكثير من الحدود المرجعية الموصي بها من قبلICNIRP. وبينما تؤكد الدراسة الالتزام بالمعايير الدولية للسلامة، فإنها تُبرز وجود تباينات في مستوى التعرض بحسب المسافة والارتفاع والوقت خلال اليوم، ما قد يُسهم في توجيه خطط السلامة العامة ودراسات مستقبلية حول التعرض للإشعاع في البيئات الحضرية.

الكلمات المفتاحية: كثافة الطاقة، الهاتف المحمول، الإشعاع الكهرومغناطيسي، التعرض للترددات الراديوية.

1 .Introduction

Most of the studies of radio frequency (RF) power density and its potential health effects has become a significant area of research, particularly with the expansion of mobile telecommunications infrastructure. Various international and regional studies have provided valuable insights into the levels of RF emissions and their

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implications. Unlike ionizing radiation, non-ionizing radiation does not have enough energy to remove electrons from atoms or molecules. Instead, it causes excitation, which can result in heat or other effects, especially with intense or prolonged exposure [1, 2]. In many developed countries, specialized devices have been established for monitoring non-ionizing radiation. Laws, regulations, and necessary procedures have been implemented to protect against non-ionizing radiation and its potential effects. Additionally, proactive measures and plans have been developed to prevent exposure and to raise awareness of the associated risks [3]. Some Arab countries have prioritized this aspect, including Iraq, Kuwait, and Egypt. Egypt issued its first protocol in the 2000s, which was based on the recommendations of the International Commission on Non-Ionizing Radiation Protection (ICNIRP) and the Institute of Electrical and Electronics Engineers (IEEE) [4]. Determination of energy density levels for mobile phone radiation in Hilla City. This letter is the first study in the Middle Euphrates region and Iraq to detect the intensity levels of electromagnetic wave radiation emitted from the towers of mobile phone companies in the center of Hilla city. Where HF59B analyses were used in this research to measure the energy density of electromagnetic radiation manufactured by the German company GIGAHERTZ SOLUTION, which works within frequencies located between 800 and 2700 GHz, the measurement range using a special antenna installed in the device is 0-1999.99 μW/m². The study presented that the highest energy density and the lowest density were 277.5 μW/m² and 15 μW/m², respectively Also, to study the change of energy density with time in a specific area, its coordinates were fixed and the energy density was recorded throughout the day at a rate of four readings per hour and fixed peak hours, which are below the values mentioned in the radio frequency safety controls. And the outcome of this study is that because of the increase in population distribution in the city center compared to its outskirts, there was an increase in the levels of energy density in city center and after working hours [5]

A study calculation was done in the Nile Center; the study focuses on measuring and understanding the levels of electromagnetic energy emitted by mobile phone towers. It highlights that mobile phones and their towers use electromagnetic radiation for communication, specifically in the radio wave part of the electromagnetic spectrum. The researchers used a German-made

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HF59B analyzer device to measure the electromagnetic energy density within the frequency range between 700 and 2700 MHz in the range of mobile phone operation. The study measured energy density levels across the surveyed area. The lowest recorded energy density was 18.15 µW/m², and the highest was 162 µW/m². The locations of mobile phone towers were identified and mapped. The results showed that the energy density levels generally decreased as the measurement point moved farther away from a mobile phone tower. The study also noted that energy density levels are influenced by several factors, including the type of tower, distance from the tower, and height. The measured energy density levels were categorized into four intensity levels: low, medium, above average, and high. The study observed a clear relationship between distance from the tower and the increase in energy density levels. The presence of towers on residential rooftops is also mentioned as a potential health risk [6]. A comprehensive, broad-spectrum framework conducted by the Institute for Psychological Thinking in Germany. 38 health questions have been responded to by about 51,444 persons. A multi-locus linear model was used to predict health problems, including closeness to mobile phone transmitter tower. About 30,047 participants (58.6% of all), 18.7% were concerned about the harmful effects of mobile phone base stations, while 10.3% living near a mobile phone base station (500 meters), have more health problems than others. Therefore, the harmful effects of mobile phones have health risks [7]. In a comprehensive study conducted in Nigeria, researchers measured RF power density around base stations situated in residential neighborhoods. The mobile phone frequency bands considered in the study included GSM 900 MHz, GSM 1800 MHz, and Wi-Fi 2400 MHz. A spectrum analyzer (HF2025E) was utilized for the measurements. The findings revealed that the maximum power density observed was often higher during peak hours of mobile phone usage. The results indicate that RF fields fluctuate over time and vary by location, reflecting different power densities. Additionally, this study compared the measured values with national and international exposure limits (ICNRP), concluding that continuous monitoring and stricter regulations are essential to ensure public safety [8]. A similar study conducted in South Korea evaluated the RF power density levels in both urban and rural environments. The findings revealed that urban areas displayed higher power density levels, attributed to a greater concentration of cell towers and increased

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mobile phone usage. Notably, the study also recorded a significant decrease in power density levels during night-time, which correlated with reduced mobile phone activity [9].

1.1 Health Implications of RF Exposure

The potential health effects of RF radiation from mobile phone base stations have been the subject of extensive research and debate. The World Health Organization (WHO) and the International Commission on Non-Ionizing Radiation Protection (ICNIRP) have established guidelines to limit exposure to RF radiation in order to mitigate potential health risks [10, 11]. Studies have suggested potential links between prolonged exposures to RF radiation and various health issues. For instance, one study indicated an increased risk of glioma and acoustic neuroma among heavy mobile phone users. Additionally, another report highlighted potential risks, including cognitive impairments, sleep disturbances, and an increased incidence of cancer associated with chronic RF exposure [12, 13]. Many clinical studies agree that no confirmed health damage has been found as a result of exposure to electromagnetic radiation at levels below 0.5 mW/cm². However, exposure to higher levels of this radiation in cumulative doses may lead to various symptoms, including fatigue, headaches, tension, cancers, and organic symptoms affecting the visual, cardiovascular, and immune systems. Additionally, psychological changes may occur after exposure to electromagnetic radiation at a level of 10 mW/cm² [14]. Although, there remains a lack of consensus within the scientific community concerning the long-term health effects of low-level RF exposure. The World Health Organization's International Agency for Research on Cancer (IARC) has classified RF electromagnetic fields as possibly carcinogenic to humans (Group 2B), based on an increased risk of glioma associated with wireless phone use [15]. Despite these findings, other studies have not provided conclusive evidence of health risks at exposure levels below the ICNIRP guidelines. For instance, the rising use of mobile phones raises questions about cancers, particularly in the head region (such as eye tumours, brain cancer, and acoustic neuromas), where exposure to electromagnetic fields is especially sensitive. The study selected all Danish citizens whose first mobile phone subscription occurred between 1982 and 1995. The results indicate that no association was found between mobile phone use and an increased risk of cancer. These overall findings are consistent with other epidemiological studies that have demonstrated no increased cancer risk associated

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with mobile phone use during the first decade [16]. Given the mixed results, ongoing research and continuous monitoring are essential to fully understand the potential health implications of RF radiation. Furthermore, the precautionary principle suggests that it is prudent to minimize unnecessary exposure, especially for vulnerable populations such as children and pregnant women [17]. Although numerous studies have measured electromagnetic radiation intensity around communication towers in regions other than the study area, this research represents the first of its kind in the city of Al-Ajailat. It offers precise temporal and spatial coverage, relying on measurements taken at multiple locations containing mobile phone transmitting and receiving stations. Additionally, it includes measurements at various heights and at a fixed point over a continuous 13-hour period. The integration of spatial and temporal analysis, along with comparisons to international standards, makes this study a unique contribution to the assessment of radiofrequency (RF) exposure in urban environments. It is important to note that this study focuses on measuring the maximum levels of electromagnetic radiation, rather than minimal values, which are biologically insignificant. Furthermore, the results are compared with permissible exposure limits established by international organizations, such as the International Commission on Non-Ionizing Radiation Protection (ICNIRP). Consequently, the measurement uncertainty associated with the device's ±6 dB accuracy does not significantly affect the study's conclusions. Potential signal interference from other sources was significantly reduced by using a three-dimensional directional antenna that was accurately aimed at the primary radiation source, thereby improving the precision of the readings. Environmental factors, such as temperature fluctuations or nearby human movement, are inherently considered within the context of on-site field measurements, under the assumption that the measured values reflect the exposure of an individual present at the measurement location at that moment. This methodology enhances practical relevance and reflects the real-world environmental context of exposure.

1.2 Examples of non-ionizing radiation sources:[18]

Visible light, microwaves, radio waves, displays, electrical supply lines, high pressure, medical devices, lasers, mobile phones and their towers, along with many other sources of non-ionizing radiation, are illustrated in Figure 1.

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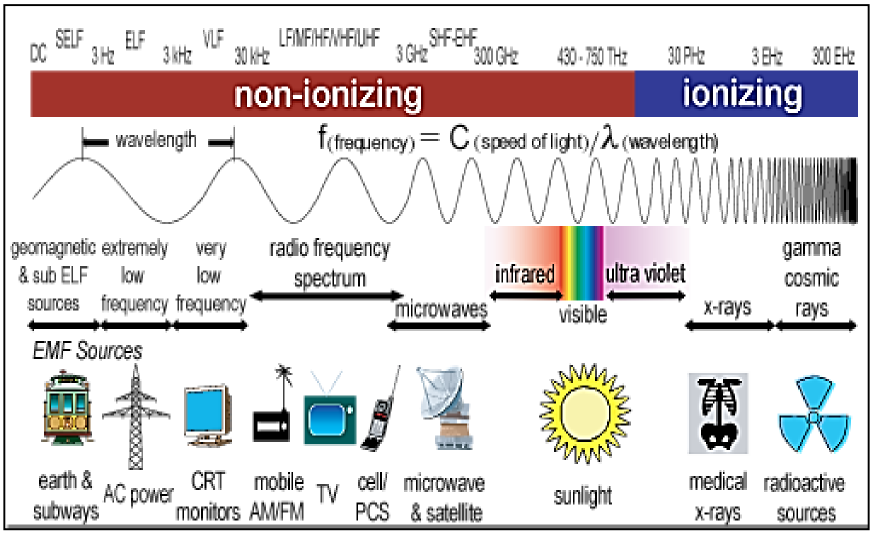

Figure 1: Examples of non-ionizing radiation source [19]

International Organizations and Authorities Concerned with Non-Ionizing Radiation:

- International Agency for Research on Cancer (IARC)
- International Commission on Non-Ionizing Radiation Protection (ICNIRP).
- Environmental Protection Organization (EPO).
- American National Standards Institute (ANSI).
- United Kingdom Health Security Agency (UKHSA).
- American Institute of Electrical and Electronics Engineers (IEEE).
- The International Association of Electrical, Electronic, Energy and Engineering (IAEEEE).
- International Electro-technical Commission (IEC)
- Swedish Radiation Protection Institute (SSI).
- World Health Organization (WHO).
- National Radiological Protection Board (NRPB).
- And analysis of process deviations will be assessed.

3. Experimental Work

3.1 Objectives of measurements

A. Knowing the radiation emission levels in the entire study area.

B. Studying the relationship between average power density and height.

C. Studying the relationship between average power density and time.

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D. Studying the relationship between average power density and distance.

3.2 Devices and Software Used:

3.2.1 Power density measuring device

The measurements were taken using the HF32D RF signal meter, as shown in Fig.2. This device is manufactured by the German company GIGAHERTZ-SOLUTIONS and has an accuracy of ±6 dB. This means that the measured value could be up to 6 dB higher or lower than the actual value. The meter features a zero deviation and measures power flux density from 1 µW/m² to 1,999 µW/m² within a frequency range of 800 MHz to 2,500 MHz, making it suitable for mobile phones. The measurements were recorded in microwatts per square meter (µW/m²). This device utilizes an open signal program that allows the user to determine the transmission signal, coverage area, and the nearest tower. It is a compact, lightweight, hand-held device equipped with a long antenna that measures in three dimensions. The antenna was oriented directly toward the radiation source to ensure optimal readings.

Figure. 2: HF32D field strength meter

3.2.2. Google Maps:

Google Maps was utilized to determine the coordinates of the towers and the locations where power density would be detected and measured. These coordinates represent the distance of each point in degrees, minutes, and seconds (deg, min, sec) from the eastern longitude E and northern latitude N.

3.2.3. Maple 18:

A free program developed by Maple Software, this advanced analytical calculation system employs mathematical and computational concepts to solve a wide range of simple and

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complex problems across various scientific engineering, and economic fields. It facilitates both numerical and visual computation, making it useful for drawing curves and analyzing collected data.

3.2.4 Method of Work:

The side survey measurements were divided into two parts: Part 1 focused on the power density levels within a 1 km radius, taking into account time variations, height, and distance from the towers. Part 2 measured radiation emission levels across the entire study area, which included 40 selected points around the city center and within an area of 3 km².

Part 1:

The study area was initially defined as a circle with a radius of 1 km around the center of Al-Ajilat, which has a population of approximately 150,000 people. It is located in the northern part of Libya, about 80 kilometers west of the capital, Tripoli .There are nine towers in this area, classified according to their respective companies and commercial subsidiaries: New Orbit, Libyana, and Libya Telecom & Technology (LTT), as shown in Table No.1, and their locations are illustrated in Fig. 3. All points in the study area were recorded in seconds (sec") only, as they share the same coordinates in degrees and minutes (12° 22'E, 32° 45'N). The variable measured is the coordinates in seconds (sec) only, where 1° = 60', and 1' = 60". At each measuring point, the three highest readings were recorded.

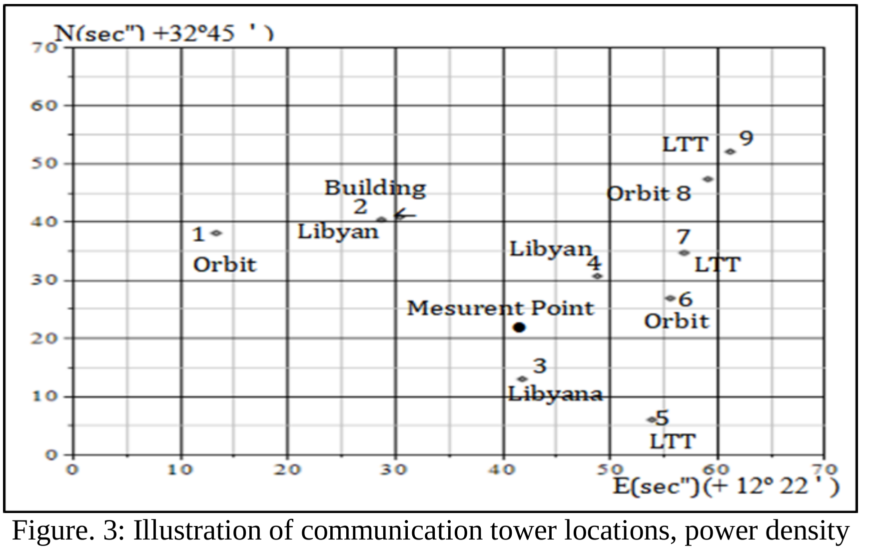

Figure. 3: Illustration of communication tower locations, power density measurement point with time and measurement point with height

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Table 1. Tower coordinates and classification by companies

Tower No.	Frequency MHz	Coordinates	Company Name	Limited Values (f/2000) mW/cm2
1	900	32°45'38.0"N 12°22'13.4"E	New Orbit	0.45
2	2100	32°45'40.3"N 12°22'28.8"E	Libyana	1.05
3	1800	32°45'12.9"N 12°22'41.9"E	Libyana	0.90
4	1800	32°45'30.6"N 12°22'48.9"E	Libyana	0.90
5	2000	32°45'05.9"N 12°22'54.0"E	LTT	1.00
6	900	32°45'26.8"N 12°22'55.7"E	New Orbit	0.45
7	2000	32°45'34.61"N 12°22'56.97"E	LTT	1.00
8	900	32°45'47.28"N 12°22'59.2"E	New Orbit	0.45
9	2000	32°45'52"N 12°23'01.26"E	LTT	1.00

1. Average power density and time:

To begin identifying measurement points, we selected a point with coordinates [32°45'20.4 12°22'41.1"E] on one of the main streets of Al-Ajilat city, situated 221 meters from Tower 3. Using Google Maps, we accurately pinpointed the measurement location corresponding to these coordinates. Figure 4 illustrates the location where the average power density was measured over time. As detailed in Table 2, measurements were recorded at a rate of three readings per hour, starting at 8:00 a.m. and concluding at 9:00 p.m. Maple 18 was subsequently utilized to plot the relationship between average power density and time, as shown in Fig. 5.

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Figure. 4: Location for measuring the average power density over time.

Table 2. Measured values of average power density over time

Average Readings µW/m²	Third Reading µW/m²	Second Reading µW/m²	First Reading µW/m²	Reading / Time
1018	1024	1012	1018	am 8:00
1069	1072	1067	1068	am9:00
1120	1124	1121	1115	am 10:00
1145	1140	1150	1145	am 11:00
1146	1151	1144	1143	12:00 pm
1247	1244	1247	1250	01:00 pm
1250	1253	1248	1249	02:00 pm
1298	1299	1298	1297	03:00 pm
1349	1369	1339	1339	04:00 pm
1527	1528	1543	1510	05:00 pm
1832	1839	1825	1832	06:00 pm
1953	1954	1945	1960	07:00 pm
1171	1176	1175	1162	08:00 pm
1044	1048	1034	1050	09:00 pm

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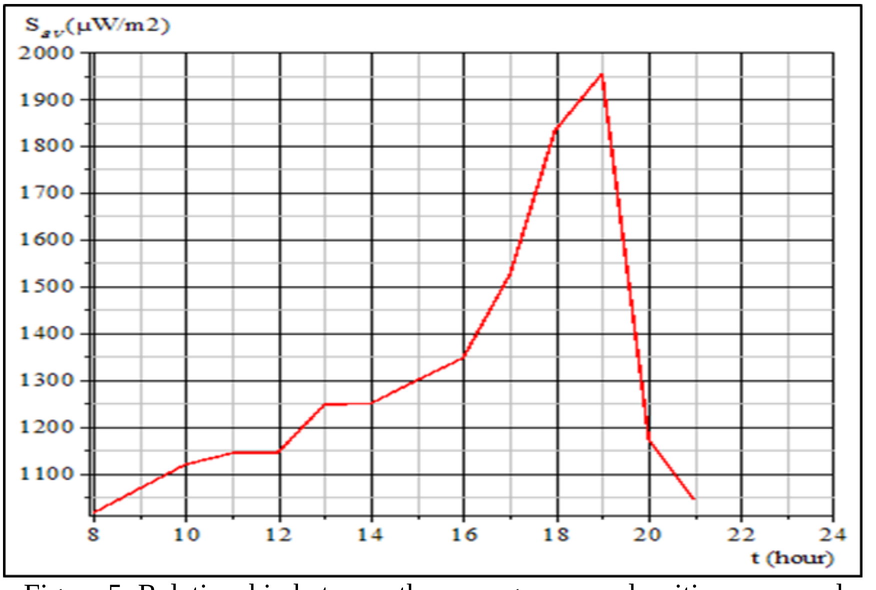

Figure 5: Relationship between the average power densities measured over time (t)

2. Average Power Density and Height :

In this case, a seven-story building was utilized. Its coordinates are [32°45′40.8″N, 12°22′30.5″E]. The building was 28 meters tall and was located 29 meters away from Tower No. 2, which is situated directly opposite it. As referred to in Figure 6.

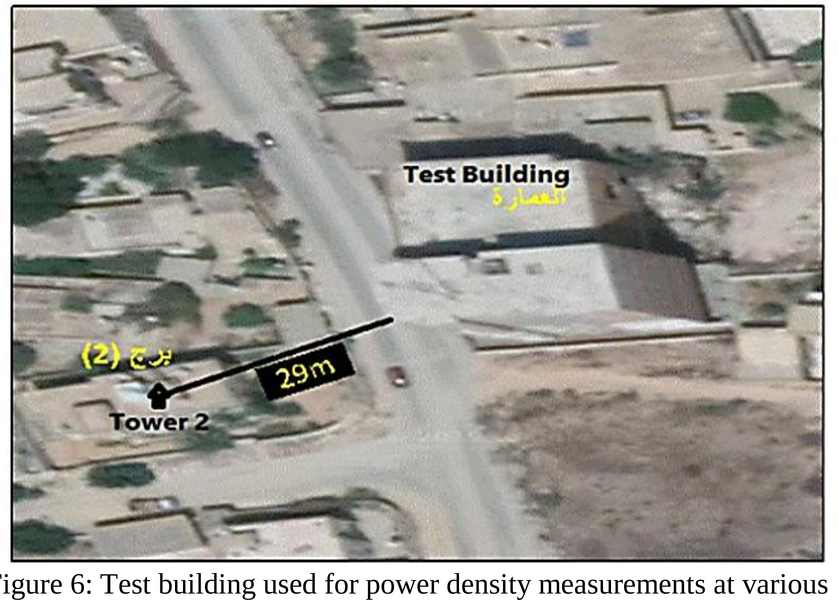

Figure 6: Test building used for power density measurements at various heights

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In Tables 3 and 4, the average power density was measured on each floor at distances of 35 and 40 meters from Tower No.2, respectively. Consequently, Figures 7 and 8 illustrate the graphical relationship.

Table 3. Measured values of average power density with height at 35m from Tower No.2

Reading Average μW/m^2	Third Reading μW/m^2	Second Reading μW/m^2	First Reading μW/m^2	Reading / Height
302	289	306	311	Ground floor 1m
498	486	493	515	First floor 5m
1008	1100	924	1000	Second floor 9m
1759	1797	1700	1780	Third floor 13m
1857	1799	1895	1877	Fourth floor 17m
1958	1993	1901	1980	Fifth floor 21m
1910	1911	1907	1912	Sixth floor 25m
1609	1608	1602	1617	Seventh floor 29m

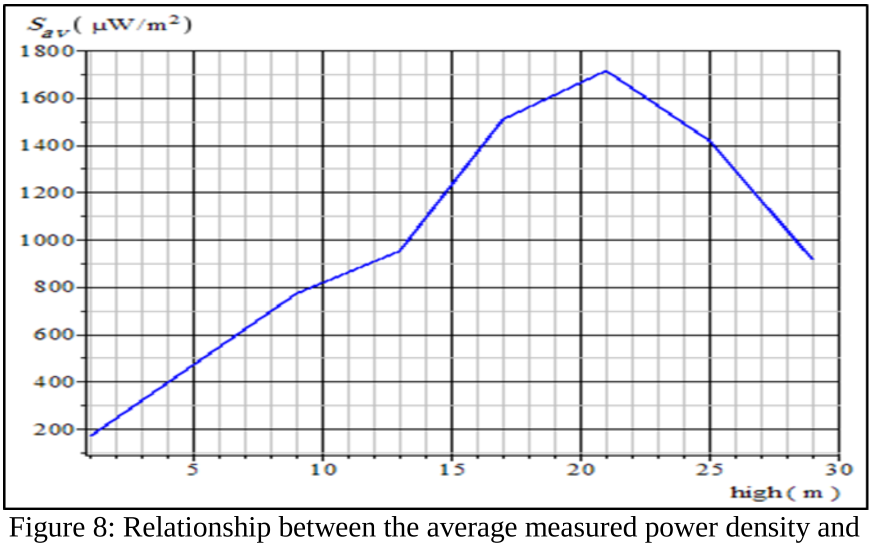

Figure 8: Relationship between the average measured power density and height at a distance of 40 m from Tower No 2.

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Summary of part 1:

This section describes the relationship between the average power density measured and the height at a distance of 35 meters from Tower No. 2. The graphical representation is based on the data presented in Table 2. The x-axis indicates the height of each floor of the building, with measurements taken on the roof of each level, which is 4 meters high, as well as at a height of 1 meter above the ground. The tower and the measuring point are positioned 35 meters apart horizontally. The average power density at each height is displayed on the y-axis, with the lowest value recorded at 302 µW/m² and the highest at 1958 µW/m².

Table 4 illustrates the graphical relationship between the average the roof of each level, which is 4 meters high, as well as at a height of 1 meter above the ground. The average measured power density values at each height are displayed on the Y-axis; the lowest value recorded is 167 µW/m², while the highest is 1713 µW/m²power density measured and the height at a distance of 40 meters from Tower No. 2. The horizontal distance between the tower and the measurement site is 40 meters, with the X-axis representing the height of each level of the building, measurements were taken on

Part 2

To evaluate the mean power density across a region of 3 km², 40 field measurements were taken between 12:00 PM and 1:00 PM, as illustrated in Fig. 9. The recorded values for each measurement ranged from 12 µW/m² to 1934 µW/m², depending on the measurement site's distance from the towers, as detailed in Table 5. The data from Table 5 were categorized into intervals of 100 µW/m² and plotted using Maple 18 software, as shown in Fig. 10. The average power density for the 40 points of interest is represented for the study area. On the X-axis, twenty measurement intervals, each consisting of 100 µW/m², are displayed, while the Y-axis indicates the count of readings (n) taken. Average values of power density, along with their respective counts, are presented in shaded columns. The readings for the first through third intervals begin at 12, 100, 200, and 300 µW/m², while the fourth interval starts at 300 and continues with 376, 476, 576, and so forth, until the twentieth interval.

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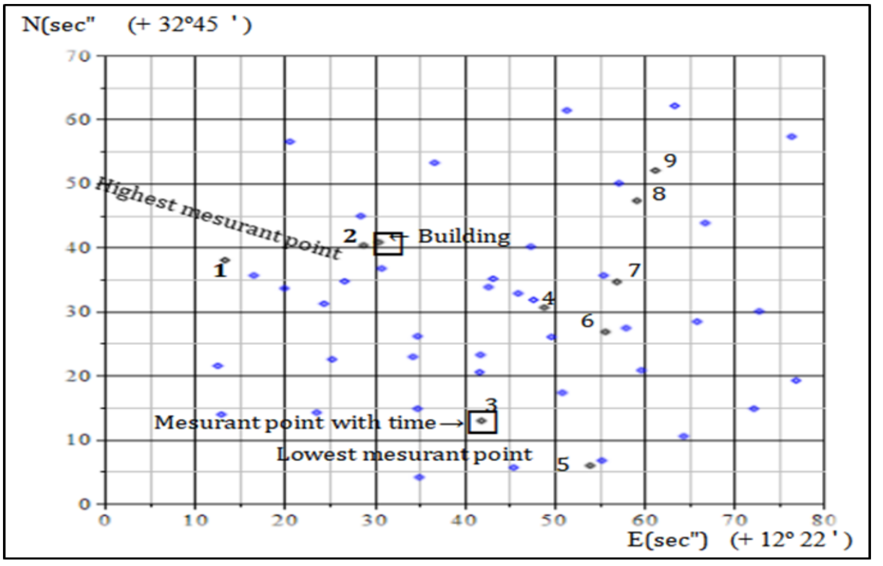

Figure 9: 40 field measurements within 3km2 to evaluate the mean power density

Table 5. Measured values of average power density for 40 points within 3km2

Reading Average µW/m²	Third Reading µW/m²	Second Reading µW/m²	First Reading µW/m²	Coordinates	Point No.
571	115	166	154	32°45'21.5"N 12°22'12.6"E	.1
21	41	12	10	32°45'13.9"N 12°22'13.0"E	.2
888	878	903	838	32°45'35.6"N 12°22'16.6"E	.3
230	233	228	229	32°45'33.6"N 12°22'20.0"E	.4
62	32	82	27	32°45'56.5"N 12°22'20.6"E	.5
24	24	23	52	32°45'14.2"N 12°22'23.6"E	.6
010	210	98	010	32°45'31.2"N 12°22'24.4"E	.7
861	861	219	801	32°45'22.5"N 12°22'25.3"E	.8
1894	1860	4081	1982	32°45'34.7"N 12°22'26.7"E	.9

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7731	0871	8164	1855	32°45'44.9"N 12°22'28.5"E	.10
3491	6691	1863	1973	32°45'36.7"N 12°22'30.8"E	.11
1213	1234	1204	1201	32°45'22.9"N 12°22'34.3"E	.12
62	58	36	65	N″32°45'14.8 E″12°22'34.8	.13
600	609	601	590	32°45'26.1"N 12°22'34.8"E	.14
092	692	272	302	32°45'4.1"N 12°22'35"E	.15
68	80	85	93	32°45'15.0"N 12°22'36.3"E	.16
1247	1244	1247	1250	32°45'20.4"N 12°22'41.1"E	.17
306	730	302	309	32°45'23.2"N 12°22'41.8"E	.18
736	704	207	613	32°45'33.8"N 12°22'42.7"E	.19
200	195	204	201	32°45'35.1"N 12°22'43.2"E	.20
457	492	462	741	32°45'5.6"N 12°22'45.5"E	.21
300	295	290	315	32°45'32.8"N 12°22'46.0"E	.22
874	931	877	814	32°45'40.1"N 12°22'47.4"E	.23
812	805	813	818	32°45'31.8"N 12°22'47.7"E	.24
1092	1113	2711	8101	32°45'26.0"N 12°22'49.7"E	.25
473	447	491	445	32°45'17.3"N 12°22'50.9"E	.26
39	40	36	41	32°46'01.4"N 12°22'51.4"E	.27
435	435	428	442	32°45'06.9"N 12°22'55.5"E	.28
676	886	716	624	32°45'35.6"N 12°22'55.5" E	.29
691	806	967	714	32°45'50"N 12°22'57.2"E	.30
575	540	528	657	32°45'27.4"N 12°22'58.0"E	.31
274	592	283	082	32°45'20.8"N 12°22'59.7"E	.32

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1423	7142	3641	4061	32°46'02.1"N 12°23'03.4" E	.33
637	137	390	736	32°45'10.5"N 12°23'04.4"E	.34
354	357	350	355	32°45'28.4"N 12°23'05.9"E	.35
464	506	429	457	32°45'43.8"N 12°23'06.8"E	.36
342	364	320	234	32°45'14.8"N 12°23'12.2"E	.37
184	178	186	188	32°45'30.0"N 12°23'12.8"E	.38
317	263	630	931	32°45'57.3"N 12°23'16.4"E	.39
181	189	019	164	32°45'19.2"N 12°23'16.9"E	.40

1. Studying the Relationship between Average Power Density and Distance

The following points were selected to illustrate the relationship between average power density and distance: points (3, 4, 7) near Tower No. 1, points (20, 22, 24) near Tower No. 4, points (28, 34, 37) near Tower No. 5, and points (31, 35, 38) near Tower No. 6. The distance of each point from the adjacent tower was calculated and is presented in Table 6. Fig. 10 displays the data representation for all points in the study area. As shown in Figure11, 12, 13, and 14, the average power density and distance were graphically plotted.

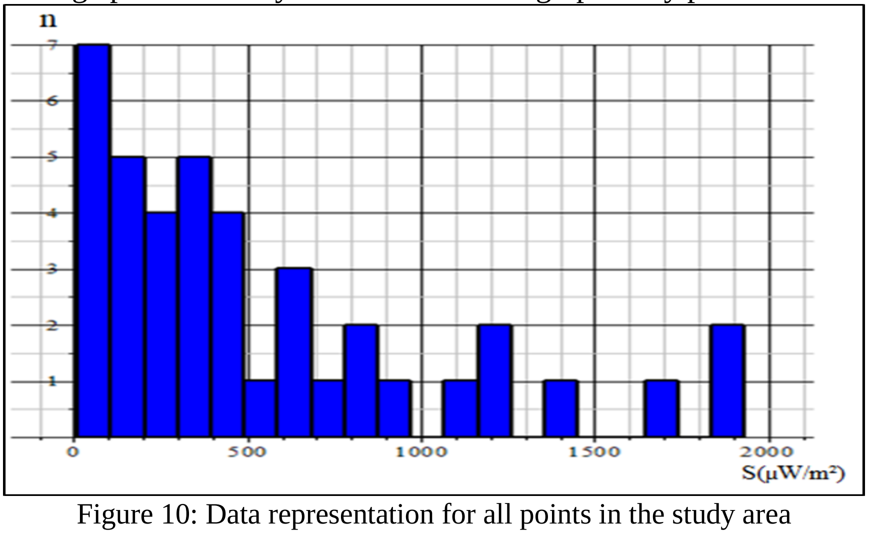

Figure 10: Data representation for all points in the study area

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Table 6. Average power density values measured with distance

Reading Average μW/m^2	Distance m	Tower No.	Point No.
888	89	1	3
230	300		4
100	430		7
812	48	4	24
300	100		22
200	200		20
435	50	5	28
376	310		34
342	530		37
575	80	6	31
354	270		35
184	450		38

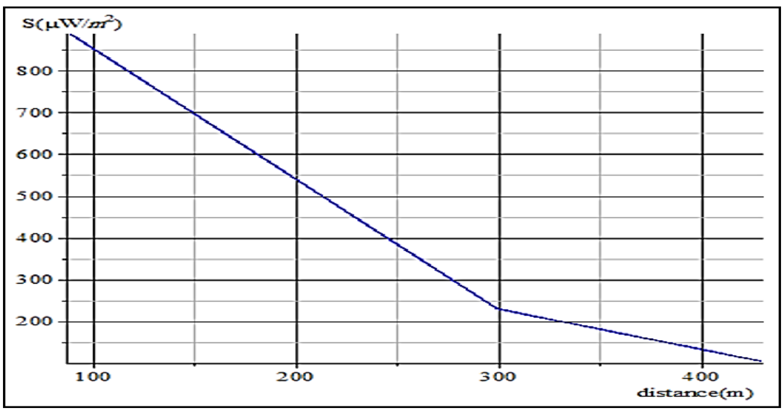

Figure 11: Relationship between the average power densities measured near Tower No.1 and the distance

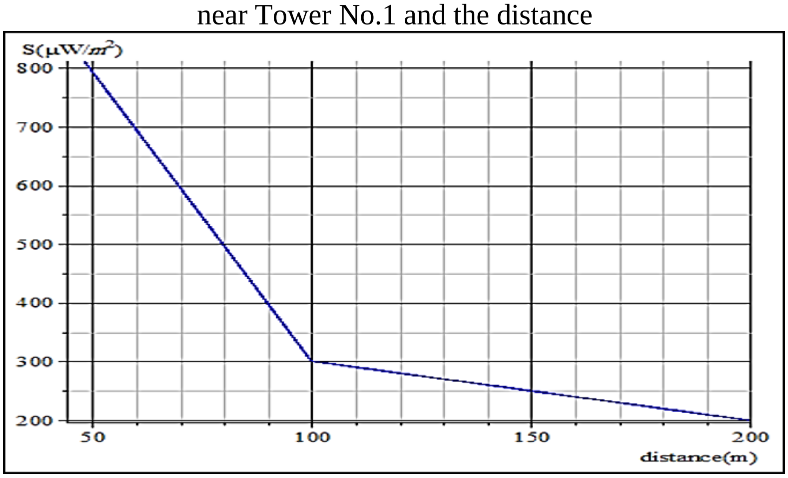

Figure 12: Relationship between the average power densities measured near Tower No. 4 and the distance

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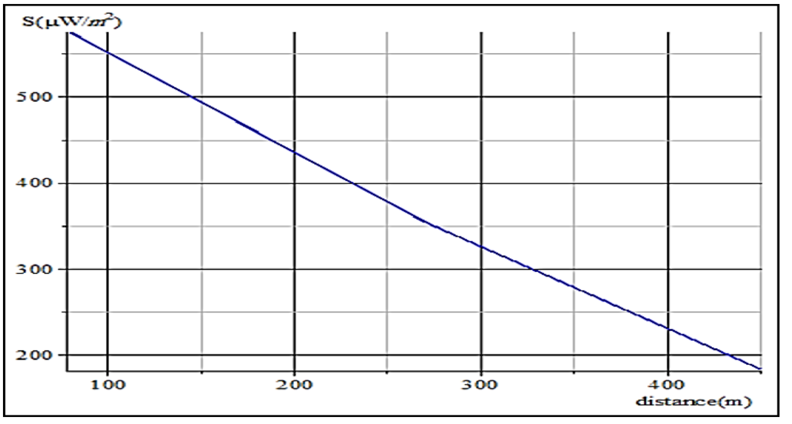

Figure 13: Relationship between the average power densities measured near Tower No. 5 and the distance

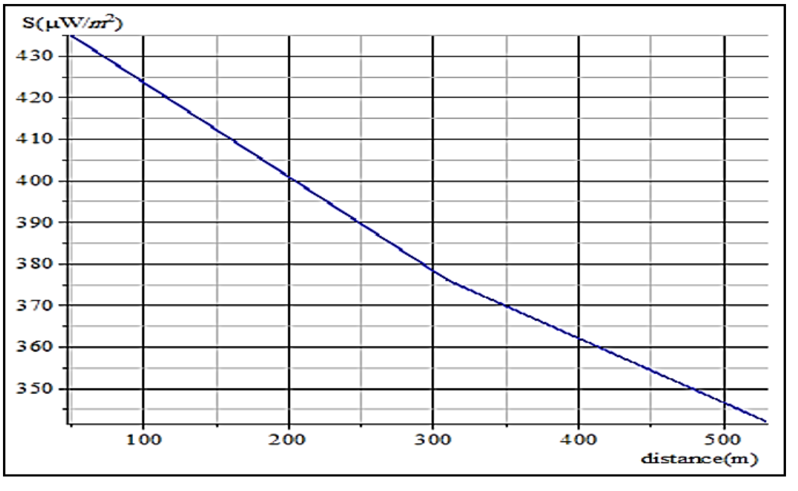

Figure 14: Relationship between the average power densities measured near Tower No. (6) and the distance

Summary of Part 2

Regarding the power density measurements taken at 40 points within the target area, the data provides a clear understanding of the maximum and minimum power levels emitted by the tower transmitters. It identifies areas with relatively high exposure and offers quantitative data on power densities. Notably, the recorded readings indicated that high radiation levels were occasionally detected in uninhabited areas, while populated regions exhibited lower levels in certain instances.

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It is evident from the graphical representation of the data in Table 6 that the measured power density decreases as the distance increases. Fig. 11 and 12 illustrate the relationship between measured power density and distance. However, points 28 and 31, which are located near towers 5 and 6, exhibit lower values compared to other points near the towers, resulting in a non-linear curve. In contrast, the curves in Fig.13 and 14 appear to be nearly linear.

4. Results and Discussion

The results of this study indicate significant variations in RF power density levels, influenced by factors such as distance from cell towers, time of day, and physical obstructions. Additionally, the observed variations suggest that physical structures and environmental factors play a crucial role in the distribution of RF radiation. For instance, buildings can reflect or absorb RF waves, resulting in areas of higher or lower power density depending on the materials and design of the structures. The temporal variation in power density, with elevated levels during peak usage times, aligns with previous studies that indicate mobile phone usage patterns significantly impact RF emissions. The increased power density during peak hours suggests that base stations operate at higher power levels to accommodate the increased data traffic, thereby raising exposure levels.

The average power output recorded at 8:00 a.m. was 1018 $\mu W/m^2$, which is the lowest reading, as shown in Fig. 5. The highest value, 1953 $\mu W/m^2$, was obtained at 7:00 p.m., the hour of completion. After 8:00 p.m., the output began to decline and eventually decreased to a very small value. Additionally, the graph indicates that the rate of change remains unpredictable, and the correlation continues to develop during this period.

Since the measurement point was in direct line of sight with the opposite tower, Figures 7 and 8 illustrate that the measured average power density, at heights of 40 and 35 meters from Tower No. 2, increases from ground level to the fifth floor, where the maximum value is recorded. This occurs because the measurement point maintains a direct line of sight with the opposite tower ($\theta \approx 90°$). Subsequently, the effective value changes on the sixth and seventh floors, indicating that the average power density is influenced by both height and the line of sight (measurement angle). The two Figures also demonstrate that the average power density increases

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as the signal meter approaches the tower. To represent the data for all points in the study area, the values were divided into appropriate intervals to complete a period, with each period measuring 100 µW/m², as illustrated in Fig.10. The results are as follows: In the first period, there were seven values, six of which were less than 100 µW/m² and were located on the outskirts of the city. The seventh value, which was exactly 100 µW/m², was situated far from Tower No1 .

The values recorded during the periods from the second to the fifth consisted of twenty-eight measurements. These values were relatively distant from the transmission towers or obstructed by obstacles. The recorded values ranged from greater than 100 µW/m² to less than 500 µW/m², with the exception of point (28) near Tower No. 5, which recorded a value of less than 500 µW/m². In the periods from six to twenty, there were fifteen measurements taken near the towers. These values ranged from greater than 500 µW/m² to less than 2000 µW/m². The highest recorded values were 1934 µW/m², 1894 µW/m², and 1737 µW/m², all near Tower No.2 of the Libyana company, as well as 1423 µW/m², which was close to Tower No.9 of the Libyan Telecommunications and Technology Company. Additionally, two values of 1247 µW/m² and 1213 µW/m² were recorded near Tower No.3, followed by a value of 1092 µW/m² near Tower No.4, both associated with the Libyana telecommunication company.

The measurements conducted over an area of 3 km² revealed that the power density values on the ground at 1 PM ranged from 12 µW/m² to 1934 µW/m². The average mean deviation was 400.125 µW/m², which is relatively high due to the variation in the range of ideal values. Additionally, the mean and median power density values were calculated to be 555.1 µW/m² and 365 µW/m², respectively. The graphical representation of the values, as shown in Table No. 6, clearly indicates that the measured power density decreases with increasing distance. The relationship between the measured power density and distance, illustrated in Figures 11 and 12, is non-linear. In contrast, Figures 13 and 14 display a nearly linear curve, attributed to the low values of points 28 and 31, which are located close to towers 5 and 6, compared to the other points near the towers .

4.1 .Implications for Public Health

The results of this study raise significant public health concerns, particularly in regions where power density levels exceed the limits

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recommended by the International Commission on Non-Ionizing Radiation Protection (ICNIRP). Chronic exposure to elevated levels of radio frequency (RF) radiation may increase the risk of adverse health effects, as indicated by several epidemiological studies. This highlights the necessity for rigorous monitoring and regulatory measures to ensure that exposure levels remain within safe limits. Public health authorities should prioritize areas with high exposure levels for further investigation and implement measures to mitigate potential risks. For instance, relocating cell towers away from residential neighborhoods, schools, and hospitals could significantly reduce exposure levels for vulnerable populations. Furthermore, public awareness campaigns can educate communities about safe mobile phone usage practices, such as using hands-free devices and limiting call durations. The precautionary principle suggests that minimizing RF exposure is very significant, particularly given the existing scientific uncertainties regarding long-term health effects.

5. Conclusion

This study enhances the understanding of electromagnetic radiation levels emitted by mobile phone towers in a specific geographical area. By presenting measured data and comparing it with international safety guidelines, the research provides valuable insights for assessing potential exposure levels in the Al-Ajailat city center, which serves as the initial focus of this investigation. Additionally, it highlights the factors that influence these radiation levels, offering useful information for future studies and potentially informing urban planning related to tower placement. The study successfully measured and mapped the power density levels of mobile phone tower radiation in the target area. It identified the range of power density values and demonstrated the relationship between distance from the tower and radiation levels at different times of the day, taking into account elevation and distance. The comparison with ICNIRP safety limits was considered, and the results were consistent with numerous studies conducted worldwide. Furthermore, measurements and analyses of RF power density levels in Al-Ajailat City have been done, focusing on areas within a 1 km radius of the city center. Forty points of interest were selected within the overall study area of 3 km². The results revealed significant variations in power density levels, influenced by factors such as distance from cell towers, time of day, and physical obstructions. Several measurements exceeded the ICNIRP

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recommended limits, raising concerns about potential health risks associated with prolonged exposure. The highest power density recorded was 1958 µW/m², observed at a horizontal distance of 35 meters and a vertical distance of 21 meters from Tower No. 2. The median power density across all measurement points was 555.1 µW/m², with a minimum value of 12 µW/m².

6. Recommendations

Based on the results and conclusions, the following recommendations are proposed:

- Regular Monitoring: Implement continuous monitoring programs to track RF power density levels and identify areas with potentially harmful exposure.
- Public Awareness: Enhance public awareness regarding the potential health risks associated with radio frequency (RF) exposure and advocate for safe usage practices for mobile phones and other wireless devices. Educate the public on strategies such as utilizing hands-free devices, limiting call duration, and avoiding carrying phones in close proximity to the body.
- Urban Planning: Incorporate considerations for radio frequency (RF) exposure into urban planning by strategically locating cell towers to minimize exposure in residential areas, schools, and hospitals. Additionally, attention should be given to the design and materials of buildings to reduce RF wave absorption and reflection.
- Regulatory Compliance: Enhance collaboration among telecommunication companies, health authorities, and regulatory bodies to ensure adherence to ICNIRP guidelines and other safety standards. Implement more stringent regulations regarding the installation and operation of cell towers, including mandatory safety audits and exposure assessments.

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