British Journal of Global Ecology and Sustainable Development
Volume-08, Sep., 2022
ISSN (E): 2754-9291

ASSESSMENT OF THE POWER INTENSITY LEVELS EMITTED BY THE INTERNET NETWORK TOWERS IN SELECTED AREAS OF MOSUL CITY

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Abstract
The aim of this study is to evaluate the energy density levels of internet network towers in Mosul city that operate in the 5 GHz frequency band, and then compare the observed energy density levels to national and international standards for radiation protection. In this study, the HF-B8G instrument used to measure the energy density of electromagnetic radiation. The data collected from Internet network towers from both the right and left sides of Mosul city, with the towers' locations determined using the Global Positioning System (GPS). The results of field researches showed that radiofrequency radiation levels are significantly lower than the nationally and globally allowed limits. The highest average power density (PD) within the frequency band (5GH) for the left and right sides of Mosul, respectively, was 0.005362W/m2 and 0.003516W/m2, while the highest recorded value for max power density was 0.00848W/m2 on the left side and 0.007045W/m2 on the right side of the city. The radiation power values recorded at distances of 10, 25, 50, 75,100 meters from the Internet towers, with the results were 0.001361 W/m2, 0.001249 W/m2, 0.002537 W/m2, 0.000914 W/m2 and 0.000633 W/m2 respectively.

Keywords: Radiofrequency (RF) Radiation, Electromagnetic Radiation (EMR), Power density, Mobile tower, Wireless broadcasting, Standard for EMF exposure.

Introduction

The end of the twentieth century and the beginning of the twenty-first century witnessed a rapid development in information and communication technology, which led to radical changes in all aspects of life for all societies in all levels. This rapid technological development has provided many inventions that have benefited the humanity in these days, and the Internet now considered as one of the most important and advanced achievements as it transformed the entire world into a small city. Connecting to the Internet is no longer a luxury, but rather a necessity in this era, as new technologies for the Internet have witnessed great interest in all sectors of society, especially in the education sector, over the past few years (Ali et al., 2021). Its uses are in all commercial, educational, medical, cultural and other fields.

The Radiation from mobile phone networks and Internet towers is radio-electromagnetic waves. The radio waves that used in various communication systems fall within the lower part of the electromagnetic spectrum and the frequency of these radio waves (RF) ranges between 200 MHz to 2200 MHz, where frequencies between 800 MHz to 2200 MHz used in mobile phones (Ofli et al., 2008).

As for the most used frequencies in wireless Internet service, they can divided into the 2.4-GHz frequency band, where this band is usually used in the Wi-Fi service-broadcasting device (Router), which used to deliver the service to various devices such as phones and computers inside the house, and used in the signal-receiving device outside the house (Nano station devices). The other section is a 5 GHz frequency band, and this pand used primarily in the external Nano station-receiving device, and to a lesser extent in some routers. Its stability is good, as well as its high performance (EarthLink, 2020). The most important types of antennas that are used in communication towers and Internet network towers are the sector antenna and the dish antenna.

Dish Antennas transmit and receive a highly focused radio wave in one direction and used for point-to-point links. These antennas produce narrow beams with a width of 1 to 2 degrees, allow data transmission between mobile phone base stations over long distances as well, and not directed towards the ground, they have a direct line of sight to the receiving antenna at the remote location (Hammash, 2009). Sector antennas produce beams of radio frequency waves that sent to the cell around the base station (BST). The top edge of the primary beam is almost vertical, while the bottom edge is directed 5 to 10 degrees down; these beams are narrow in altitude and sloped downward. A sector antenna's main beam should be able to touch the ground. Typically, between 50 and 300 m from the mast (Abu Subha, 2014).The exposure levels at ground level of RF waves from microwave dish antennas are negligible compared to sectoral antennas (Fuller et al., 2002).

The use of information technology by universities, colleges and schools is gradually increasing to transfer training and educational programs (Saeed et al., 2017). This sector depends on the laws and standards issued by the Iraqi Ministry of Communications (IMC) and the Communications and Media Commission (CMC) (ALRikabi, 2016). Despite the existence of these standards, some violations can observed within Iraqi cities, especially the city of Mosul, which has become suffering from visual pollution and the lack of urban appearance of the city due to the large and increasing numbers of Internet towers erected on the roofs of houses, buildings and government institutions, as well as the inefficiency of the spatial distribution of those towers. This caused confusion to the population about the nature of these outgoing waves and their impact on human health. The wireless transmission through the networks of the Internet towers is unknown and not used at the present time in the world, so most of the studies are related to the radiation emitted by the mobile phone station, but the nature of the electromagnetic waves and the way they are emitted are exactly the same as for the Internet towers. Similar studies have been conducted in

Volume-08, Sep., 2022
ISSN (E): 2754-9291

many countries, such as the study of (Nahuku et al., 2020), where The RF radiation levels of mobile stations were measured and analyzed at different distances from the base station, and a maximum radiation level was 0.00139 W/m². Also, study of (Kljajic and Djuric, 2020) To monitor and measure electromagnetic fields on the campus of the University of Novi Sad in Serbia and study of (Carlberg et al., 2019) In Stockholm, Sweden.

Materials and Methods

Study Site:

The research focused on the crowded neighborhoods with high population density, as well as the important areas in Mosul for both sides that filled with markets, such as (Al-Majmoa'a Al-Thaqafiyah Street, Al-Zohour neighborhood, Al-Muthanna neighborhood and Mosul Al-Jadidah area. In terms of size and population, the Tigris River divides Mosul into two main sides, the left and right sides, the left side defined by greater area and population compared to the right side. Thus, the number of Internet towers on the left side is greater than it is on the right side, reaching approximately 2257 towers, compared to the right side, in which the number of towers reaches 704 towers (Nineveh Communications and Informatics Department), where the density of towers decreases or increases according to the area and population density. 60 sites chosen on the left side and 30 sites on the right side of the city to measure the intensity of the radiation power emitted by the Internet network towers. As shown in Fig. 1.

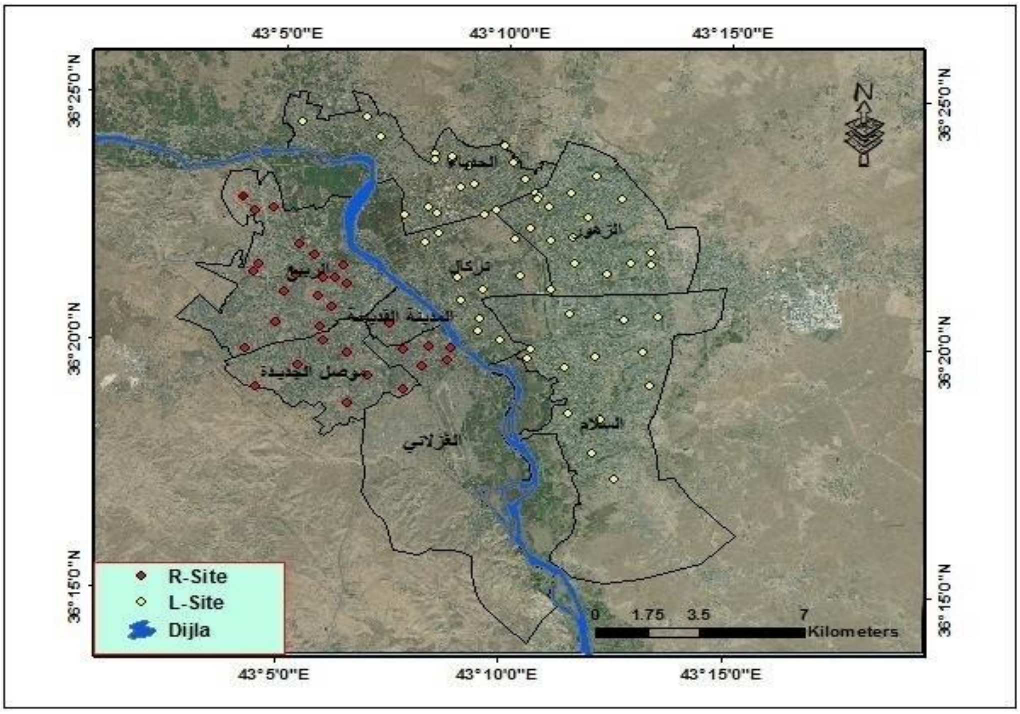

Fig.1: A map of Mosul city showing the distribution of measurement locations.

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ISSN (E): 2754-9291

Measuring device used in the project:

In this study, the HF-B8G measurement gadget was used, which was manufactured by LATNEX Company in Canada, Toronto. This device is designed for use in open space and in hard-to-reach measurement sites. It works on a simple principle of magnetic flux, which is very similar to the principle used in any electrical transformer this makes the measurement process easier. The device is used to measure and monitor the electromagnetic field intensity of Radio Frequency (RF). Because it is a broadband instrument, it can measure frequencies ranging from 10MHz to 8GHz. It can also be used for non-directional measurements because to the device's three-axis measurement sensor, which makes it very sensitive. The antenna is specific to the device and is attached to it because it is simple to install on the base unit and is designed for use in space. Different units of measurement can be used for the same parameter. This device gives readings of the instantaneous value, maximum value, average value and maximum average value of electromagnetic radiation (Latnex, 2022).

Fig.2: LATNEX®HF-B8G Professional High Frequency and RF Meter.

The Programs used:

1. ArcGIS 10.6.1
2. MAPS.ME
3. UTM Converter

Method

The field measuring procedure lasted four months (January 2022-April 2022), and it required about 5 to 6 hours per day, five days a week, during peak hours from four o'clock in the afternoon to ten o'clock in the evening. The Information about the different sites that selected for measurement was collected, and the coordinates of the internet towers sites for the study areas were verified. The HF-B8G device was used at a 45° angle and a height of around 1.2-1.5m above ground level Pointing to the antenna as it was applied in previous studies (Parajuli et al., 2015; Abdulmohson, 2017; Ayinmode and Farai, 2013). All measurements were made through using open space condition, which ensures that there are no obstacles or barriers that cause distortion or interference in the observed power levels. The electromagnetic power density was measured at its maximum and average values, with the data stabilizing after three minutes. As a result, recording each measurement took around 25-30 minutes at one tower. According to the Iraqi Ministry of Health and Environment's recommendations, the measuring process was repeated in the directions corresponding to the antennas. After capturing the measurements and storing them in the device's memory, they are analyzed and processed using the Excel application. As well as entering data using ArcGIS 10.6.1 to create IDW analysis maps, which display the distribution for levels of radiation power density for the study regions. During the field work, many internet network towers were found that contain a large number of internet transmitters. These towers are installed on the roofs of residential and governmental buildings and shops with different heights ranging from 15-30 meters as shown in Figure 3.

Fig.3: Internet broadcast towers.

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Results and Discussion

The left side:

The measurements were recorded for (60) different sites of the Internet network towers, and the measurement results were lower than the determinants and standards set for radiation protection. Table 1 shows the highest maximum values of electromagnetic power density and the percentages it represents for the parameters. It is noted from the table that the highest maximum value was for the tower (A5) in the Al-Hadba area, which amounted to 0.00848W/m², which is less than the Iraqi determinant by 99.79% and the Russian determinant, FCC, Chinese determinant and ICNIRP by (91.52%, 99.91%, 97.88%, 99.91%) respectively. The tower (A17) in Al-Andalus neighborhood was recorded 0.008351W/m² of the maximum radiation power density, which is less than the Iraqi determinant by 99.8%, the Russian determinant by 91.6%, and the Chinese determinant by 97.9%, and the FCC, ICNIRP determinants by 99.9%. The maximum value of radiation power density in Al-Zohour neighborhood was 0.007431W/m², which is less than the Iraqi, Russian, FCC, Chinese and ICNIRP determinants by (99.82%, 92.57%, 99.93%, 98.15%, 99.93%) respectively. As for the highest average of radiation, power density was shown in Table2.

Table 1: shows the percentages of the highest recorded maximum values of the determinants / left side.

Percentage of Determinants					Max Value W/m²	Tower Symbol	Region
ICNIRP 10	CHINA 0.4	FCC 10	RUSSIA 0.1	IRAQ 4			
0.08%	2.12%	0.08%	8.48%	0.21%	0.00848	A5	Al-Hadbaa
0.05%	1.2%	0.05%	4.83%	0.12%	0.004834	A11	Al-Baladiat
0.04%	1.07%	0.04%	4.29%	0.1%	0.004291	A12	Al-Baladiat
0.04%	1.02%	0.04%	4.1%	0.1%	0.004102	A16	Almajmoa Althaqafia
0.07%	1.85%	0.07%	7.43%	0.18%	0.007431	A26	Al-Zohor
0.05%	1.15%	0.05%	4.61%	0.11%	0.004615	A25	Al-Zohor
0.08%	2.08%	0.08%	8.35%	0.2%	0.008351	A17	Al-Andalus
0.04%	1.03%	0.04%	4.13%	0.1%	0.004132	B2	Al-Thobat
0.05%	1.14%	0.05%	4.59%	0.11%	0.004593	B11	Al- Wahda
0.05%	1.14%	0.05%	4.57%	0.11%	0.004571	B18	Al-Tameem

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Table 2: shows the percentage values of the average radiation power density for the determinants / left side.

Percentage of Determinants					Average W/m²	Tower Symbol	Region
ICNIRP 10	CHINA 0.4	FCC 10	RUSSIA 0.1	IRAQ 4			
0.053%	1.34%	0.053%	5.36%	0.13%	0.005362	A5	Al-Hadbaa
0.025%	0.64%	0.025%	2.56%	0.06%	0.002567	A11	Al-Baladiat
0.028%	0.7%	0.028%	2.81%	0.07%	0.002816	A12	Al-Baladiat
0.023%	0.58%	0.023%	2.34%	0.058%	0.002344	A16	Almajmoa Althaqafia
0.03%	0.76%	0.03%	3.05%	0.076%	0.003055	A26	Al-Zohor
0.045%	1.14%	0.045%	4.56%	0.11%	0.004561	A25	Al-Zohor
0.04%	1.02%	0.04%	4.09%	0.1%	0.004093	A17	Al-Andalus
0.023%	0.57%	0.023%	2.39%	0.059%	0.00229	A14	Al-Soqar
0.022%	0.55%	0.022%	2.21%	0.055%	0.00221	B2	Al-Thobat
0.0265	0.66%	0.026%	2.63%	0.065%	0.002636	B4	Almazare'e
0.024%	0.59%	0.024%	2.39%	0.059%	0.002391	B11	Al- Wahda
0.026%	0.65%	0.026%	2.61%	0.065%	0.00261	B18	Al-Tameem

Where the highest average was 0.005362W/m² for the tower (A5) in the Al-Hadba region, and the value was lower than the Iraqi determinant by 99.8%, the Russian determinant by 94.6%, the FCC determinant by 99.9%, the Chinese determinant by 98.6%, and the ICNIRP determinant by 99.9 %. The average value of the power density of the tower (A25) in Al-Zohour area was 0.004561W/m², which is less than the Iraqi determinant by 99.8%, the Russian determinant by 95.4%, the Chinese determinant by 98.8%, and the determinant by FCC and ICNIRP by 99.9%. In Al-Andalus neighborhood the highest Average for (A17) tower is reached 0.004093W/m², which is lower than the Iraqi, Russian, FCC, Chinese and ICNIRP determinants by (99.9%, 95.9%, 99.96%, 98.98%, 99.96%) respectively.

The right side:
The measurements were recorded for (30) different sites of the Internet network towers, and the results of the measurements of the radiation power density obtained from the fieldwork were much less than the international determinants.
As noted from Table 3, the highest recorded maximum values for power density. Where the highest value reached 0.007045W/m², which is for the tower (C18) in the Mosul Aljadeda area and was less than the Iraqi determinant by 99.83% and less than the Russian determinant by 92.96% and less than determinants (FCC, CHINA, ICNIRP) by (99.93%, 98.24%, 99.93 %)respectively. As for the tower (C8) in Mushairifa, the highest maximum value was lower than the determinants (IRAQ, RUSSIA, FCC, CHINA, ICNIRP) with a percentage of (99.85%, 99.93%, 93.78%, 98.45%, 99.93%), respectively. The maximum value of the tower (C12) was less than

the Iraqi determinant by 99.87%, the Russian determinant by 94.94%, the FCC determinant by 99.95%, the Chinese determinant by 98.74%, and the ICNIRP determinant by 99.95%.

Table 3: shows the highest maximum values and their percentage of determinants /right side.

Percentage of Determinants					Max Value W/m²	Tower Symbol	Region
ICNIRP 10	CHINA 0.4	FCC 10	RUSSIA 0.1	IRAQ 4			
0.04%	1.04%	0.04%	4.18%	0.1%	0.004181	C1	Al-Najjar
0.05%	1.23%	0.05%	4.95%	0.12%	0.004951	C7	17 Tamoz
0.06%	1.55%	0.06%	6.22%	0.15%	0.006227	C8	Msherfa
0.05%	1.26%	0.05%	5.06%	0.13%	0.005062	C12	Industrial area
0.07%	1.76%	0.07%	7.04%	0.17%	0.007045	C18	Mosul Aljadeda
0.05%	1.14%	0.05%	4.56%	0.11%	0.004562	C19	Mosul Aljadeda
0.04%	1.05%	0.04%	4.19%	0.1%	0.00419	C27	Al-Dandan

The highest average radiation power density reached 0.003516W/m² for the tower (C8) in Mushairifa, which is less than the determinants (IRAQ, RUSSIA, FCC, CHINA, ICNIRP) by (99.91%, 99.96% 96.85%, 99.13%, 99.96%)respectively. Also for the tower (C18), the average value was 0.003381W/m² and was less than the Iraqi determinant by 99.92% and less than the Russian, Chinese, and FCC and ICNIRP determinant by 96.62%, 99.61% and 99.97%, respectively. The average value was 0.003163W/m² for the tower (C12) in the industrial area and was lower than the determinants (IRAQ, RUSSIA, FCC, CHINA, ICNIRP) by (99.92%, 99.96%, 96.84%, 99.21%, 99.96%), respectively. As for the tower (C18) in the Mosul Aljadeda area, the average value of the radiation power density was less than the Iraqi determinant by 99.91% and less than the determinants (RUSSIA, FCC, CHINA, ICNIRP) by (96.92%, 99.96%, 99.16, 99.96%), respectively As shown in Table 4.

Volume-08, Sep., 2022
ISSN (E): 2754-9291

Table 4: shows the percentages of the highest average radiation power density for the determinants /right side.

Percentage of Determinants					**Average W/m²**	**Tower Symbol**	**Region**
ICNIRP 10	**CHINA 0.4**	**FCC 10**	**RUSSIA 0.1**	**IRAQ 4**			
0.023%	0.57%	0.023%	2.31%	0.05	0.002312	C1	Al-Najjar
0.02%	0.52%	0.02%	2.09%	0.052	0.00209	C4	Al- Rifai
0.022%	0.57%	0.022%	2.29%	0.057	0.002291	C7	17 Tamoz
0.035%	0.87%	0.035%	3.51%	0.087	0.003516	C8	Msherfa
0.031%	0.79%	0.031%	3.16%	0.079	0.003163	C12	Industrial area
0.033%	0.84%	0.033%	3.38%	0.084	0.003381	C18	Mosul Aljadedah
0.027%	0.68%	0.027%	2.73%	0.068	0.002733	C19	Mosul Aljadedah
0.0265	0.65%	0.026%	2.63%	0.065	0.002635	C20	Al-amel
0.022%	0.55%	0.022%	2.2%	0.055	0.0022	C27	Al-Dandan

The inverse distance-weighted analysis (IDW) was used with the (Arc GIS 10.6.1) program to draw maps showing the distribution of the levels of radiation power density emitted from the Internet network towers in the form of bands of different colors representing the emission intensity in the study areas and the surrounding areas. As shown in the following figures:

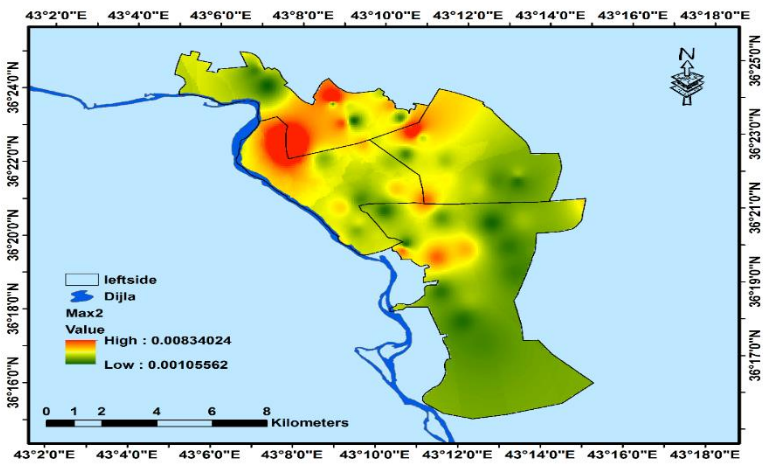

Fig. 4: a map of the levels of maximum value of the radiation power density in the left side of the city.

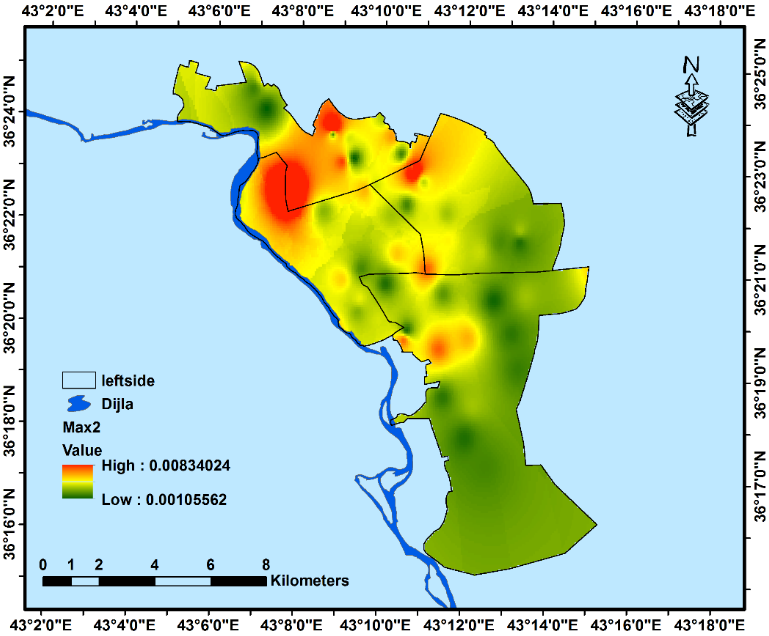

Fig. 5: a map of the average levels of radiation power density in the left side of the city.

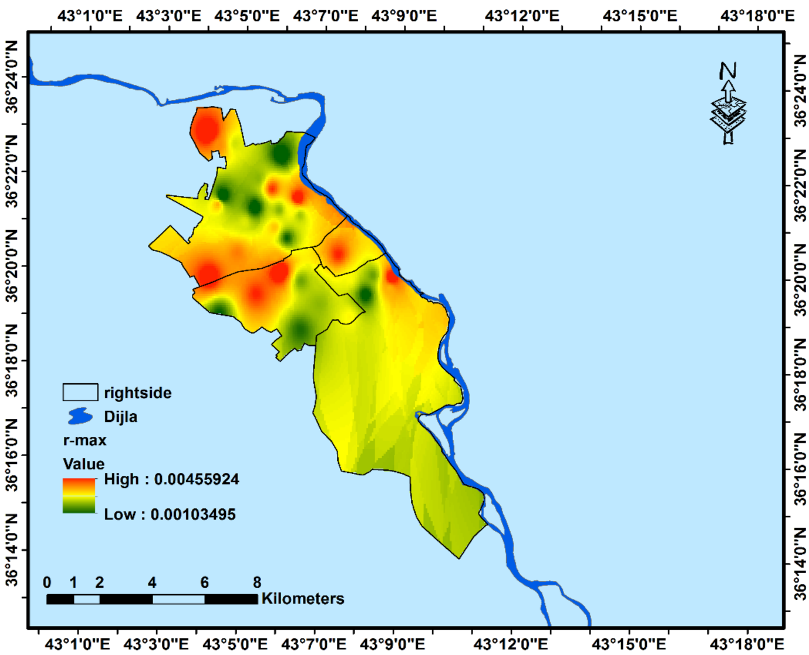

Fig.6: a map of the levels of maximum value of the radiation power density in the right side of the city.

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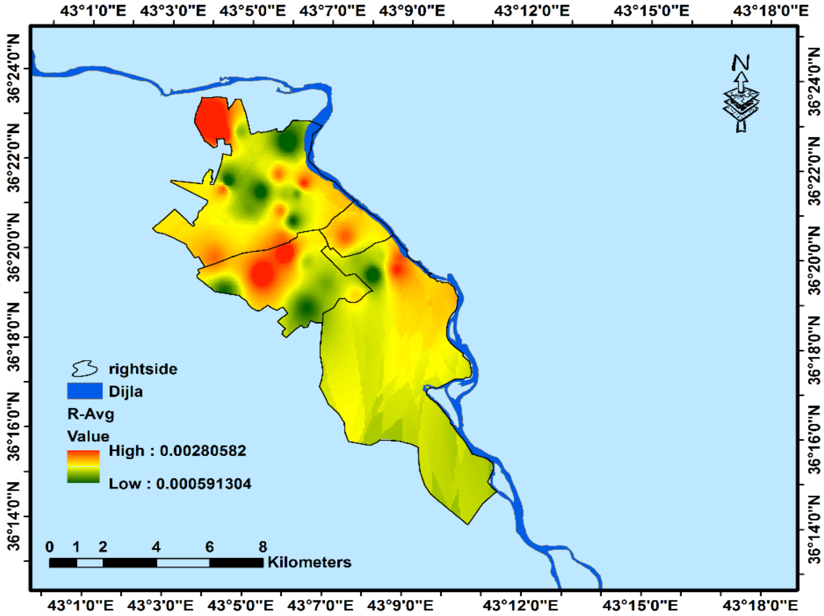

Fig. 7: a map of the average levels of radioactive power density on the right side of the city.

Distance:

To find out the effect of distance on the radiation power density values, the radiation power density emitted from the internet network towers was measured at different distances from the towers as followed in the studies (Abdulmohson and Ali, 2018; Ali et al., 2021; Nahuku et al., 2020; Buckus et al., 2017) and the results were as shown below:

Table 5: Shows the change of power density with distance

Max Power Density W/m^2	Distance (m)
0.001361	10
0.001249	25
0.002537	50
0.000914	75
0.000633	100

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Figure 8, which represents the relationship between the distance and the levels of the maximum value of the radiation power density of an Internet tower located in the Mosul Aljadeda area, shows that the highest value of the radiation power density was at a distance of 50 m within the frequency band (5GHz), as the maximum value reached 0.002537W/ m^2. Then the radiation power density begins to decrease as we move away from the tower to reach 0.000633 W/m^2 at a distance of 100 m.

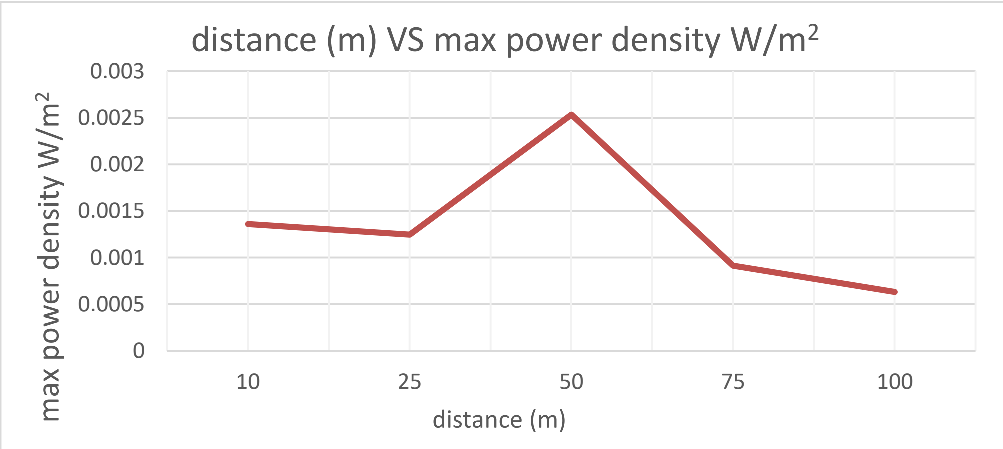

Fig 8: The relationship between distance and power density.

By reviewing the results, it can observed that there is a difference, fluctuation, and irregularity in the change in the levels of radiation power density with distance. This indicates the inefficiency of the spatial distribution of Internet towers and the lack of commitment by Internet companies and tower owners from Internet service providers (ISP) to apply the inverse square law, which it is one of the prerequisites for ensuring the regularity of electromagnetic fields. The results also showed that the intensity of the radiation power decreases as we move away from the antenna, and this is consistent with previous studies (Mohammed et al., 2021; Nahuku et al., 2020; Buckus et al., 2017; Marinescu and Poparlan, 2016).

Conclusions

This paper aims to obtain measurements of the density of electromagnetic energy emitted from the networks of Internet towers for different places in the Mosul city, which contains approximately 2961 Internet towers on both the right and left sides of the city. Despite the towers' widespread distribution, the measured power density values are significantly lower than the international standards, where the highest maximum energy density value was recorded, the left city side gets 0.00848W/m^2, while the right city side gets 0.007045W/m^2. The power density was measured at various distances from the towers with the maximum value reaching 0.002537W/m^2 at a distance of 50 m. Interference is a significant problem for Internet broadcasting using free frequencies especially in Mosul city. This interference forces Internet service providers (ISP) to find new devices with much power to send Internet signal to users, which means EMF exposure intensity may increase. This problem can be solved by completing the requirements of the national project for optical fiber as soon as possible. As this project will use optical cable to connect all switches in the Mosul city and then distribute Internet service to all homes using this technology, as well as imposing restrictions on Internet service providers in terms of the number of towers and adherence to the conditions for erecting towers in terms of height and distance. Where the height of the antenna should not be less than 15 meters from the ground level, with the necessity of having a barrier or a non-metallic fence around the antennas, the antennas should not be installed in the yards of schools and hospitals, not even near them. The distribution of towers should be at regular distances so that each tower has a field of view to reduce the effect of obstacles that could lead to distortion or interference in the received signal.

Acknowledgments

The researcher would like to thank the Nineveh Communications and Informatics Department and Remote Sensing Center at the University of Mosul for all the effort and time they spent in providing information and completing the research requirements.

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