



RESEARCH PAPER

Assessment of Radio-Frequency Electromagnetic Field Radiation within the Vicinity of Some Selected Mobile Phone Towers in Abuja, Nigeria

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ABSTRACT

Rapid growth in mobile communication technology in Abuja has led to numerous base stations, causing electromagnetic pollution in residential, school, and market areas, resulting in environmental and human health concerns worldwide. This research examined the effects of radio-frequency (RF) radiation emitted from cellular base stations on the biological systems of the human body. The power densities were calculated in close proximity to cellular mobile base stations. The research findings show that maximum power density of 133.3 nW/m² and 432.3 nW/m² and 491.70 nW/m² was recorded at 0.0 m for Residential Areas, Market Places and School Premises, respectively, while the minimum power density of 9.6 nW/m², 10.09 nW/m² and 7.57 nW/m² was recorded at 145 m radial distance in Base Transceiver Station for Residential Areas, Market Places and School Premises, respectively. Therefore, the Radio frequency exposure hazard index in all the locations was significantly below the permitted RF exposure limit of 4.5 W/m² to 9.0 W/m² to the general public as recommended by International Commission on Non-Ionizing Radiation Protection (ICRNIP). Therefore, people living within the School premises absorb large percent of the radiofrequency radiation which could be as a result of the large number of clustered GSM masts. Comparing the calculated values of Power Density with ICRNIP, and IEEE (Institute of Electrical and Electronics Engineers) exposure limits, an idea for the compliance distance where the radiation level is safe for public exposures was estimated.

Keywords: Base Transceiver Station, Spectrum Analyser, Radio-Frequency Electromagnetic Field.

INTRODUCTION

Radio frequency radiation is an electromagnetic radiation combining electric and magnetic fields. Its impact on human perception and public perception is of concern. As demand for high-quality telecommunications increases, infrastructure development, particularly cellular phone base stations, is needed to maintain service quality. However, concerns about health effects from exposure to electromagnetic fields persist.

Electromagnetic radiation is defined as energy that travels through open space or a solid medium in the form of electromagnetic waves such as radio waves, visible light, and gamma rays. Exposure to EMF radiation negatively impacts human health by causing electrolyte displacement and interference with communication. This weakens the body's ability to correct imbalances, and weakens the body's defense mechanisms. Biophysics shows that illness occurs when the body's defense

mechanisms are weak, making living or working within the EMR field a significant risk factor (Victor, 2007).

The ongoing enormous development of Global System for Mobile Communication (GSM) system in Nigeria requires regulatory agencies to mitigate potential hazards of RF radiation from Base Transceiver Stations. National guidelines are developed to ensure wireless communication system emissions meet EMF safety levels, with Nigeria adopting the ICNIRP standard through its nation assembly. Bolaji et al. (2012) found that low frequency electromagnetic fields (EMFs) and related electromagnetic radiation are harmful. While shielding houses from electric fields is easy, protecting houses from magnetic fields is difficult due to high costs. Long-term exposure

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can cause health problems like fatigue, irritability, aggression, sleep disorders, and emotional instability.

Similarly, Ahlbom *et al.* (2002) found that individuals become hyperactive to electromagnetic radiation (EMR) around power lines, appliances, and handheld devices, causing energy drain. Carlberg *et al.* (2018) found that non-thermal radiation has detrimental health effects, making the apartment unsuitable for long-term living, especially for children who are more sensitive to radio frequency. Furthermore, Jagbir and Sharing (2012) studied cell phone mast orientation to determine radiation exposure levels in delta state, revealing maximum and minimum exposure zones and power density changes with distance, with peak power density observed at 40m. This research was therefore designed to assess electromagnetic fields and its adverse effect on human body.

METHODOLOGY

This research work utilized the broadband analysis method to carry out measurements. The handheld spectrum analyzer with model number N9342C-ATO-88246, serial number CNOS2 768 was used. High frequency radiation was measured in the range of 50 MHz to 3.5 GHz. The value of electric field E was measured and later converted into magnetic field H, with the value of power density Pd automatically calculated using equation 3.1 according to ICNIRP, 1998. The radio frequency radiation values (power density) were estimated by pointing the spectrum analyzer to the source of radiation (mobile base station). A maximum of 25 m radial distance from the base of the mobile station was considered with traversing distance of 5 m each. Measurements were taken at every 5 m interval from the base station. During the data collection, proximity of residential buildings, schools and market areas were put into consideration. A total of 30 mobile base stations were strategically selected irrespective of the telecommunication industry service providers. Each measurement was conducted by holding the spectrum analyzer away from the mobile base station of arm's length and at 1.5 m above the ground level pointing towards the mast as opined by Ismail *et al.*, (2001). Measurements were taken after ensuring the meter is stable and all

unwanted signals sources (e.g. phone calls) and disturbances (e.g. cars) were reduced to the minimum.



Fig. 1: The front view of N9342C Handheld Spectrum Analyser

Data Collection and Sampling Site

This research was conducted in three (3) areas in Abuja, Federal Capital Territory (FCT) and the location for the research are Dakwa, zuba and Dei-dei. 18 GSM base stations were considered; six (6) in residential areas, six (6) in market places and six (6) in school premises. Spectrum analyser was used in taking reading from the network mast at a total distance of 145 metres away from the GSM base station starting from 0 m as the starting point and the measurement was taking in 5 m intervals. The same distance was considered for both frequency band of 900 Hz and 1800 Hz.

The GSM antennas were selected according to their proximity to buildings, school, and Market places. Measurements were taken in a convenient direction around the towers at every 5 m interval away for each of the transmitting towers location. Most of the base stations have at least 3 sectorial antennas and each antenna covers 120° radii. Each of the measurement was made by holding the spectrum analyser and antenna away from the GSM tower at a distance of about 5 meter and the pole which the antenna is mounted on pointing towards any direction within the radius of the antenna sector. The measured power densities vary at each different point from the tower and thus, measured values were recorded.

However, the received signal powers detected by the measuring instrument at various distances are the received radiated powers

with respect to distance from the transmitting tower.

Power density Pd at a distance R is calculated using;

$$Pd = \frac{Pt \times Gt}{4\pi R^2} \quad 1$$

where Pt = transmitted power or received signal strength in watts

Gt = gain of transmitting antenna

R = distance from the antenna in meters

Power received Pr (watts) by an antenna at a distance R is calculated using;

$$Pr = \frac{Pt \times Gt \times Area}{4\pi R^2} \quad 2$$

Most of the mobile base station radiates power of 20 watts through an antenna of 18 dB gain (63.095), therefore, the maximum power density (Pd) will be in an area near the antenna base station (at a radial distance of 0 m away from the foot of the base station), and is inversely proportional to the square of the distance (r) as noticed from equation 1. Therefore, maximum power density was recorded from each of the Base transceiver stations surveyed, while minimum values were recorded at 145 m radial distance for each Base Transceiver Station. These maximum values recorded (table 1, 2 and 3) at 0.0 m radial distance decreased progressively as the distance of separation increased with significant variations.

RESULTS AND DISCUSSION

Table 1: Variation of Power Density At Residential Areas at 5 m intervals

S/N	Distance (m)	Frequency (MHz)	Power Density (nW/m ²)	Frequency (GHz)	Power ensity (nW/m ²)
1.	0	93.2.39	87.98	1.840	133.3
2.	5	929.13	77.95	1.813	94.3
3.	10	928.47	75.25	1.807	87.09
4.	15	935.53	72.61	1.813	66.29
5.	20	935.43	64.84	1.837	65.57
6.	25	926.52	59.68	.834	60.03
7.	30	945.56	43.99	1.811	56.65
8.	35	946.30	33.42	1.822	53.39
9.	40	927.39	30.17	1.808	51.72
10.	45	935.00	28.83	1.825	44.48
11.	50	935.21	27.84	1.825	43.88
12.	55	900.00	26.44	1.822	43.07
13.	60	936.30	24.77	1.767	35.79
14.	65	905.00	22.14	1.835	32.96
15.	70	917.39	19.88	1.839	32
16.	75	925.00	16.97	1.840	31.58
17.	80	875.00	15.62	1.848	23.81
18.	85	882.39	15.59	1.754	23.09
19.	90	857.60	15.29	1.822	22.7
20.	95	946.08	14.08	1.822	20.63
21.	100	948.26	13.51	1.825	18.21
22.	105	93.95	13.25	1.837	16.83
23.	110	932.39	12.03	1.822	13.21
24.	115	946.30	11.89	1.822	12.61
25.	120	947.60	10.20	1.820	12.35
26.	125	948.04	8.98	1.820	12.23
27.	130	947.39	8.75	1.820	12.19
28.	135	947.60	8.07	1.834	12.15
29.	140	947.82	8.04	1.820	10.4
30.	145	947.17	7.06	1.820	9.6

Table 2: Variation of Power Density at Market Places at 5 m intervals

S/N	Distance (m)	Frequency (MHz)	Power Density (nW/m ²)	Frequency (GHz)	Power Density (nW/m ²)
1.	0	935.86	142.50	1.751	432.3
2.	5	935.65	139.8	1.834	377.4
3.	10	935.86	87.22	1.824	362.7
4.	15	935.43	66.01	1.806	330.5
5.	20	935.65	65.50	1.815	303.1
6.	25	935.86	64.82	1.798	261.2
7.	30	935.65	61.21	1.820	253.8
8.	35	935.65	36.79	1.850	227.8
9.	40	932.82	32.48	1.850	127.9
10.	45	935.86	31.27	1.809	102.9
11.	50	942.39	29.82	1.814	85.62
12.	55	935.86	27.89	1.812	80.75
13.	60	902.82	25.95	1.845	56.68
14.	65	949.13	20.85	1.841	52.89
15.	70	873.04	20.34	1.847	45.82
16.	75	866.30	20.10	1.847	43.93
17.	80	933.05	17.99	1.840	36.08
18.	85	927.39	16.71	1.849	29.54
19.	90	948.26	16.37	1.837	22.44
20.	95	926.08	15.14	1.840	21.99
21.	100	936.73	15.00	1.845	20.25
22.	105	927.82	14.47	1.845	18.76
23.	110	938.68	13.86	1.846	15.98
24.	115	929.13	13.84	1.846	15.18
25.	120	937.17	10.84	1.837	14.98
26.	125	914.34	10.14	1.837	13.69
27.	130	936.95	8.52	1.837	11.12
28.	135	937.17	8.23	1.839	11.06
29.	140	937.39	6.86	1.836	10.74
30.	145	935.21	6.81	1.849	10.09

In general, the maximum power density of 133.3 nW/m² and 432.3 nW/m² and 491.70 nW/m² was recorded at 0.0 m for Residential Areas, Market Places and School Premises, respectively, while the minimum power density of 9.6 nW/m², 10.09 nW/m² and 7.57 nW/m² was recorded at 145 m radial distance in Base Transceiver Station for Residential Areas, Market Places and School Premises, respectively as shown in tale 1, 2 and 3. However, the existence of a large number of scatters and absorbed objects around the base station in all the locations lead to highly non-uniform field distribution as shown in figure 4, 5 and 6, respectively. As a result, this brought about shadowing and fast fading effects of signals. Therefore, cars, trees, houses and other objects seen around the base station can lead to variations of radiation/signal. In fact,

building alone can cause the radiation field distribution to be very heterogeneous (Miclausi *et al.*, 2007; Hammerius *et al.*, 2008; Stewart, 2000 and Jochen, 2003).

For different heights of base station antenna (H), the power density (Pd) in nW/m² is plotted for different exposed body heights (h) when it is located at different distances (d) from the radiating source. Figures 1, 2 and 3, shows that the power density has no considerable variation with the height of the exposed body while it decreases as the distance (d) and transmitting antenna height (H) is increased with the highest exposure occurring at 0 m in all the base stations as seen in figures 1, 2 and 3, respectively. Therefore, increasing the base station antenna height can

be used as one of the main technique for RF pollution reduction.

Table 3: Variation of Power Density At School Premises at 5 m intervals

S/N	Distance (m)	Frequency (MHz)	Power Density (nW/m ²)	Frequency (GHz)	Power Density (nW/m ²)
1.	0	947.60	505.40	1.820	491.70
2.	5	948.04	343.90	1.820	459.00
3.	10	947.39	119.50	1.820	301.70
4.	15	947.60	97.46	1.834	272.80
5.	20	947.82	97.46	1.820	203.70
6.	25	947.17	87.98	1.820	193.10
7.	30	931.30	86.14	1.833	191.20
8.	35	911.08	77.95	1.843	106.60
9.	40	867.39	65.53	1.809	87.68
10.	45	896.52	39.62	1.780	66.29
11.	50	937.17	28.83	1.77	62.27
12.	55	944.56	27.16	1.845	55.97
13.	60	946.91	24.35	1.821	44.01
14.	65	874.56	22.14	1.754	35.79
15.	70	933.69	19.73	1.849	31.58
16.	75	865.21	15.59	1.849	28.85
17.	80	850.86	15.29	1.837	20.24
18.	85	875.00	10.11	1.838	20.23
19.	90	946.30	9.79	1.834	16.83
20.	95	932.60	8.922	1.820	15.62
21.	100	949.56	8.40	1.820	12.70
22.	105	949.34	8.28	1.820	12.35
23.	110	946.95	8.24	1.846	12.15
24.	115	946.95	8.00	1.840	10.28
25.	120	933.69	7.89	1.836	9.62
26.	125	935.21	7.37	1.836	9.47
27.	130	931.30	7.14	1.836	9.09
28.	135	931.52	6.83	1.836	8.49
29.	140	933.04	6.14	1.836	7.94
30.	145	933.26	1.838	1.836	7.57

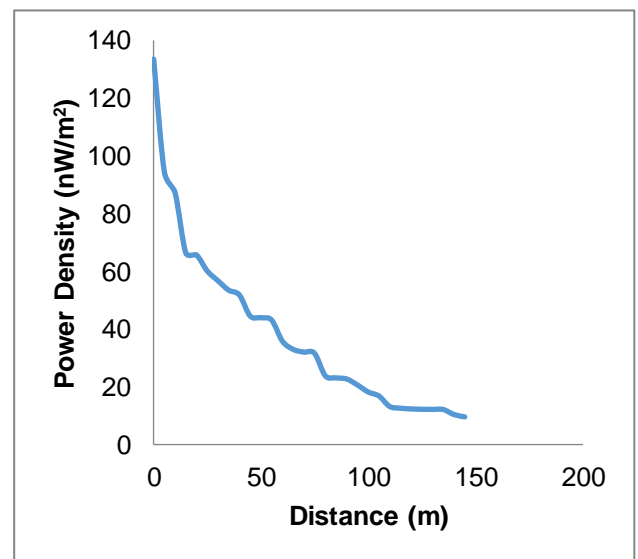
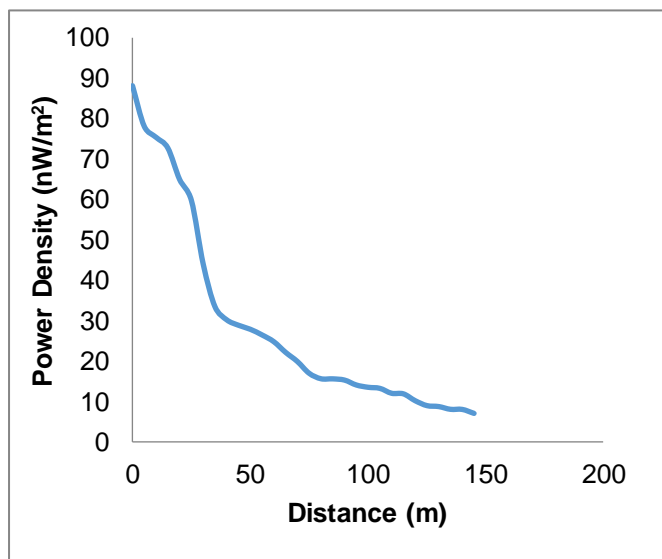


Figure 1: Average Power Density Variation with Distance in Residential Areas

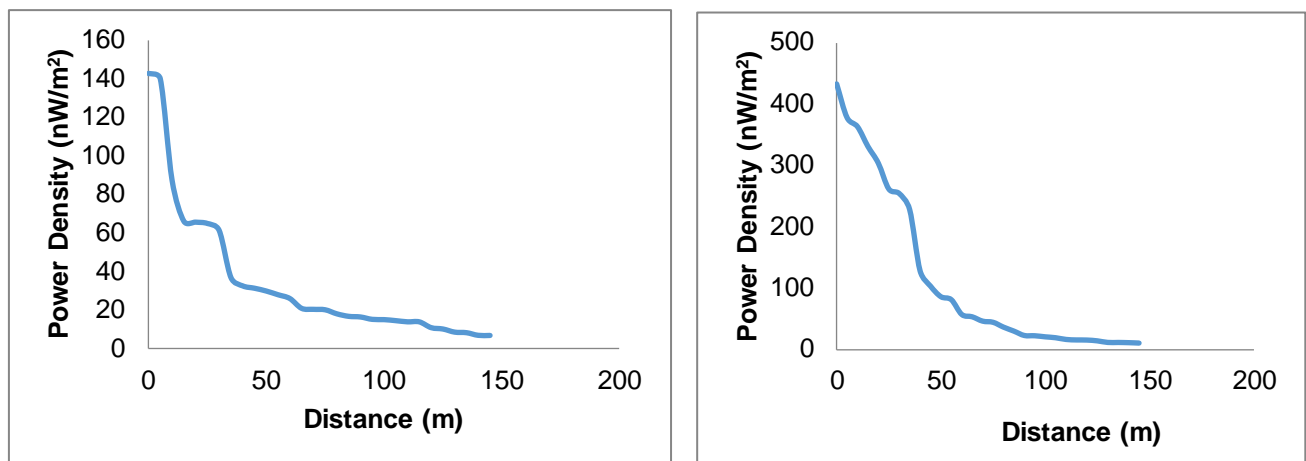


Figure 2: Average Power Density Variation with Distance in Market Places

Conclusion

The values of irradiated power from GSM mast base station was examine using a simple hand-held spectrum analyser on people living nearby GSM cellular base stations. The results show that the power density varies directly with distance. This means the closer the distance from the GSM base station the higher the radiofrequency radiation. The research findings shows that maximum power density of 133.3 nW/m², 432.3 nW/m² and 491.70 nW/m² were recorded at 0.0 m for Residential Areas, Market Places and School Premises, respectively, while the minimum power density of 9.6 nW/m², 10.09 nW/m² and 7.57 nW/m² was recorded at 145 m radial distance in Base Transceiver Station for Residential Areas, Market Places and School Premises, respectively. Therefore, the RF exposure hazard index in all the locations was significantly below the permitted RF exposure limit of 4.5 W/m² to 9.0 W/m² to the general public as recommended by ICRNIP. Therefore, people living within the School premises absorb large percent of the radio-frequency radiation which could be as a result of the large number of clustered GSM masts. Comparing the calculated values of Power Density with ICNIRP, and IEEE exposure limits, an idea for the compliance distance where the radiation level is safe for public exposures was estimated.

Recommendation

Theoretical results show that when cellular base stations are mounted on houses rooftops, it is possible that a person at a distance less than 5.0 m or very close to the base station

could be exposed to high RF levels greater than the maximum permissible exposure (MPE) limits. Hence, exposure levels exceeding the safety limits are likely to be found very close to and directly in front of the base station antennas, and at this hazardous distance, access to this circumference should be limited, and should not be reached by the public. Although the level of exposure in all the locations examined are far less than the recommended reference levels, precautions should be taken on how close a base transceiver station is installed to residential buildings and on the rapid increase in the number of installed base transceiver stations may lead to possible changes in exposure level, an independent audit of all base stations throughout the country be carried out to ensure that exposure guidelines are not exceeded.

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