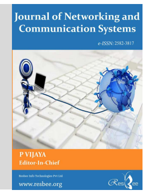
Vol.6 No.2 April 2023

Journal of Networking and Communication Systems

Received 24 March, Revised 20 April, Accepted 28 April



Measurement of Electromagnetic Fields (EMF) from Mobile Phone Base Stations and Health Effect in Abeokuta, Ogun State, South-Western Nigeria

Taiwo T.K.*
Ministry of Education, TESCOM, Leaf Road, Ibadan, Oyo State, Nigeria.

Alausa S.K.
Department of Physics, Olabisi Onabanjo University, Ago-Iwoye,Nigeria.

Adegbile A.A.
Department of Computer Technology, Federal College of Animal Health and Production Technology, Moor Plantation, Ibadan, Nigeria.

Oluwafisoye P.A.
Department of Physics, Osun State University, Osogbo, Nigeria.

Bayode O.P.
Department of physics, Osun state University, Osogbo, Nigeria.

Abstract: The general public is concerned about the potentially dangerous health effects of human exposure to Electromagnetic Radiation (EMR) released by Phone base stations. Concerns about the purported detrimental effects of Electromagnetic Field (EMF) radiations emitted by Phone base transceivers prompted protests against the construction of phone base stations (BTS). As a result, measuring levels of EMF exposure to the population and potential hazards is critical. In this paper, a wideband TES-90 Electro smog meter is used to measure public exposure to electromagnetic radiation from the BTS at several places in Abeokuta. After surveying using a Global Positioning System (GPS) meter, measurements are taken from 62 base stations in Abeokuta. The maximum and average power density from all of the investigated base station antennas was compared with the International Commission on Non-Ionizing Radiation for public exposure (ICNIRP) to get accurate results. From the given input, the greatest power density for the system of mobile telecommunication signal at BTS is 9.02 10^{-4} $mWcm^{-2}$ at a 2m radius, while the mean value of power densities collected from all base stations is 3.61 10^{-4} $mWcm^{-2}$ at 2m radius which is significantly lower than the 1 $mWcm^{-2}$ limit imposed by the International Commission on Non-Ionizing Radiation for public exposure (ICNIRP). The measurement is within the ICNIRP-recommended limiting standard (1$mWcm^{-2}$). In this study, it was found that radiation exposure from BTS poses no health risk and does not appear to have any known harmful effect on human health.

Keywords: Electromagnetic radiations, Electromagnetic field, Phone base stations, Abeokuta, TES-90 electro smog meter.

Nomenclature

Acronym	Description
MBTS	Mobile phone Base Station
PEM	Personal Exposure Meter
RF-EMF	Radiofrequency Electromagnetic Fields
GIS	Geographic Information System
RBS	Radio Base Station
ICNRP	International Commission on Non-ionizing Radiation Protection
BTS	Base Station
EMF	Electromagnetic Field
EMR	Electromagnetic Radiation

1. Introduction

All humans are subjected to EMF/EMR from both natural and man-made sources [16]. Every day, humans are exposed to natural EMF (Sun) and it is impossible to say that EMFs are hazardous to humans [9]. Artificial EMF had introduced into the environment for many years as a result of technological innovation and research [10][12]. Humans in modern society are subjected to a growing number of EMFs emitted by the production and distribution of energy, television sets, personal computers, radio transmission, security equipment, and, most recently, mobile phones and their base

https://doi.org/10.46253/jnacs.v6i2.a1

stations. Although they have various benefits (e.g., telecommunication, medical, and agricultural purposes), it has been discovered that exposure to these EMFs might be hazardous to us.

The rising use of 5G mobile phones and citing masts/towers inside residential areas has created public concern about potential health risks connected with non-ionization electromagnetic radiation exposure from BTSs and mobile handsets [11]. The apparent unrestricted development of masts and antennas, in some cases with little public engagement, has sparked suspicion and organized protest, particularly where facilities have been or are scheduled to be located near schools, daycare centers, and other sensitive areas. Mobile phone base stations emit microwave electromagnetic radiation (450-2100 MHz) [17]. Similar radiation is produced by other digital wireless systems, such as communication networks. This emission may pose a significant health risk; nonetheless, several National Radiation Advisory Authorities [18] have recommended preventive actions to reduce exposure to their citizens without specifying the exact health effect.

The radiation emitted by fixed infrastructure called base stations and their antennas that provide a link to and from mobile phones is a source of concern in the telecommunications industry. Mobile phones continuously release radiation into the surroundings. Base stations are typically 50 to 200 feet tall [19]. Cell phones communicate with local cell towers primarily using radio wave energy in the electromagnetic band between FM radio waves and microwaves. They are non-ionizing and differ from strong forms of radiation such as X-rays, gamma rays, and ultraviolet, which can cause health problems such as DNA-cell breakage. The installation of Phone base stations in populated areas has sparked concerns about the potential health impacts of emitted EMF [20]. Nearly every new invention contributes to pollution. The rate is increasing at an exponential rate.

This research provides an overview of electromagnetic fields and their negative impact on the human body. The public in Nigeria has voiced concern about living or working near a cell phone tower due to potential health dangers. There have previously been few reports on the health effects of EMR exposure from mobile phone base stations. As a result, it is required to analyze whether or not there is a health effect from MBTS EMF exposure and to guide the horizontal safety distance of the house/structure from the cell tower. This method proposed a TES-90 Electro smog meter to measure the power density of the RF. GPS helped to find the base station location. The results were compared with the power density behavior and distance change. To overcome all such drawbacks and limitations encountered in the former method, it is necessary to develop a reliable and robust process to analyze long-term RF emissions.

The objective of this paper is as follows.

1. To calculate the RF level in the MBTS around Abeokuta.
2. To investigate the average power density of BTS and compared it with the ICNIRP.
3. To find a solution for the voice of the Nigerian people related to the concern of health risks of RF Exposure.

The organization of this paper is in this order: Section 2 presents the literature review, and Section 3 portrays the methodology. The result is illustrated in section 4. Section 5 covers the discussion section 6 provides the advantages and disadvantages, and Section 7 concludes the paper.

2. Literature Review

2.1 Related Works

In 2010, Khurana *et al.* [1] have collected data from the PubMed database that helped to examine the health effects of MPBS in seven countries. Initially, ten studies from seven countries were examined and summarized in a table. Then the data were separated into base station proximity and neurobehavior symptoms through questionnaires and medical records. However, meta-analysis was not possible due to the difference in statistic measurement, study design, exposure categories, and endpoints. In 2021, Martin *et al.* [2] have used a cross-sectional study to identify the association between residential exposure to radiofrequency electromagnetic fields from the mobile base station and health disturbances. Initially, two questionnaires were prepared to identify the health disturbance and environmental perception of the people nearby MPBS. Then the results were compared through statistical analysis. The result suggested that there is no adverse effect of RF exposure in the general population. In 2021, De Giudici*et al.* [3] have experimented with using PEM to measure the RF-EMF. Initially, 250 meters around the MPBS location was identified. Then using spot measurement, the highest field strength was identified. Using PEM, the RF_EMF was measured for 48 hours or 7 continuous days. The results were then evaluated and identified more than 60% of RF was exposed in the surveyed areas. In 2020, Pesaresi*et al.* [4] have implemented GIS to identify the exposure of EMF from RBS. Initially, a field survey was conducted and recorded in data and images with geo-technological and geomatics instruments. Then retracted the route by joining the materials through the GIS environment. Through different functions, the concentric circular buffer zones were connected with different exposure levels. The levels were measured to identify risk factors and outbreaks of diseases and symptoms. This method helped to identify dynamic and multiscale digital systems functions. In 2021, Olorunsola *et al.* [5] have executed a Spectrum HF-2025E analyzer to measure the RF-EMF. Initially, the analyzer was set up in the main areas of RF exposure. The GPS was used to record the temporal data every second. The collected data was then processed through Aaronia software to analyze the temporal variation in the area. Finally, the result was compared with the ICNRP guidelines. In 2020, Ayugi *et al.* [6] have ensembled Spectrum analysis to identify the exposure of RF. Initially, the RF was measured using the spectrum analyzer in the sensitive areas. The measurement was taken repetitively to accurately predict the exposure levels. Then they compare with the ICNIRP standards to get accurate results. This method helps to safeguard the public from RF exposure. In 2020, Nahuku *et al.* [7] have experimented with a Spectran HF V4 spectrum analyzer to measure the RF radiation levels. Initially, the spectrum analyzer measured the RF radiation levels in Watts per square meter (Wm^{-2}) at every 25m interval from the fence of the BTS to a maximum distance of 150m. The data was analyzed using Microsoft Excel and IBM SPSS statistics version 23.0. Then they selected 17 BTSs and measured their RF radiation levels at different distances from the BTS fence. The results were compared to the ICNIRP standard guidelines to determine radiation levels that were safe for the public. In 2019, Karunarathna *et al.* [8] have applied a Yagi antenna and spectrum analyzer to detect RF. Initially, the antenna and analyzer were placed in populated areas above 1.4 m ground level. The measurement was carried out by rotating the antenna at 360°. The measurement was converted to field intensity and converted to a numerical value. Finally, by calculating the field intensity and power density, the value was compared with the FCC standards to get accurate results.

2.2 Review

Table 1 portrays the methodology, advantages, and disadvantages of the existing method. We considered eight papers that used a different methodology that helped to detect RF at various levels. Each method has certain benefits and shortcomings that were explained in detail.

Table 1: Review Based on Existing Methods.

Author	Methodology	Advantages	Disadvantages
Khurana *et al.* [1]	**PubMed**	• Helped to understand potential health risks in the identified location better.	• Only used Pub Met Database. • The reports were self-reported. Can contain inaccuracies. • Didn't measure the exposure level of RF.
Martin *et al.* [2]	**Cross-sectional study**	• Simple and cost-effective. • Non-invasive method.	• Assessed only self-reported symptoms. • Didn't consider potential effects. • Didn't consider long-term exposure.
De Giudici *et al.* [3]	**PEM**	• Can be used for other research because of its consistency and comparability. • Helped to spot the highest field strength easily.	• Didn't represent the various exposure of individuals. • Didn't consider long-term exposure.
Pesaresi *et al.* [4]	**GIS**	• Can adjust with other distances and measurements.	• Didn't provide a detailed analysis of potential risk factors and disease symptoms.
Olorunsola *et al.* [5]	**Spectrum HF-2025E analyzer**	• Help to access the levels of exposure of the RF. • Benefited for researchers and policymakers to compare the recommended guidelines.	• Only considered Cellphone and WIFI frequency bands. • Didn't investigate the health effects.
Ayugi *et al.* [6]	**Spectrum Analyzer**	• Accurate and reliable results. • Used as the reference for other studies.	• Didn't consider multiple resources of exposure.
Nahuku *et al.* [7]	**Spectran HF V4 spectrum analyzer**	• Practical and effective method. • Accurate results.	• Didn't discuss the long-term health effects. • Used only small sample size.
Karunarathna *et al.* [8]	**Yagi antenna and spectrum analyzer**	• Easy identification of exposure levels.	• Didn't consider cumulative effects of exposure.

2.3 Challenges

Some of the issues faced in the RF-EMF are as follows,

In [1], used PubMed to understand the potential risk. However, it failed to explain the long-term mobile phone base station exposure and its health impact. The PEM in [3] helped to identify the highest RF strength in the location. It failed to consider personal exposure devices, such as Wi-Fi and Bluetooth. The determination of RF level in the particular location [5] was easy but didn't cover all weather conditions. Furthermore, in [8], RF was easily identified, and haven't investigated the impacts of the distance between the mobile base station and the measurement points.

3. Methodology

In the proposed method, the 62 base stations in Abeokuta are considered to measure power density and to statistically analyze the curves and correlations characteristics of the power density behavior as distance changes. The measurements were taken for antennas radiating (800-2300 MHz) on towers ranging in height from 35 to 50 meters. In Fig 1, the BTS and the distance of EMR were illustrated.

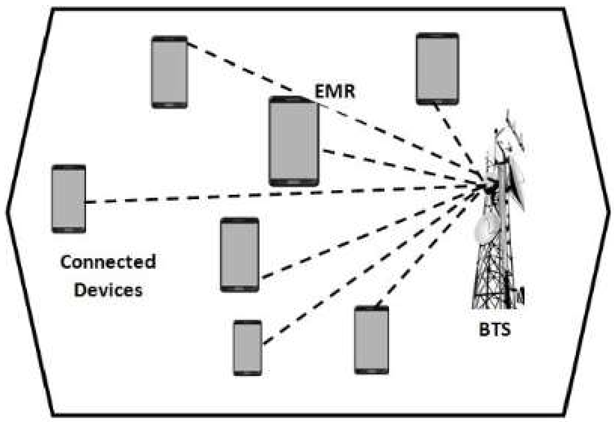


Fig 1. *Base station and Electromagnetic radiation*

3.1 Study Area

Because of its geographical setting (near rocky outcrops, relief characterized by escarpments that rose from the river plane to a height of approximately 150 m above sea level in the west, southern, and northern plains, and spatial distribution of BTS in the city), Abeokuta, the capital of Ogun State, was chosen as a study area (Fig 2 and 3). Around 90% of base stations are near human habitation. Over a surface mass of 879 km^2 (339 ml^2), Abeokuta contains about seventy mobile phone base stations, with a population density of 510 km^{-2} (1300 ml^2). Masts were calculated based on the size of the study region, and a total of 62 masts formed the sample frame. Fig 2 represents the distribution of telecommunication masts in the Abeokuta regions.

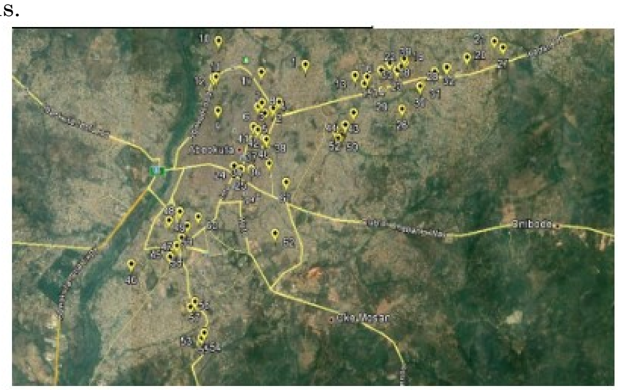


Fig 2. *Distribution of telecommunication masts in Abeokuta.*

Source: *Google Map*

3.2 Materials Used

This project evaluated 62 base stations throughout the Abeokuta metropolitan. The power density was assessed using an RF-EMF strength meter (Electro smog meter), The locations of each base station were established using a GPS. It is a gadget that receives signals to determine the precise location of any object on the Earth's surface. GPS devices provide information about a location's latitude, longitude, and elevation (altitude). The coordinates of the stations in Abeokuta were determined using a portable GPS. Engineering steel tape was used to measure distance and height. The Electro Smog meter is a wide-band device for measuring high-frequency radiation ranging from 50 MHz to 3.5 GHz. It is a non-directional digital (isotropic radio frequency) meter with three axes.

3.3 Measurement and Computation

The RF meter measures the strength of the electric field (E) and translates it to the magnetic field (H) and power density (S). When set to the triaxial mode of operation, the meter may measure field strength along several axes and collect measurements of all field strengths at the same time. Power density S in milli watts per square centimeter is connected to both E and H. ($mWcm^{-2}$)

An electromagnetic wave's propagation conveys energy. Albert Einstein was awarded the Nobel Prize in Physics in 1921 for his discovery that electromagnetic waves are conveyed by discrete particles (photons). Each photon in the wave train has the following energy:

$$E=hf \tag{1}$$

When f is the frequency and h is a constant known as Plank's constant (6.63×10^{-34} Js). The frequency of an EM field dictates the amount of energy it carries and, thus, how it will interact with the medium in which it is traveling.

The amount of power per unit area in a connected electromagnetic field is measured as power density (S). The power density (energy per unit area) received at a place is used to calculate human exposure to radiation (RF). According to ICNIRP (1998), the magnitude of the electric field strength (E) and magnetic field strength (H) is related to power density S as follows:

$$S = EH = E^2/377 = 377\Omega\, H^2 \tag{2}$$

where 377 Ω is the typical impedance of space, E is the intensity of the electric field, and H is the strength of the magnetic field. Power density characterizes the external EMF and can be measured experimentally. The strength of an electric or magnetic field is measured or computed.

Personal exposure levels are typically accurately assessed by onsite field measurement, as indicated in Fig 2. Equation 3 represents an approximation of far-field free space in which the reflected effect is ignored. It does, however, provide tolerable Prediction of radiofrequency radiation level based on free propagation loss as:

$$S = P4\pi Z^2 \tag{3}$$

where P represents total EMF power (watts) (Equivalent Isotropic Radiated Power EIRP), S represents EMF power density (W/m2), and Z represents the distance from the radio source (m).

All sector antennas have an isotropic antenna radiating pattern, which means that radiation power is distributed evenly in all directions:

$$P=X-Y+G \tag{4}$$

where X is total output power TRX, Y is loss of waveguide, G is antenna gain and S is limit = EIRP total/$4piZ^2$.

In general, the field strength drops fast with distance from the source due to geometric dilution matching to point source radiation into three-dimensional space, as predicted by the inverse square law. It is expressed as

$$\text{Intensity} \propto \frac{1}{\text{distance}^2}$$

Fig 2 depicts the spread of GSM base stations, whereas Fig 3 depicts a computerized topographical map of Abeokuta.

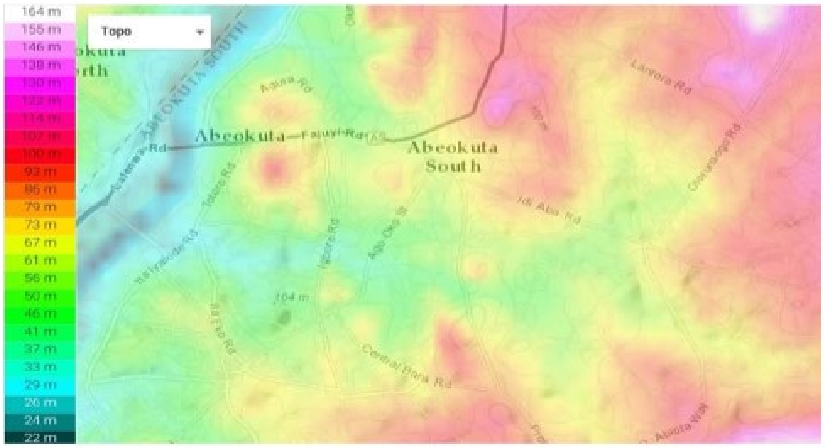


Fig 3. *Topographical map of Abeokuta.*

Source: *Topographic-map.com.*

The study included both primary and secondary data collection methods. Primary sources include measurement and observation, whereas secondary sources include the internet and journal papers. Measurements were taken from 800 to 2300 MHz exposure frequency. This frequency range corresponds to mobile phone BTS frequencies in Nigeria. The frequency of each antenna can be precisely calculated using the field measuring technique. To check the flux pattern, the RF was measured at various distances such as 0, 5, 10, 20, 40, 50, 100, 150, 200, 250, and 300 m from a properly selected base station.

The presentation and interpretation of the data collected served as the basis for data analysis. The power density was compared with the reference point to determine whether the power density value was less or more than the recommended exposure limits (10 Wm^{-2} = 1 $mWcm^{-2}$) for conclusion and recommendations.

4. Results

This section elaborates on the results with the comparison of power density with distance and height.

4.1 Experimental Setup

This experiment was conducted in Abeokuta, Ogun State, South-Western Nigeria where 62 base stations from Abeokuta were considered.

4.2 Evaluation Metrics

The performance of the proposed approach is evaluated with various variables influencing RF from BTS tower cells. Table 2 represents the parameters used for the evaluation.

Table 2: Evaluation Parameter

S.NO	Parameter
1.	Frequency/Wavelength of transmitted RF signals
2.	Number of antennas attached per BTS
3.	Length of RF signal exposure at a particular distance
4.	Exposure from other antennas in the neighborhood
5.	Duration/frequency of recurrent exposure
6.	Environmental temperature and humidity
7.	Antenna height

4.3 Measurement of Power Density from MPBS

Table 3: RF Energy Levels in Abeokuta

BTS No.	Station location-(GPSY)	RF level (Power density) ($mWcm^{-2}$)
1	07°10·448^{1}N,03°22.180^{1}E	1.71×10^{-4}
2	07°10·185^{1}N·03°21·560^{1}E	1.5×10^{-4}
3	07°10.092^{1}N,03°21.461^{1}E	3.0×10^{-4}
4	07°10·084^{1}N,03°21.440^{1}E	5.60×10^{-4}
5	07°10.016^{1}N,03°21.192^{1}E	3.68×10^{-4}
6	07°10.099^{1}N,03°21.316^{1}E	2.58×10^{-4}
7	07°10.112^{1}N,03°21.204^{1}E	4.19×10^{-4}
8	07°10.174^{1}N,03°21·266^{1}E	1.49×10^{-4}
9	07°11.054^{1}N,03°20.531^{1}E	3.0×10^{-4}
10	07°11.106^{1}N,03°20.538^{1}E	2.02×10^{-4}
11	07°10.567^{1}N,03°20.493^{1}E	2.20×10^{-4}
12	07°10.557^{1}N,03°20.451^{1}E	1.89×10^{-4}
13	07°10.591^{1}N,03°22·833^{1}E	2.46×10^{-4}
14	07°10.648^{1}N,03°22.995^{1}E	5.44×10^{-4}
15	07°10.5661N,03°23.0381E	9.02×10-4
16	07°10.667^{1}N,03°23.271^{1}E	6.16×10^{-4}
17	07°10.637^{1}N,03°21.258^{1}E	3.90×10^{-4}
18	07°10.768^{1}N,03°23.411^{1}E	2.36×10^{-4}
19	07°10.841^{1}N,03°23.653^{1}E	4.64×10^{-4}
20	07°10.864^{1}N,03°24.705^{1}E	2.17×10^{-4}
21	07°11.108^{1}N,03°25.169^{1}E	6.7×10^{-5}
22	07°10.839^{1}N,03°23.655^{1}E	4.64×10^{-4}
23	07°10·674^{1}N,03°23. 538^{1}E	2.67×10^{-4}
24	07°09.225^{1}N,03°20^{1}.809^{1}E	1.97×10^{-4}
25	07°09.175^{1}N,03°20.925^{1}E	1.96×10^{-4}
26	07°10.085^{1}N,03°23.620^{1}E	8.61×10^{-4}
27	07°11.016^{1}N,03°25.315^{1}E	1.10×10^{-4}
28	07°10.714^{1}N,03°24.373^{1}E	1.84×10^{-4}
29	07°10.360^{1}N,03°23.288^{1}E	1.83×10^{-4}
30	07°10.431^{1}N,03°23.924^{1}E	1.87×10^{-4}
31	07°10.452^{1}N,03°23.949^{1}E	2.16×10^{-4}
32	07°10.651^{1}N,03°24.170^{1}E	2.27×10^{-4}
33	07°10.728^{1}N,03°23.606^{1}E	2.92×10^{-4}
34	07°09.174^{1}N,03°21.092^{1}E	2.34×10^{-4}
35	07°09.178^{1}N,03^{v}21.243^{1}E	2.68×10^{-4}
36	07°09.267^{1}N,03°21.395^{1}E	3.55×10^{-4}
37	07°09.490^{1}N,03°21.336^{1}E	7.12×10^{-4}
38	07°09.620^{1}N,03°21.346^{1}E	4.66×10^{-4}
39	07°10.799^{1}N,03°23.677^{1}E	4.50×10^{-4}
40	07°09.644^{1}N,03°21.310^{1}E	2.68×10^{-4}
41	07°09.763^{1}N,03°21.203^{1}E	3.57×10^{-4}
42	07°09.808^{1}N,03°21.132^{1}E	2.95×10^{-4}
43	07°10.028^{1}N,03°22.813^{1}E	2.29×10^{-4}
44	07°09.845^{1}N,03°22.674^{1}E	1.27×10^{-4}
45	07°07.851^{1}N,03°19.737^{1}E	7.39×10^{-4}
46	07°07.739^{1}N,03°19.76^{1}E	8.41×10^{-4}
47	07°08.132^{1}N,03°19.924^{1}E	1.52×10^{-4}
48	07°08.395^{1}N,03°19.716^{1}E	5.68×10^{-4}
49	07°08.529^{1}N,03°19.891^{1}E	6.42×10^{-4}
50	07°09.641^{1}N,03°22.554^{1}E	6.69×10^{-4}
51	07°09.685^{1}N,03°22.617^{1}E	2.04×10^{-4}
52	07°09.770^{1}N,03°22.497^{1}E	2.76×10^{-4}
53	07°06.545^{1}N,03°20.256^{1}E	2.30×10^{-4}
54	07°06.625^{1}N,03°20.274^{1}E	6.0×10^{-5}
55	07°06.702^{1}N,03°20.315^{1}E	2.08×10^{-4}
56	07°07.091^{1}N,03°20.080^{1}E	5.30×10^{-4}
57	07°07.175^{1}N,03°20.158^{1}E	3.55×10^{-4}
58	07°08.012^{1}N,03^{v}19.843^{1}E	7.25×10^{-4}
59	07°08.313^{1}N,03^{v}20.018^{1}E	5.11×10^{-4}
60	07°08.453^{1}N,03°20.203^{1}E	5.12×10^{-4}
61	07°08.982^{1}N,03°21.684^{1}E	3.23×10^{-4}
62	07°08.207^{1}N,03°21.502^{1}E	1.14×10^{-4}
	Mean	3.61×10^{-4}

T ... power density was found at BTS-15, and the lowest was at BTS-54. The average power density in the research region was 3.61 10-

^{2} mWcm^{-2}, which is substantially lower than the maximum permissible exposure of 1mWcm^{-2} set by the ICNIRP.

4.4 Variations of Power Density with Distance (BTS-49)

The findings of electromagnetic power density measurements in the MPBS surrounding area as a function of distance from the antenna of 50 m high are presented here.

The association between RF power density and distance from the tower where the mobile phone base antenna was positioned is shown in Table 4. Table 4 displays the measured power densities from the tower. At 300 m, the value was 6.30 X 10^{-8} mWcm^{-2}, while at 0 m, the value was 6.42 X 10^{-4} mWcm^{-2}. At a distance of 150 m from the BTS, the power density encounters interference from other adjacent communication infrastructure causing the recorded value of 2.50 X10^{-6} mWcm^{-2} to fluctuate.

Table 4: Measurement of Power density with distance

Distance (m)	Power density (mW cm^{-2})
0.0	6.42×10^{-4}
5.0	2.30×10^{-4}
10.0	5.72×10^{-5}
20.0	1.45×10^{-5}
40.0	3.58×10^{-6}
50.0	2.28×10^{-6}
100.0	5.70×10^{-7}
150.0	2.50×10^{-6}
200.0	1.42×10^{-7}
250.0	9.10×10^{-8}
300.0	6.30×10^{-8}

The graph (Fig 4) depicts the behavior of power density as distance changes. It demonstrates that the RF field strength is greatest at the source and rapidly decreases with distance. However, the intensity of the radiation decreases fast as one moves away from the transmitter's base due to power attenuation. Power density characterizes the external EMF and can be measured experimentally or computed from the measured electric or magnetic field strength.

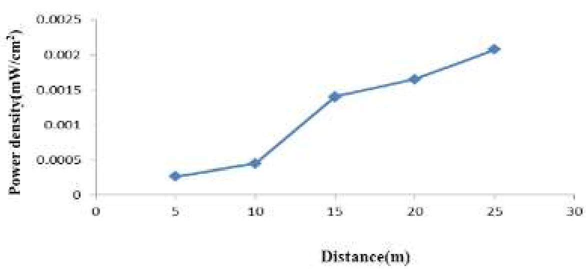


Fig 4: *Power density vs. distance.*
Source: *On field Measurement at Abeokuta*

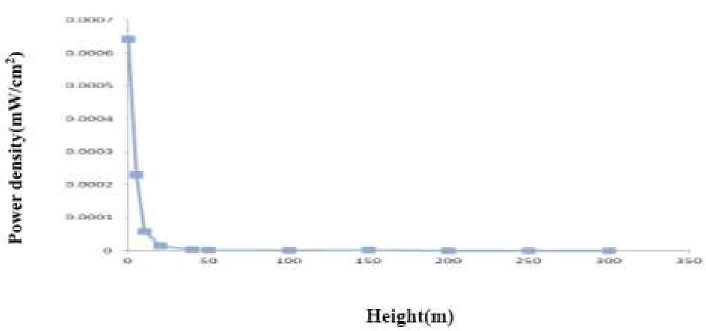


Fig 5: Power density vs. height.
Source: *On field Measurement at Abeokuta*

5. Discussion

The data provided here showed that the maximum power density was 9.02 X 10^{-4} $mWcm^{-2}$ at BTS-15 and the lowest was 6.0 X 10^{-4} $mWcm^{-2}$ at BTS-54, with a mean value of 3.61 X 10^{-4} $mWcm^{-2}$ (Table 2). The study's finding is approximately 1.2 times greater than the value reported [13]. The outcome is approximately 99.96% less than the ICNIRP exposure limit. This is approximately 2770 times less than the ICNIRP standard. The ICNIRP and FCC recommended safety limits are greater than the study's exposure levels.

Because of the small vertical spread of the beam, the RF intensity reduces rapidly as one moves away from the antenna, as seen in Table 2. The lowest power density fig was 6.30 X 10^{-8} m Wcm^{-2} at 300 m and the highest was 6.42 X 10^{-4} $mWcm^{-2}$ at the BTS basement. The power density fluctuates at a distance of 150 m from the BTS. However, EM field intensities decrease fast as one moves away from a mobile base station due to power attenuation with the square of the distance. This could be attributed to the environment of the tower's location, as well as the effect of hills and buildings on EMF radiation caused by multiple reflections (interference) from other nearby communication infrastructure or multipath propagation from the transmitting antenna on the tower to the receiving probe, causing a fluctuation in the recorded value 2.5 X 10^{-6} $mWcm^{-2}$. It begins to drop after 150 m and continues to decrease until it reaches 300 m. As a result, it remains within the permitted limited standard (1 $mWcm^{-2}$). Power density (S) at a point source is defined as $S \alpha 1/R^2$, where R is the distance from the tower. Fig 5 depicts the radiation pattern observed to obey the inverse square rule from a GSM tower antenna. When the distance from the GSM tower antenna doubles, the power density drops to 1/4, 1/9 when the distance triples, and so on. The fluctuation of power density with a height from the ground of a 50 m antenna is shown in Table 5. Measurements at varied heights of 5, 10, 15, 20, and 25 m were found to increase as the height from the ground increased. As a result, the RF field intensity at the ground level of the tower cell is significantly lower than at the height above the ground. Fig 5 depicts the linear fluctuation of power density with a height ranging from 5 to 25 m above ground. These results are substantially below the ICNIRP maximum exposure limit when compared to those achieved by others.

Table 6 depicts the link between RF power density and cell tower heights of 15 and 54 m. Table 4 displays the measured values from cell towers BTS-15 and BTS-54. The maximum power density measured from the two towers BTS-15 (35 m) and BTS-54 (50 m) was 9.02 10^{-4} and 6.0 10^{-4} $mWcm^{-2}$, respectively. The findings of this analysis also revealed that the higher the BTS tower, the lesser the risk, yet both measures are significantly below the ICNIRP public exposure standards.

The average horizontal safe distance from MPBS is calculated to be 10 to 13 m. The horizontal and vertical position of the transmitter antenna is the most essential parameter in identifying the radiation intensity area on occupants, according to the study.

The results imply that radiation exposure from the BTS poses no health risk because the limits established in the ICNIRP recommendations do not appear to have any known harmful effect on human health.

Yet, chronic exposure to EMFs in the human body has been linked to immune system weakening [14]. Such disruptions enhance the likelihood of disease transmission.

Table 5: Measurement of power density with height

Source: On field Measurement at Abeokuta

Height (m)	Power density (mW cm^{-2})
5.0	2.65×10^{-4}
10.0	4.48×10^{-4}
15.0	1.40×10^{-3}
20.0	1.65×10^{-3}
25.0	2.08×10^{-3}

Table 6: Measurement of Power Density from two BTS of Different Height.

Source: On field Measurement at Abeokuta

Height (m)	Power density (mW cm^{-2})
BTS-15(height 35m)	9.02×10^{-4}
BTS-54(height 50m)	6.0×10^{-4}

The findings of this study revealed that the fluctuations in power density with distance from mobile base stations follow the inverse square law, which means that the intensity decreases rapidly with distance from the tower. The finding was consistent with other international and national investigations. As a result, there is no reason to believe that MPBS pose a potential health risk to humans. To avoid any negative health impacts, we must operate our gadgets by scientifically established safety standards.

6. Advantages and Disadvantages

Advantages

- This method was used to determine the RF level accurately.
- It mainly helped to identify the safe distance zone from the MPBS.
- It determines the long-term potential health risk of RF exposure.

Disadvantages

- This method hasn't researched the effects of climate change on RF exposure.
- This method was not automated, the calculation was performed manually.

7. Conclusion

Distance and the height of EMF play a huge role in the emission of RF. According to the study's findings, residents in Abeokuta are exposed to significantly less RF radiation from MPBS than the ICNIRP's maximum allowable exposure of 1 $mWcm^{-2}$. The RF exposure hazard index in Abeokuta was significantly below the ICNIRP-recommended RF exposure limit for the population, however, preventive steps are required for a safer environment.

The consequence of modest EMF exposure can only be the heating of the bodily tissues. As a result, residents in the research area should not be concerned about the health effects of RF from phone base stations. Furthermore, It is necessary to conduct additional research on RF emission to explore the potential effects of EMFs on the human body. The current study aims to look at the level of the electromagnetic field from MPBS and the safety of human exposure in only Abeokuta. Further research has to be enhanced worldwide with long-time solutions.

8. Compliance with Ethical Standards

Conflicts of interest: Authors declared that they have no conflict of interest.

Human participants: The conducted research follows the ethical standards and the authors ensured that they have not conducted any studies with human participants or animals.

References

[1] Khurana, V.G., Hardell, L., Everaert, J., Bortkiewicz, A., Carlberg, M. and Ahonen, M., "Epidemiological evidence for a health risk from mobile phone base stations", *International journal of occupational and environmental health*, Vol. 16. No. 3, pp. 263-267, 2010.

[2] Martin, S., De Giudici, P., Genier, J.C., Cassagne, E., Doré, J.F., Ducimetière, P., Evrard, A.S., Letertre, T. and Ségala, C., "Health disturbances and exposure to radiofrequency electromagnetic fields from mobile-phone base stations in French urban areas", Environmental Research, Vol. 193, pp.110583, 2021.

[3] De Giudici, P., Genier, J.C., Martin, S., Doré, J.F., Ducimetiere, P., Evrard, A.S., Letertre, T. and Ségala, C., "Radiofrequency exposure of people living near mobile-phone base stations in France", Environmental Research, Vol. 194, pp.110500, 2021.

[4] Pesaresi, C. and Pavia, D., "Radio Base Stations and Electromagnetic Fields: GIS Applications and Models for Identifying Possible Risk Factors and Areas Exposed. Some Exemplifications in Rome", ISPRS International Journal of Geo-Information, Vol. 10, No. 1. pp. 3, 2020.

[5] Olorunsola, A.B., Ikumapayi, O.M., Oladapo, B.I., Alimi, A.O. and Adeoye, A.O., "Temporal variation of exposure from radio-frequency electromagnetic fields around mobile communication base stations", Scientific African, Vol. 12, pp. e00724, 2021.

[6] Ayugi, G., Kisolo, A., Ireeta, T.W. and Opio, P., "Temporal variation of radiofrequency electromagnetic field exposure from mobile phone base stations in sensitive environments", IOSR Journal of Applied Physics, Vol. 9, No. 5, pp.9-15, 2020.

[7] Nahuku, A.M., Tembo, K., Ngwira, F., Katengeza, E. and Nahuku, D.M., "Measurement And Analysis of Radiation Levels From Mobile Phone Base Station in Lilongwe Urban", Adv. in Ecol. & Env. Res, Vol. 5(04), pp.121-134, 2020.

[8] Karunarathna, M.A.A., Fernando, C.A.N. and Samarasekara, P.R.F., "Radiation distribution & corresponding exposure levels due to Mobile Base stations in Sri Lanka", Int. J. Adv. Res. Sci. Eng. Technol., Vol. 6, pp.7909-7916, 2019.
[9] Levitt, B.B., Lai, H.C. and Manville, A.M., "Effects of non-ionizing electromagnetic fields on flora and fauna, part 2 impacts: how species interact with natural and man-made EMF", Reviews on Environmental Health, Vol. 37, No. 3, pp.327-406, 2022.
[10] Berg-Beckhoff, G., Blettner, M., Kowall, B., Breckenkamp, J., Schlehofer, B., Schmiedel, S., Bornkessel, C., Reis, U., Potthoff, P. and Schüz, J., "Mobile phone base stations and adverse health effects: phase 2 of a cross-sectional study with measured radio frequency electromagnetic fields", Occupational and environmental medicine, Vol. 66, No. 2, pp.124-130, 2009.
[11] Rumeng, T., Ying, S., Tong, W. and Wentao, Z., "Electromagnetic field safety compliance assessments for 5G wireless networks", In 2020 IEEE International Symposium on Electromagnetic Compatibility & Signal/Power Integrity (EMCSI), pp. 659-662, 2020.
[12] Ramirez-Vazquez, R., Escobar, I., Martinez-Plaza, A. and Arribas, E., "Comparison of personal exposure to Radiofrequency Electromagnetic Fields from Wi-Fi in a Spanish university over three years", Science of The Total Environment, Vol. 858, pp.160008, 2023.
[13] Ayinmode B.O, Farai I.P., "Review of Variation EMF with distance from mobile phone base station", Radial pros Dosimetry Vol. 154, No. 4, pp. 424-428, 2017.
[14] Johansson.O.,"Disturbance of the immune system by electromagnetic field", Pathophysiology, Vol. 16, No. (2-3), pp. 157-177, 2009.
[15] Ahlbom, A., Bergqvist, U., Bernhardt, J.H., Cesarini, J.P., Grandolfo, M., Hietanen, M., Mckinlay, A.F., Repacholi, M.H., Sliney, D.H., Stolwijk, J.A. and Swicord, M.L., "Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz)". Health physics, Vol. 74, No. 4, pp. 494-521, 1998.
[16] Kıvrak, E.G., Yurt, K.K., Kaplan, A.A., Alkan, I. and Altun, G., "Effects of electromagnetic fields exposure on the antioxidant defense system. Journal of microscopy and ultrastructure", Vol. 5(4), pp.167-176, 2017.
[17] Dasdag, S., Akdag, M.Z., Kizil, G., Kizil, M., Cakir, D.U. and Yokus, B., "Effect of 900 MHz radio frequency radiation on beta amyloid protein, protein carbonyl, and malondialdehyde in the brain", Electromagnetic biology and medicine, Vol. 31, No. 1, pp.67-74, 2012.
[18] NPRB, "Health Effects from Radiofrequency Electromagnetic Fields: Report of an Independent Advisory Group on Non-Ionizing Radiation", Doc, NRRPB14(2), 2003.
[19] Renke, A. and Chavan, M., "An estimation of electromagnetic field exposure from cellular mobile base station towers in densely populated residential areas", Communications on Applied Electronics, Vol. 4, No. 3, pp.5-9, 2016.
[20] Singh, K., Nagaraj, A., Yousuf, A., Ganta, S., Pareek, S. and Vishnani, P., "Effect of electromagnetic radiations from mobile phone base stations on general health and salivary function", Journal of International Society of Preventive & Community Dentistry, Vol. 6, No. 1, pp.54, 2016.