Diurnal variation of RF power density with distance from selected mobile phone base transceiver stations in Offa metropolis, Kwara State Nigeria.

K O Olawale¹, O S Ajayi² and J S Ojo²
¹Physics/Electronic Unit, Department of Science Technology, Federal Polytechnic, Offa, Kwara State, Nigeria.
²Department of Physics, Federal University of Technology Akure, Nigeria

Corresponding e-mail: ¹kazeem.olawale@fedpoffaonline.edu.ng

Abstract. Diurnal variation of radiofrequency power density with distance from some 20 (20) selected mobile phone base transceiver stations of four (4) major mobile phone network providers (MTN, GLO, 9Mobile, and Airtel) in the Offa metropolis Kwara State Nigeria were studied. A digital Radio-frequency (RF) meter (HF-B8G High Frequency 10 Mhz - 8 GHz RF EMF Meter) is used to measure RF field strength first at foot at the base station and subsequently at every interval of 25 m up to 250 m in radial routes. Concurrently, the distance, geographical coordinates, and altitude of each point were measured using a Global Positioning System (GPS). The average maximum power density obtained ranged from 0.294 Wm⁻² and 0.057 Wm⁻² at a radial distance of 150 m and 0 m away from the base transceiver station respectively. The result of the study shows that the degree of power density variation with distance during the morning, afternoon, and night hours of the day was found to be highly different. The maximum level of exposure to RF electromagnetic radiation was experienced at night, followed by noon, and the minimum in the morning hours of the day in the majority of the base transceiver stations. For the different time of the day considered in this study, the results show that the power density obtained constitute no RF exposure hazard to the dwellers of Offa metropolis when compared with the RF exposure limit prescribed by the International Commission on Non-Ionizing Radiation Protection (ICNIRP).

1. Introduction

The tremendous growing in wireless communication services in every part of the world over the decades, particularly in Nigeria, has contributed to a rise in the number of mobile phone base transceiver stations (BTS) in the city's residential areas. However, the possible effect of this growth on the people in the vicinity base transceiver stations has posed a serious public concern.

The Global System of Mobile (GSM) communication uses radiofrequency, a lower energy part of the electromagnetic spectrum, categorized as non-ionizing radiation due to its inadequate energy to induce ionization of matter (unlike x-rays and gamma rays, etc.), to transmit and receive signals. As a result, non-ionizing radiation is considered safe at low levels, but it can be hazardous at higher levels due to heat generation. Though non-ionizing, radiofrequency radiation can penetrate the exposed tissues and induce significant thermal biological consequences, especially when exposure is consistent [1, 2].
This radio frequency (RF) generally covers frequencies within the range of 3 kHz to 300 GHz. The intensity of RF electromagnetic waves in an environment at a given location is often measured in terms of electric field strength (V/m) and magnetic field strength (Am⁻¹). Meanwhile, the most suitable unit for characterizing the total electromagnetic field is the power density, measured in the fraunhofer (far-field) region of the antenna [3].

A range of national and international organizations such as Nigerian Communications Commission (NCC), World Health organization (WHO) and International Commission in Non-ionizing Radiation Protection (ICNIRP), has formulated guidelines defining thresholds for occupational and residential EMF exposure. The International Commission on Non-Ionizing Radiation Protection (ICNIRP), a non-governmental body officially recognized by the World Health Organization (WHO), has set the EMF field exposure limits [4]. The guidelines apply to mobile phone base transceiver station sites as well as mobile phones and incorporate wide safety margins to protect against all established hazards of RF exposure. The exposure reference level of the RF electromagnetic fields (100 kHz to 300 GHz) recommended by the ICNIRP guidelines are 4.5 W/m² and 9.0 W/m² at a radiofrequency of 900 MHz and 1800 MHz respectively [5].

Several scientific researches support the view that it is unlikely to experience health hazard due to RF electromagnetic emission from BTS antennas if exposure is below international guidelines. Ahanek and Nzeako carried out an investigation on the intensity of RF radiation exposure around some mobile phone BTS antennas in the university environment in Nsuka, Enugu State, Nigeria, in 2012. The study discovered that the highest RF electromagnetic emission occurs at a distance where the main beam reaches the ground, whereas the value obtained closer to the antenna is lowest [6]. An estimated maximum power density of 2972 µWm⁻² at a 50 m radius was recorded from the study conducted by Ayinmode and Farai in 2013 on the variations of RF power density with distance within from some randomly selected BTS in Ibadan, Nigeria. The result revealed that in Ibadan, public exposure to RF radiation from BTS was below the international recommended limit [7]. In a similar study in 2016 by Fawole and Adekanye on the estimation of RF electromagnetic radiation around GSM base stations in some selected parts of Lagos State, Nigeria. Values of power density obtained range between 2.4 µWm⁻² and 71530 µWm⁻². These values below the ICNIRP recommended Radiation exposure limit. Therefore, there no significant hazardous effect from the electromagnetic emission from the base station to the public within the vicinity [8].

Therefore, this study attempt to assess the average maximum power density around the selected mobile phone base transceiver stations diurnally in Offa metropolis, Kwara State Nigeria. Also, how exposed are the dwellers to the radiation from the BTS antennas is assessed.

2. Materials and Method

This study was conducted in Offa Metropolis, Kwara State, Nigeria. Offa Metropolis is situated in Kwara State, Northcentral of Nigeria. The population of the dwellers is about 90,000. The vegetation of the city is Savanna, and its geographical coordinates are latitude 8° 8'21.66" N and longitude 4°43’2.66" E [9].

Measurement of RF field strength was done with a digital RF meter first at the foot of all the 20 selected mobile phone base transceiver stations (BTS) of four (4) major mobile phone network providers (MTN, GLO, 9Mobile, and Airtel) and subsequently at every interval of 25 m up to 250 m in radial routes. Concurrently, geographical coordinates and altitude of each point of measurement were taken using Global Positioning System (GPS) device. The measurement is carried out by pointing the RF meter to the radiation source at about 1.5 m above the ground level. Any possible direction (with or without a line of sight) within a particular sector is considered. The electric field strength and magnetic field strength data were collected three times daily (morning, afternoon, and night hours) in each of the base stations.

The data collected were used to determine the power density S using [10-11]:
\[ S = E \times H = \frac{E^2}{377} = H^2 377 \Omega \]  

(1)

where \( E \) is Electric field strength (Vm\(^{-1}\)), \( H \) is the Magnetic field strength (Am\(^{-1}\)) and \( S \) is the Power density (Wm\(^{-2}\)).

The resultant electric field intensity \( E^2 \) was calculated using:

\[ E^2 = E_x^2 + E_y^2 + E_z^2 \]  

(2)

Average maximum diurnal variations in power density with distance obtained were analyzed and compared diurnally. These results were also compared to the ICNIRP 2020 RF electromagnetic radiation exposure limit value recommended guidelines for the public [5].

### 3. Results and Discussion

Table 1 shows the results of the estimated average power density at various radial distances for each time of day. The highest average power density from the distances from all the BTS was 0.2119 Wm\(^{-2}\) obtained at 150 m radial distance, and the lowest value of average power density from the distances from all the BTS was 0.0573 Wm\(^{-2}\) obtained at the foot base station.

| Distance m | Morning hours (W/m\(^2\)) | Afternoon hours (W/m\(^2\)) | Night hours (W/m\(^2\)) |
|------------|---------------------------|----------------------------|------------------------|
| 0          | 0.0573                    | 0.0673                     | 0.0994                 |
| 25         | 0.1206                    | 0.0997                     | 0.1113                 |
| 50         | 0.0816                    | 0.1138                     | 0.1259                 |
| 75         | 0.1084                    | 0.1262                     | 0.1805                 |
| 100        | 0.1089                    | 0.1247                     | 0.1660                 |
| 125        | 0.0600                    | 0.1531                     | 0.1678                 |
| 150        | 0.0672                    | 0.1711                     | 0.2119                 |
| 175        | 0.0706                    | 0.1741                     | 0.2428                 |
| 200        | 0.0954                    | 0.1835                     | 0.2949                 |
| 225        | 0.1090                    | 0.1745                     | 0.2111                 |
| 250        | 0.0745                    | 0.1246                     | 0.1902                 |

When comparing the degree of variation of average power density with distance at three different times of the day (Figure 1), a high degree of variation was observed. As observed in Figure 1, the results follow the same trend of highest power density in the night, followed by afternoon and lowest in the morning except for one occasion; at 25 m distance in the morning hour. The exception could be ascribed to the sudden interference from other transmitting equipment when taken a reading of that point at one of the selected base stations; Site 10, that caused a spike in power density at the said distance. In view of this, maximum level of exposure to RF electromagnetic radiation was experienced at night (0.2119 Wm\(^{-2}\)), and the minimum was in the morning (0.0573 Wm\(^{-2}\)). These could be due to the interfering of different atmospheric parameters. As the troposphere changes as a function of time, so does the propagation of the radio waves. It could also be as a result of better reception of the radiofrequency signal at night hours than during the daytime from nearby transmitting stations.
Figure 1: Plot of Average maximum power density at a various radial distance for the three-time of the day

Power density variation with distance in the far-field region, considered to start from approximately 16 m distance from the BTS antenna panels in this study, is expected to obey the inverse-square law. According to inverse square law, the magnitude of one's exposure decreases inversely as the square of one's distance from the source. However, average power density obtained in this study at all the selected sites in the morning, afternoon, and night hours of the day were found to deviate from the inverse square law. As seen in Figure 2 (a) – (c), there is a gradual increase in power density as one moves away from the base stations and decreases at a far distance, especially. It also shows that the power densities were not concentrated within any particular area, which could be due to the base station antenna's directivity. Some other factors are the topography of the land area around the base stations, interference from vehicular activities, and structures (high-rise buildings, water tank towers, etc.) erect within the line of sight measurement.

Averagely, the maximum power density obtained in this study was found to be far less than the recommended general public exposure limit by ICNIRP.
Figure 2: Plot of Average maximum power density at various radial distance in; (a) Morning Hours (b) Afternoon hours (c) Night hours

4. Conclusion

The results of this work revealed that the highest average RF electromagnetic radiation was 0.2119 Wm\(^{-2}\) experienced in the night hours of the day. Given this, people in the studied area are likely to expose to RF electromagnetic radiation in the night hours than other periods of the day. Although the result revealed that there is no possible RF exposure hazard to the public in Offa metropolis, as the value is within the ICNIRP recommended general public RF exposure limit of 4.5 Wm\(^{-2}\) and 9.0 Wm\(^{-2}\) for the GSM network operating at frequency 900 MHz and 1800 MHz respectively.
References

[1] Inskip P D, Tarone R E, Hatch E E, Wilcosky T C, Shapiro W R, Selker R G, Fine H A, Black P M, Loeffler J S and Linet M S 2001. Cellular-telephone use and brain tumors N Engl. J. Med. 344 79–86

[2] Lonn S, Ahlbom A, Hall P, and Feychting M 2004 Mobile phone use and the risk of acoustic neuroepidemiology 15 653–659

[3] Ushie, P O, Victor, U J N, Ayomide B and Osahun, O D 2013 Measurement and Analysis of Radiofrequency Radiation Exposure Level from Different Mobile Base Transceiver Stations in Ajaokuta and Environs, Nigeria. IOSR Journal of Applied Physics, 3(6); 17-21.

[4] WHO 2006 Electromagnetic field and public health – Base station and wireless technologies. https://www.who.int/teams/environment-climate-change-and-health/radiation-and-health/electromagnetic-fields-and-public-health. Retrieved on 25/06/2020

[5] ICNIRP 2020 Guidelines for Limiting Exposure to Electromagnetic fields (100 kHz to 300 GHz)'. Health Physics 118(5); 483–524

[6] Ahanek, M and Nzeako, A 2012 GSM base station radiation level: a case study of University of Nigeria environment. International Journal of Scientific and Technology Research, 1 (8); 102-107.

[7] Ayinmode, B O and Farai, I P 2013 Study of Variation of power Density from Mobile Phone Base Stations with Distance. Radiation Protection Dosimetry. 156 (4); 424-428, Advance Access publication.

[8] Fawole, W I, and Adekanye, O O, 2016 Estimation of Radiofrequency Power Density around GSM Base Stations in Some Selected parts of Lagos State. www.iiste.org.Advance in Physics Theories and Applications 53; 49-52.

[9] Segun A, Olasehinde, P & Vrbka, P 2006 Identification of groundwater recharge conditions in crystalline basement rock aquifers of the southwestern Nigeria. 5th International symposium aquifer recharge, ISMAR Berlin.

[10] Akinyemi L A, Shoewu O, Pinponsu O A, Emagbetere J O, and Edeko F O 2014 Effect of Base Transceiver Station (BTS) on Humans in Ikeja Area of Lagos State. The Pacific Journal of Science and Technology 15 (2); 173-9. http://www.okamaiuniversity.us/PJST.htm

[11] Akpolile F A, Akpolile, F D, and Osalor O J 2014 Radiofrequency Power Density Measurements of Telecommunication Masts around Some Selected Areas in Delta State Nigeria of Journal of Natural Science Research, 4 (15); 77-9.