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Assessment of Radiofrequency Exposure from Base Stations in Some Tertiary Institutions in Rivers State, Nigeria

***Briggs-Kamara[1], M. A., Funsho[2], B. I. & Tamunobereton-Ari, I.[3]**
[1,2,3]Department of Physics, Rivers State University,
P.M.B. 5080, Port Harcourt, Rivers State, Nigeria
Email: briggs-kamara.margaret@ust.edu.ng

Abstract
The objective of this research work was to assess the effect of radiofrequency (RF) radiation exposure from Mobile Base Stations, if any, on the Environment. Measurements were carried out using the RF Strength Meter (ALRF05 Model, Toms Gadgets). Six (6) locations with a total number of ten (10) Mobile Base Stations were considered. The minimum and maximum power densities measured ranged between 0.03 μW.cm^{-2} and 4.094 μW.cm^{-2} at the Rivers State University, 0.072 μW.cm^{-2} and 3.239 μW.cm^{-2} at University of Port Harcourt - Abuja campus, 0.110 μW.cm^{-2} and 4.204 μW.cm^{-2} at the Elechi Amadi Polytechnic and 0.112 μW.cm^{-2} and 2.090 μW.cm^{-2} at the Ignatius Ajuru University of Education Rumuolumeni Campus. Mobile Base Stations were not sited within the campuses of the Catholic Institution for West Africa (CIWA) and the Eastern Polytechnic Rumuokwurusi (EPR) however, measurements show minimum and maximum power densities which ranged between 0.112 μW.cm^{-2} and 0.487 μW.cm^{-2} at CIWA and 0.112 μW.cm^{-2} and 0.487 μW.cm^{-2} at EPR. All the results were found to be below 4.5 W.cm^{-2} for the general public stipulated by the International Commission on RF radiation exposure. The correlation coefficient values of 0.87, 0.00001, 0.66 and 0.12 also revealed that the RF emission has insignificant effect on human health.

Keywords: GSM Communication, Base Station, Radiofrequency, Power Density, Exposure.

Introduction
The world and particularly Nigeria has become a global village due to the great advancement in telecommunication. The market for mobile telecommunication is very large and it is a major economic driver in many countries including Nigeria (Harald Gruber and Pantelis Koutroumpis, 2011). The breakthrough in wireless telecommunication which enables mobile phone users to access the Internet (among other uses) via the mobile phone has even added weight to this unprecedented increase in Global System for Mobile (GSM) Communications use (Qi Bi et al., 2001). Unfortunately, it is not technologically feasible to have Mobile Phones without Base Stations (BS). To communicate with each other, mobile phones and Mobile Base Stations (MBS) must exchange signals. This has therefore led to a resultant increase in the installation of Base Stations (BS) or Telecommunication Masts.

**Author for Correspondence*

Since a Base Station must be sited in close proximity to inhabited areas, the main concern here is the Radiofrequency (RF) emissions which may produce a heating effect depending on the intensity of exposure (Bello, 2010) when absorbed by the human body. There is no controversy about the thermal effect; however, the non-thermal effects have continued to be the subject of controversies between researchers, the mobile phone operators, the communities and a host of other stake holders. Some groups opined and believed to date that, the non-ionizing radiation from GSM masts is inimical to health. That is, living near the mast for a long period of time can cause several diseases such as cancer, persistent headaches, destroy reproductive organs and damage the brain (Dariusz, et al., 2002; Santini, etal., 2003; Akintonwa, 2009; Cherry, 2002). According to the International Agency of Research of Cancer (IARC, 2013) many of these studies had methodological flaws and weakness in reporting which included a difficulty to actually measure exposure to RF radiation without external influences, incomplete reporting and improper interpretation of results. The only consistent recognized biological effect of RF energy is heating. The ability of microwave ovens to heat food is one example of this effect of radiofrequency energy.

In contrast, some groups like the International Commission on Non-Ionizing Radiation (ICNIRP), World Health Organization (WHO), and GSM operators across the globe insist that radiation from Base Stations does not have sufficient energy to cause discernible effect on human body (Avwiri, et al.., 2007; Stewart, 2000; WHO, 1993; WHO, 2001). This they claim is because these parts of the human body have relatively insufficient blood to dissipate excessive heat generated due to non-ionizing radiation (Danladi, et al., 2016). However, there are growing concerns and fear, by students and workers at Higher Institutions of Learning in Rivers State on the possible health implications of the radiation from the many Base Stations seen in and around their campuses.

The Base Stations are placed directly above roofs of Lecture Theaters and Administrative Buildings, around Hostels and Offices, Banks and Café Centres. (Avwiri, et al., 2007) carried out a detailed assessment of RF radiation at the Delta Park Campus, University of Port Harcourt, Rivers State. The results obtained indicated that the mean RF radiation power density was 0.023% of the Federal Communications Commission (FCC) Guidelines, 0.015% of the National Radiological Protection Board (NRPB) permissible limit and 0.019% of International Commission on Non-Ionizing Radiation Protection (ICNIRP) standard and international public exposure maximum permissible limit (CPWR, 2016). Their value though well below all known international standards and permissible limits for the public, may have no impact or cause biological, epidemiological effects on the residents, but physiological effects should not be totally ruled out.

The permitted level for RF exposure to the general public at a frequency of 900 MHz (usually termed GSM 900) is 4.5 Wm-2 (ICNIRP, 1998). It is in the light of this, that this research work is aimed at assessing the RF radiation exposure at ten (10) MBSs located in six (6) selected Tertiary Institutions of learning in Port Harcourt, Rivers State, Nigeria (see Fig. 1).

Background of the Research

Obio-Akpor, a Local Government Area of Rivers State, one of the major centres of economic activities in Nigeria (Wikipedia), has over time also experienced this upsurge in the use of GSM. The number of MBS in the metropolis has increase as GSM Network Providers are mounting their BS (and antennas) within and around public places such as Markets, Schools, Places of Worship, Police Stations, Industrial and Residential Areas. "Since a Base Station must be sited in close proximity to inhabited areas, the main concern here is the Radiofrequency (RF) emissions from these Base Stations.

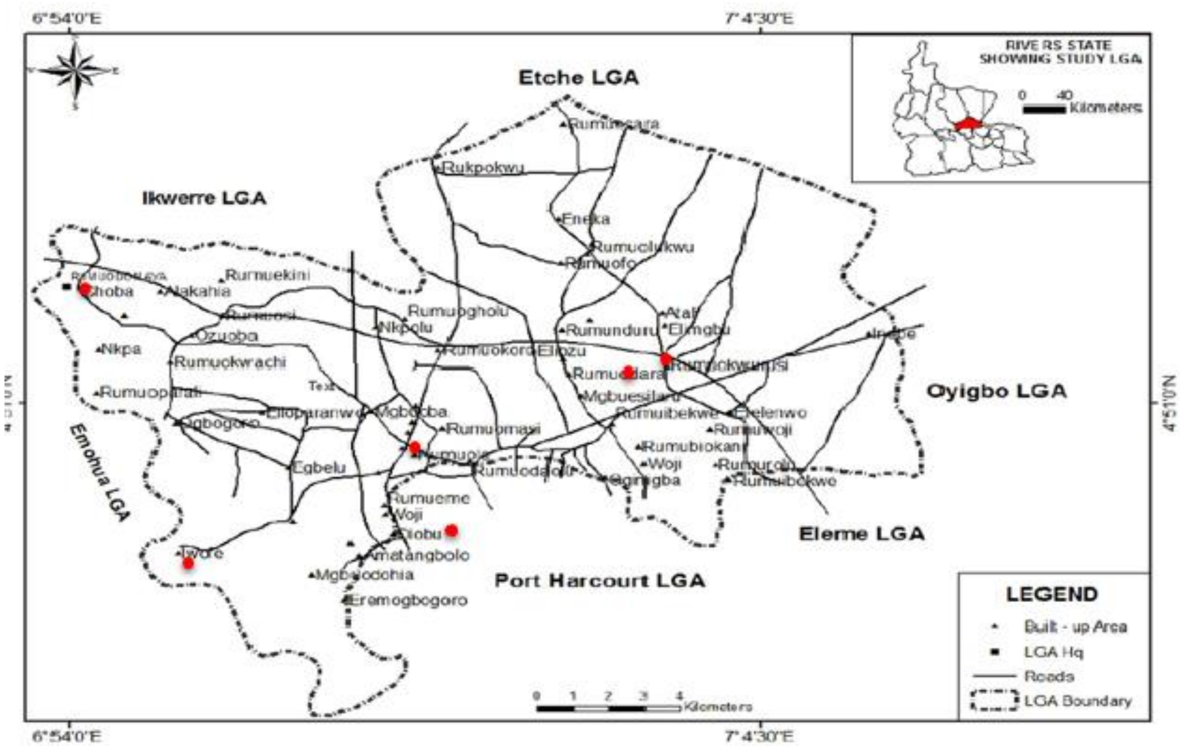

Fig.1: Map of study area (Wanyanwu, 2017) : Red spots are the locations of the selected Mobile Base Station

There has been various research studies carried out to decide the impact of RF radiation exposure all over the world including here in Nigeria. Record has shown that most research works are mainly carried out in the residential and industrial areas only. Little is known about RF radiation exposure in tertiary institutions since these areas are of more concentration of users of sophisticated mobile phone, Banks, Computer centres and Cyber café which has led to increase in Base Stations. This scenario has created uncomfortable feelings to both Lecturers and Students resident that they may be affected by the radiations from antennas.

This project work was intended to provide the relevant scientific information to the public in educating them about the myths (if any) surrounding the effects of Base Stations. It is also essential to assess the extent of exposure to RF radiation form Base Stations in these Institutions, and also to test their compliance with international set standards.

Methodology

Field measurement approach was chosen to analyse Base Stations radiations in various locations. Measurements (of radiation power density) were made using the RF strength meter (ALRF05 Model, Toms Gadgets) by holding the meter away from the body, at arm's length and at about 1.5m above the ground level to the source of the RF radiation.

The theoretical principles of this meter are as explained here-in (Copyright © 2014 FLIR Systems, 2018). It is used to measure the strength of Electromagnetic Radiation fields. Wherever there is a voltage or a current, for example from radio broadcasting and TV transmitters, electric (**E**) and magnetic (**H**) fields arise. The Electric Field Strength represents the force (**F**) on an infinitesimal unit positive test charge (q) at a point divided by that charge (see Eq. 1).

$$E = \frac{F}{q} \qquad Eq. 1$$

It is expressed in units of volts per meter (Vm-1). This unit is used for measurements in near-field area of the source or where the nature of the electromagnetic field is unknown. The Magnetic field strength (H) is equal to the magnetic flux density divided by the permeability of the medium (see Eq. 2).

$$H = \frac{\Phi}{\mu} \qquad Eq. 2$$

It is expressed in units of amperes per meter (Am-1). The Power density (S) is power per unit area in the direction of propagation (see Eq. 3), usually expressed in units of watts per square meter (Wm^{-2}) or, for convenience, as $mW.cm^{-2}$ or $\mu W.cm^{-2}$.

$$S = \frac{P}{A} \qquad Eq. 3$$

Electromagnetic fields propagate as waves and travel at the speed of light (c). The wavelength is proportional to the frequency λ (wavelength) = c (speed of light) f (frequency). Near-field is assumed if the distance to the field source is less than three wavelengths. For far-fields, the distance is more than three wavelengths. In the near-field, the ratio of electric field strength (E) and magnetic field strength (H) is not constant, so measure each field should be measured separately. In the far-field, however, it is enough to just measure one field quantity, and compute the other accordingly. The Meter finds application in High frequency (RF) electromagnetic wave field strength measurement, Mobile phone Base Station antenna radiation power density measurement, RF power measurement for transmitters, Wireless LAN (Wi-Fi) detection, Cellular/Cordless phone radiation safety level, Microwave oven leakage detection, Personal, environmental EMF safety. The RF field strength meter is technically a Power density meter which has the ability to detect radio and microwaves within a frequency range 5 MHz to 3 GHz. It expresses the field strength as power density. The meter displays the true power density on the screen. It is highly sensitive and can detect a wide range of frequencies between 0.5 MHz – 3.0 GHz or narrow frequency range which is between 100 MHz to 3GHz. At high frequencies, the power density is of particular significance. It provides a measure of the power absorbed by a person exposed to the field. This power level must be kept as low as possible at high frequencies. The meter can be set to display the instantaneous value, the maximum value measured or the average value. Instantaneous and maximum value measurements are useful for orientation, e.g. when first entering an exposed area.

The values of the measured power densities was taken after the meter is stable and recorded. Precautions were taken to avoid the movement of the meter during measurements and excessive field strength values due to electrostatic charges, and to make sure (where possible) that movement of cars and phone calls were reduced before taking measurements.

A maximum of about 100 m radial distance from the foot of the Base Station was considered and measurements were taken at 20 m intervals in every 5 minutes. The proximity of buildings and the manner of clusters to other Base Stations informed the reason for choosing this range of distance. The bandwidth of the RF field meter was set to "wide" so that a wider range of radiation can be measured. The effective power density was computed from the sum of the measured vertical and horizontal RF field densities.

The measurements were carried out within six (6) locations which had Base Stations and at two (2) other locations within which there were no Base Stations, to serve as control. Ten (10) Base Stations were selected in all. The geographical positions of the Base Stations were determined using GPS 76 (Garmin Model). Data were collected at specific locations for a period of two (2) weeks. The data were computed and analyzed using WINDOWS – 2013 EXCEL Software.

The Specific Absorption Rate (SAR) is the unit of measurement for the amount of radio frequency energy absorbed by a body when using a wireless device. It was computed using the formula (Eq. 4) (Enyinna, 2010):

$$SAR = \frac{P_d \, X \, H_{sa}}{W_A} \qquad \text{Eq. 4}$$

where:

P_d = power density ($W.cm^{-2}$),

H_{sa} = human surface area (20,128.99 cm^2),

W_A = Weight of Average human (60 kg).

Results and Discussion

The GPS locations of the different telecommunication masts are shown in Table 1. The average radiofrequency power density measurements and corresponding average Specific Absorption Rates (SARs) are presented in Tables 2 to 5. Note that the averages were calculated for each Institution as follows: for example, all values for a distance of 20.0 m from each mast location was added and then divided by the number of masts in that Institution.

Table 1: GPS locations of the different telecommunication masts at the various Institutions

S/No.	Institution	ID Number	Service Providers	GPS location of masts
1.	Rivers State University, Nkpolu-Oroworukwo	MBS 1	MTN	N 04^0 48′ 11.8′′, E 06^0 59′ 10.8′′
		MBS 2	MTN	N 04^0 47′ 21.1′′, E 06^0 58′ 44.9′′
		MBS 3	MTN	N 04^0 47′ 51.0′′, E 06^0 58′ 37.3′′
		MBS 4	MTN	N 04^0 47′ 38.8′′, E 06^0 58′ 37.6′′
		MBS 5	MTN, AIRTEL, 9MOBILE, GLO	N 04^0 47′ 88.2′′, E 06^0 58′ 69.7′′
2.	University of Port Harcourt, Choba	MBS 6	MTN, AIRTEL	N 04^0 47′ 54.1′′, E 06^0 55′ 13.0′′
		MBS 7	HIS	N 04^0 47′ 53.6′′, E 06^0 55′ 18.6′′
		MBS 8	GLO	N 04^0 54′ 12.2′′, E 06^0 55′ 23.0′′
3.	Elechi Amadi Polytechnic, Rumuola	MBS 9	MTN	N 04^0 50′ 13.7′′, E 06^0 09′ 45.1′′
4.	Ignatius Ajuru University of Education, Rumuolumini	MBS 10	MTN	N 04^0 48′ 21.9′′, E 06^0 05′ 43.7′′
5.	Catholic Institution of West Africa (CIWA)	-	-	N 04^0 50′ 42.0′′, E 07^0 02′ 32.4′′
6.	Eastern Polytechnic Rumuokwurusi	-	-	N 04^0 51′ 23.4′′, E 07^0 03′ 37.6′′

Table 2: Average power density and Average Specific Absorption Rate (SAR) at Rivers State University

Distance(m)	Average (μWcm^{-2})	Average SAR(μWKg^{-1})
0.0	0.5226	175.3235
20.0	0.6827	195.1172
40.0	0.6022	202.028
60.0	0.6600	221.4189
80.0	0.8786	294.7555
100.0	1.2294	412.4430

Table 3: Average power density and Average Specific Absorption Rate (SAR) at University of Port Harcourt (Abuja Campus)

Distance(m)	Average (μWcm^{-2})	Average SAR(μWKg^{-1})
0.0	0.3793	127.2600
20.0	1.7083	573.1171
40.0	1.7103	573.7881
60.0	1.3785	462.4635
80.0	1.0130	339.8445
100.0	0.8690	291.5349

Table 4: Average power density and Average Specific Absorption Rate (SAR) at Elechi Amadi Polytechnic

Distance(m)	Average (μWcm^{-2})	Average SAR(μWKg^{-1})
0.0	0.888	297.9091
20.0	1.0425	349.7412
40.0	4.021	1348.978
60.0	1.8485	620.1407
80.0	2.172	728.6694
100.0	1.179	395.5347

Table 5: Average power density and Specific Absorption Rate (SAR) at Ignatius Ajuru University of Education, Rumuolumeni

Distance(m)	Average (μWcm^{-2})	Average SAR(μWKg^{-1})
0.0	0.293	98.2966
20.0	0.2525	84.7095
40.0	0.263	88.2321
60.0	0.4735	158.8513
80.0	1.211	406.2701
100.0	0.5815	195.0835

Figs. 2 to 5 show the scatter plots of Average Power Density against Distance for the respective locations. The analysis of the results in Fig. 2 to Fig. 5 show that there is insignificant and scattered correlation between exposure of RF radiation and human health with coefficient of correlation of 0.87, 0.00001, 0.66 and 0.12 respectively. The analysis in Fig.2 (Rivers State University) shows a large positive linear association, followed by Fig. 4(Ignatius Ajuru University of Education), while Fig. 3(University of Port Harcourt) and Fig. 5 (Elechi Amadi Polytechnic) show no correlation between the values of the power density and human health. This means that there is no effect on human health because the low power emission has no sufficient ionization energy to destroy any cell in the human body.

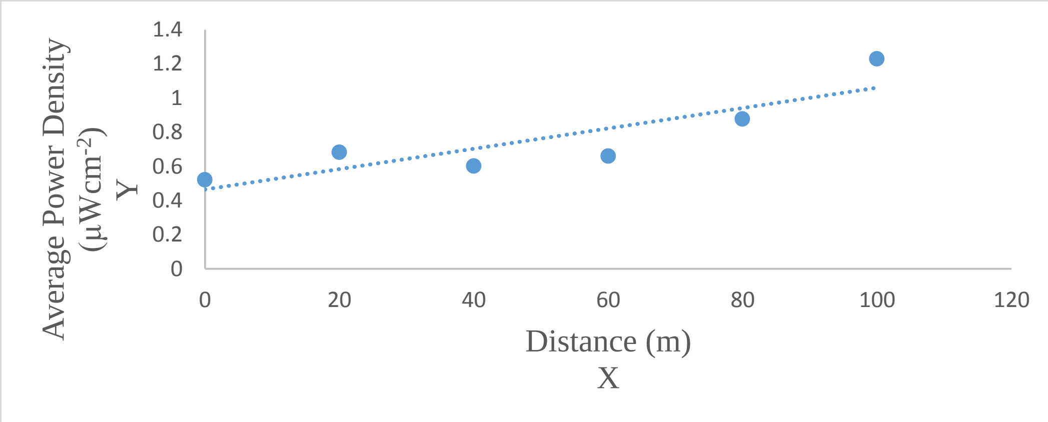

Fig. 2: Scatter plot of average power density against distance at Rivers State University

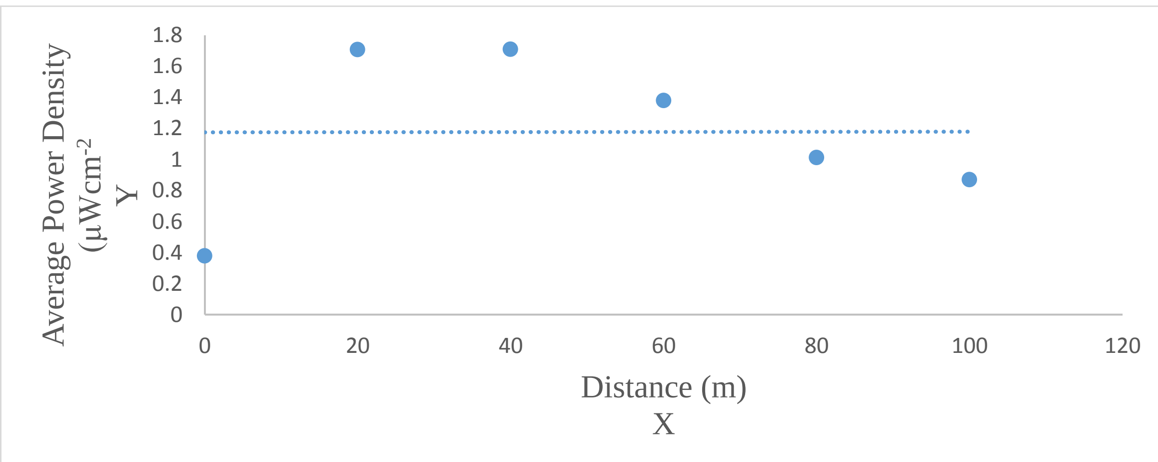

Fig. 3: Scatter plot of average power density against distance at University of Port Harcourt (Abuja Campus)

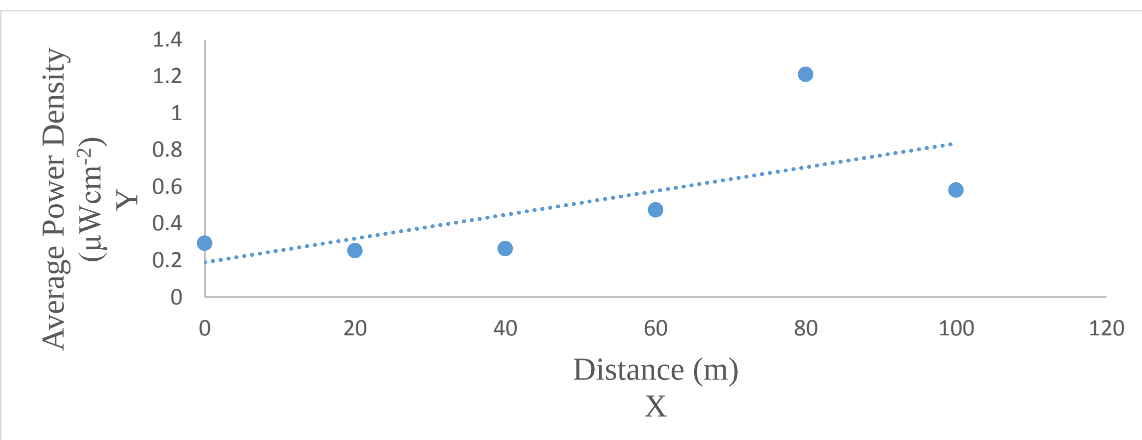

Fig. 4: Scatter plot of average power density against distance at Ignatius Ajuru University of Education

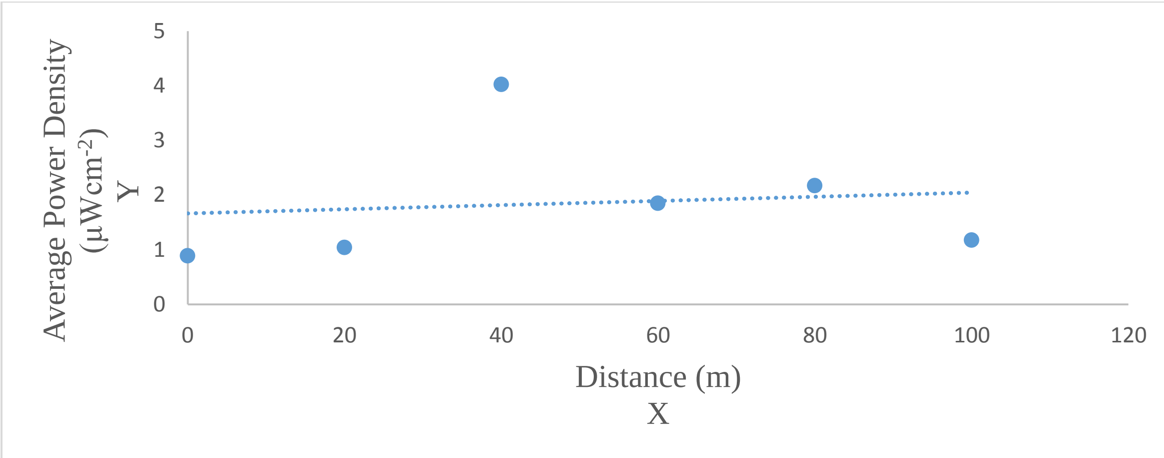

Fig. 5: Scatter plot of average power density against distance at Elechi Amadi Polytechnic

Figs. 6 to 9 are the corresponding bar charts of average SAR against distance for the respective locations. At the Rivers State University (Fig.6) and at the Elechi Amadi Polytechnic (Fig. 5) the average SAR increased with distance. At the University of Port Harcourt (Fig. 7) the average SAR started to increase and peaked at a distance of 40 m before reducing in value as the distance increased. At the Ignatius Ajuru University of Education (Fig. 8) the average SAR seem to decrease with distance.

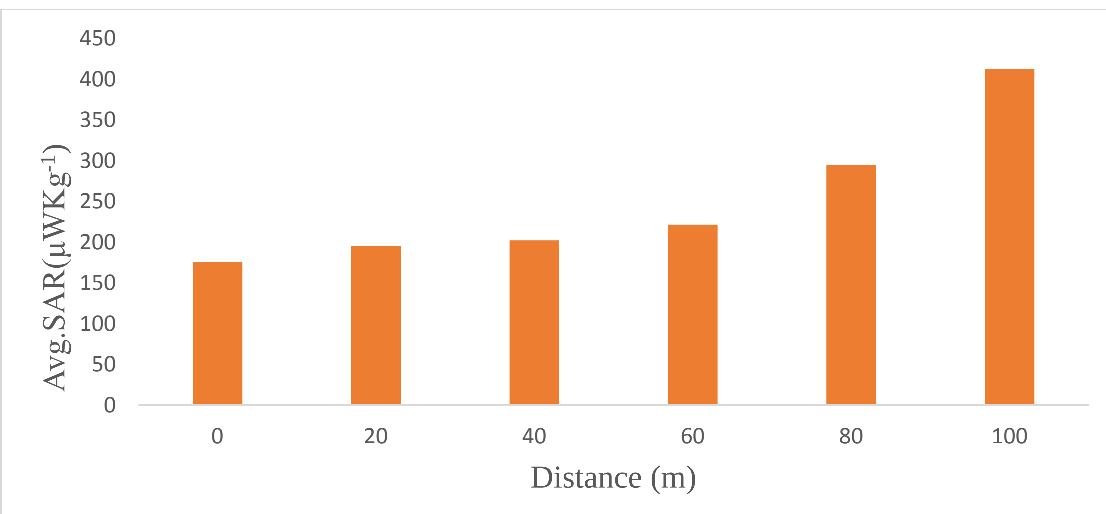

Fig 6: Bar chart of average SAR against distance at the Rivers State University

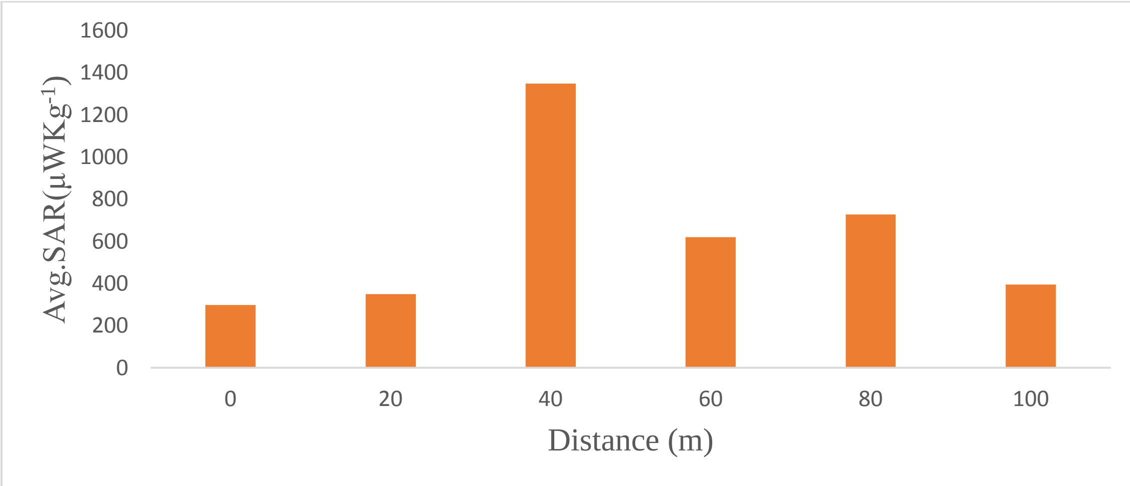

Fig. 7: Bar chart of average SAR against distance at University of Port Harcourt (Abuja Campus)

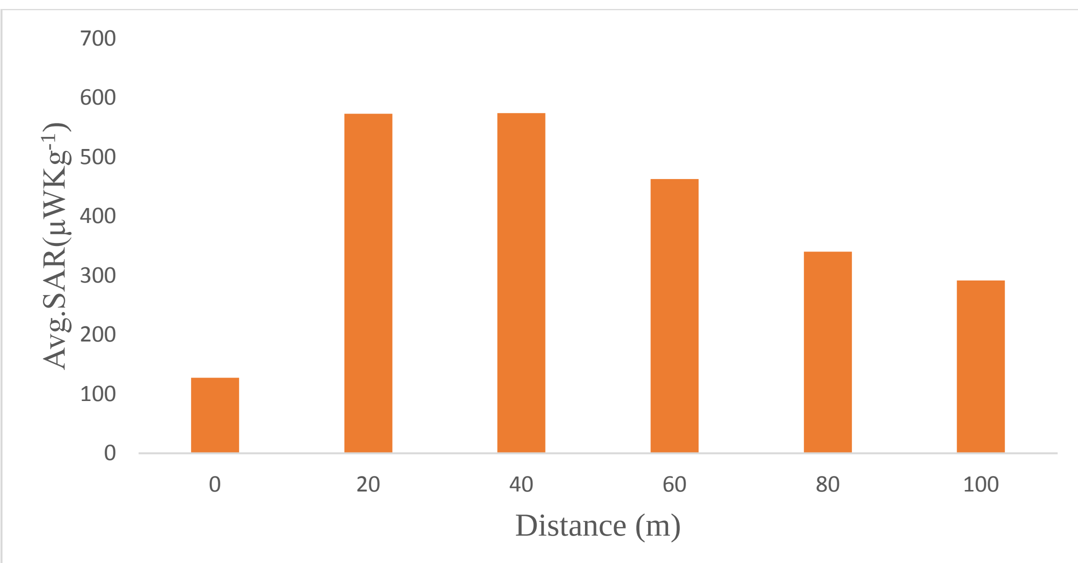

Fig. 8: Bar chart of average SAR against distance at Elechi Amadi Polytechnic

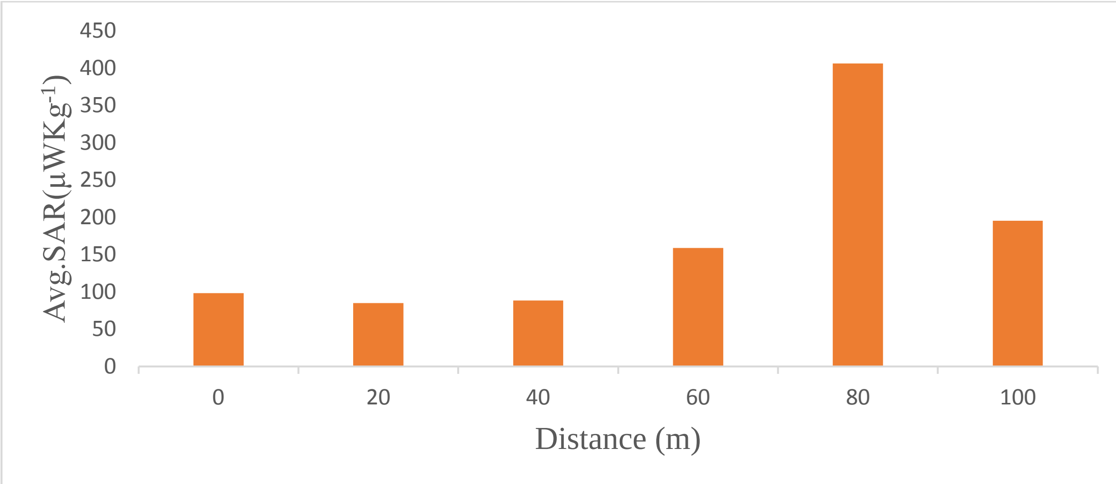

Fig. 9: Bar chart of average SAR against distance at Ignatius Ajuru University of Education, Rumuolumeni

The highest power density and the calculated specific absorption rate (SAR) were recorded at the Elechi Amadi Polytechnic as 4.204 µW.cm^{-2} and 1410.3712 µW.kg^{-1} respectively. This is attributed to the high number of mast clusters. Next was the Rivers State University with values of 4.094 µW.cm^{-2} and 1373.4681 µW.kg^{-1}. The values for University of Port Harcourt (Abuja Campus) were 3.239 µW.cm^{-2} and 1120.1783 µW.kg^{-1}. Lastly the values were 2.09 µW.cm^{-2} and 701.1598 µW.kg^{-1} at the Ignatius Ajuru University of Education Rumuolumeni Campus.

Two (2) of the locations (Catholic Institution of West Africa (CIWA) and Eastern Polytechnic Rumuokwurusi (EPR)) had no Base Stations inside the Campuses. However, five areas were identified within each campus and readings taken. At CIWA, where the closest Base Station was 500m away from the Bookshop, the power density was between 0.112µW.cm^{-2} and 0.487µW.cm^{-2}. At the EPR Campus, where the closest Base Station was 2.2Km away from Administration Office, the power density was between 0.03µW.cm^{-2} and 0.25 µW.cm^{-2}.

These values are quite lower when compared with this results 1µW.cm^{-2} and 3µW.cm^{-2} obtained by (Visser & Theeuwes, 27-31 Oct. 2008). However, they are quite high when compared with this results, 0.03 µ/cm^2 to 0.29 µ/cm^2 obtained by (Avwiri, et al., 2007). The apparent differences may be attributed to the fact that other sources of RF radiation apart from the masts might not have been taken into consideration. These other sources include banks antennas, café antennas, radio stations antennas, and mobile phone calls.

There were significant fluctuations in data during measurement. One would expect a decrease in power density away from the reference base station however; this was not the case as observed during measurement. Fluctuations observed can be attributed to one or more of these factors;

i. Buildings erected within the line of sight of measurement.
ii. Wave interference from other mobile base stations clustered around a reference base station.
iii. Wave interference from other sources of electromagnetic radiation around reference base station such as radio, banks and café antennas.

In all, the power density measured ranged between 0.03 $\mu W.cm^{-2}$ and 4.204 $\mu W.cm^{-2}$ indicating that the RF radiations emitted by Mobile Base Stations in the study area were below the Federal Communication Commission's recommended permissible limit of 570 $\mu W/cm^2$ and 1000 $\mu W/cm^2$ (power density) or 1.9 x 105 μW/kg and 3.4 x 105 μW/kg (SAR) for GSM 900 and GSM 1800 respectively and also the ICNIRP standards which are 4.5 W/m^2 for GSM 900 and 9.0W/m^2 for GSM 1800 or 0.08 W/kg (SAR). The ICNRP standards are also adopted by the Nigeria Communications Commission and National Environmental Standards and Regulations Enforcement Agency (NESRAE). The results have shown that despite the many mast-clusters noticed in some areas, the emitted RF radiation was still far below the permissible standards. This means that even if new masts are added to the existing ones, there will still be no effect on the environment. Therefore, the Network Regulatory Bodies in Nigeria and the Governing Councils of Tertiary Institutions should encourage the Network Providers to reduce the proliferation of Base Stations by adding masts to existing clusters rather than creating new clusters. This will not only reduce operational costs but minimize greenhouse gas emissions from generators (as this source of power will now be shared). It is worthy to mention here that this conclusion of "no health effect of RF radiation power density with distance" was based on a Mathematical rather than Biological Approach.

Conclusion

The results show that the RF radiations emitted by mobile base stations located in and around the selected Tertiary Institutions located in the Obio/Akpor Local Government Area were below the Federal Communication Commission's recommended permissible limit of 570 $\mu W.cm^{-2}$ and 1000 $\mu W.cm^{-2}$ (power density) or 1.9 x 105 $\mu W.kg^{-1}$ and 3.4 x 105 $\mu W.kg^{-1}$ (SAR) for GSM 900 and GSM 1800 respectively.

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