International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 2 Feb 2022, pp: 1170-1179 www.ijaem.net ISSN: 2395-5252

Analysis of Electromagnetic Pollution from GSM Masts in Some Selected Areas of Bauchi Metropolis and its Environs

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Submitted: 10-02-2022 Revised: 22-02-2022 Accepted: 25-02-2022

ABSTRACT: Electricity, radar installations, television and radio masts; rapid growth in the number of global system for mobile communications antennas, cell phones and other electronic devices continually increase the levels of electromagnetic pollution in the environment. Because of its potential health effects, electromagnetic pollution from these sources has been a serious source of concern for human beings over the past two decades. In this research work, the levels of electromagnetic pollution from global system for mobile communications masts in Wunti Area and Abubakar Tafawa Balewa University (ATBU) Gubi Campus within Bauchi Local Government Area of Bauchi State were analyzed using TM-195 Meter and GPS Dragon App. Measurements of electric field strength, magnetic field strength, and power density were conducted radially away in the vicinities of some selected GSM masts of MTN, Glo, Airtel, and 9Mobile respectively. The geographical coordinates and elevations of the selected GSM masts were determined with GPS Dragon App. Using the UTM coordinates and the maximum power densities, electromagnetic magnetic pollution maps of the study areas were generated with ARCGIS 10.8 (2021). From the analyzed results, the maximum power density registered at Wunti Area of 55.520mw/m^2 from MTN GSM mast situated around Bauchi Stadium and 25.28mw/m^2 from a double-network GSM mast of Airtel and MTN at RL4 in ATBU Gubi Campus are all found to be below the Institute of Electrical and Electronics Engineering [IEEE] 2019 Reference Levels of 1-10w/m^2 and 1-50w/m^2 for the whole-body exposure of persons in unrestricted and restricted environments to electromagnetic fields [100kHz – 300GHz] averaged over 30minutes. Also these maximum power density are below the International Commissions on Non-ionizing Radiation Protection (ICNIRP) 2020 Reference Levels for whole body exposure of persons in unrestricted and restricted environments to electromagnetic fields from 100kHz to 300GHz of 1-50w/m^2 and 1-40w/ m^2 averaged over 6minutes.

Keywords: Electromagnetic pollution, electric field strength, magnetic field strength, power density, TM-195 Meter

I. INTRODUCTION

Electromagnetic pollution is a type of environmental pollution which refers to electromagnetic interference (EMI) from electronic sources. For the past two decades, electromagnetic pollution has received considerable attention due to the massive growth in the global telecommunications systems and electronic industry. [1]. For instance, the Nigerian Telecommunications Sector had witnessed an explosive growth from a teledensity of 0.45% in 2001 to a teledensity of 110% in 2016. [2]. Electromagnetic pollution affects every components of the environment and humans are consistently exposed to this type of pollution. [3]. Concluded that beyond the reference level of specific absorption rate, certain types of radiofrequency radiations may have a number of health effects on body tissues and cells. While the potential health effects of electromagnetic pollutions from electronic sources have been scientifically established, their adverse health effects are still subject to further research [4].

Research works on electromagnetic pollutions and radiations from GSM (both 900MHz and 1800MHz) masts have been conducted by different researchers at different time in different places. [5]. Assessed the health effects of electromagnetic radiations from telecommunications masts in some selected areas

International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 2 Feb 2022, pp: 1170-1179 www.ijaem.net ISSN: 2395-5252

of Kaduna metropolis. Their assessment was based on measurement and calculation of magnetic field strength, electric field strength, and power density at some distance intervals from the selected GSM masts of the network providers of MTN, Glo, Airtel, and 9Mobile. They found a maximum power density of 0.06517w/m^2 at distance of 60m from the GSM mast of 9Mobile Network Provider. [6]. Used a Spectrum Analyzer, to determine the levels of electromagnetic pollution from GSM antennas at distance interval of 50m-200m in Ado-Ekiti, Nigeria. They obtained a maximum power density for GSM 900MHz mast at distance of 150m to be 10260mw/m^2 and for GSM 1800MHz mast. [7]. Analyzed radiation levels from 15 Base Transceiver Stations (BTS) in some selected areas within Blantyre, Malawi using a Spectran HF V$_4$ Spectrum Analyzer. They measured a maximum power of 0.00422w/m^2 at BTS 5. In most of these studies, the levels of electromagnetic pollution and radiation found by measurements and computations of magnetic field strengths, electric field strengths, and power densities were below the International Radiation Safety Standards established by Federal Communications Commission (FCC), International Commissions on Non-Ionizing Radiation Protection (ICNIRP), and Institute of Electrical and Electronics Engineering (IEEE) respectively.

Much recent research has focused extensively on the potential health effects of electromagnetic pollution and radiation from global system for mobile communications (GSM) masts, mobile phones, Bluetooth-enabled devices, Wi-Fi routers and other electronic devices on human beings. [8-14]. Although the potential health effects of electromagnetic pollution and radiation from GSM masts were extensively studied in many States of Nigeria and beyond, there has been no such research in Bauchi State from the dawn of mobile telephony in the year 2000 to date. Hence there is great need to quantify and analyze the levels of electromagnetic pollution from GSM masts and other electronic devices within Bauchi metropolis and its environs.

However, this research work analyses the levels of electromagnetic pollution in Wunti Area and Abubakar Tafawa Balewa University (ATBU) Gubi Campus within Bauchi Metropolis and its environs by measurement and computation of electric field strength, magnetic field strength and power density radially away from selected GSM masts of MTN, Glo, Airtel, and 9Mobile using TM-195 Meter. The maximum power densities obtained are compared with the current International Radiation Safety Standards of IEEE and ICNIRP respectively.

II. INTERNATIONAL GUIDELINES ON ELECTROMAGNETIC RADIATION EXPOSURE

Different countries in the world adopt varying guidelines as their safety standards on electromagnetic radiation exposure. In the United States of America for instance the radiation safety standards of Institute of Electrical and Electronics Engineering (IEEE) and Federal Communications Commission (FCC) are adopted for their own national standards. In some European countries and most African countries (including Nigeria), the radiation guidelines of the International Commission on Non-ionizing Radiation Protection (ICNIRP) are adopted as reference levels for exposure to RF electromagnetic radiations. For this research work, the current radiation guidelines of ICNIRP and IEEE will be adhered to. The current radiation reference level of IEEE for whole body exposure of persons in unrestricted environment to electromagnetic fields (400MHz-2000MHz) is 1-10w/m^2 for time averaged over 30 minutes. For frequency range between 2000MHz-300,000MHz, the safety limit is 10w/m^2. For whole body exposure of persons to electromagnetic fields (400MHz-2000MHz) in restricted environment, the radiation safety standard is 1-40w/m^2 for time averaged over 30 minutes. For frequency range between 2000MHz-300,000MHz in a restricted environment, the Radiation Safety Standard is 50w/m^2 [15]. The ICNIRP Current Reference Levels for local exposure averaged over 30 minutes and whole body to electromagnetic fields (greater than 400-2000 MHz) in occupational setting are: 100.7w/m^2 for GSM 900MHz and 182.8w/m^2 for GSM 1800MHz respectively. For general public, the ICNIRP reference levels are 20.1w/m^2 for GSM 900MHz and 36.6w/m^2 for GSM 1800MHz [16].

III. ELECTROMAGNETIC (EM) RADIATION PARAMETERS

The intensity of electromagnetic radiation emanated by a GSM mast is usually expressed in terms of power density. Power density refers to the amount of power flowing per unit area perpendicular to the direction of propagation of radio frequency (RF) electromagnetic radiation. Power density can be computed from Poynting's theorem which is a statement of the law of conservation of energy. Poynting's theorem is mathematically expressed as:

$$\delta = \vec{E} \times \vec{H} = 377H^2 = \frac{E}{377} \qquad 1.0$$

The ratio $\frac{E}{H}$ in free space is equal to 377 which is the characteristic impedance of free space. To

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compute power density using Poynting's theorem, one or two of the radiation parameters of electric field strength and magnetic field strength need to be measured.

IV. ELECTRIC FIELD STRENGTH ($\vec{E}$)

Electric field strength ($\vec{E}$) at any point is defined as force per unit charge placed at that point. It is a vector quantity measured in volt per unit metre (VM^{-1}). Electric field strength is mathematically given as:

$$\vec{E} = \frac{\vec{F}}{q} \,(Vm^{-1}) \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots 2.0$$

V. MAGNETIC FIELD STRENGTH ($\vec{H}$)

Magnetic field strength ($\vec{H}$)at a point in a magnetic field is the force experienced by a unit North pole placed at that point. Magnetic field strength is a measure of how strong or weak a magnetic field is. It can also be expressed as the ratio of magnetic flux density to permeability of free space

$$\vec{H} = \frac{\vec{B}}{\mu_0} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.0$$

VI. INTERNATIONAL GUIDELINES ON ELECTROMAGNETIC RADIATION EXPOSURE

Different countries in the world adopt varying guidelines as their safety standards on electromagnetic radiation exposure. In the United States of America for instance the radiation safety standards of Institute of Electrical and Electronics Engineering (IEEE) and Federal Communications Commission (FCC) are adopted for their own national standards. In some European countries and most African countries (including Nigeria), the radiation guidelines of the International Commission on Non-ionizing Radiation Protection (ICNIRP) are adopted as reference levels for exposure to RF electromagnetic radiations. For this research work, the current radiation guidelines of ICNIRP and IEEE will be adhered to. The current radiation reference level of IEEE for whole body exposure of persons in unrestricted environment to electromagnetic fields (400MHz-2000MHz) is 1-10w/m^2 for time averaged over 30 minutes. For frequency range between 2000MHz-300,000MHz, the safety limit is 10w/m^2. For whole body exposure of persons to electromagnetic fields (400MHz-2000MHz) in restricted environment, the radiation safety standard is 1-40w/m^2 for time averaged over 30 minutes. For frequency range between 2000MHz-300,000MHz in a restricted environment, the Radiation Safety Standard is 50w/m^2 [10]. The ICNIRP Current Reference Levels for local exposure averaged over 30 minutes and whole body to electromagnetic fields (greater than 400-2000 MHz) in occupational setting are: 100.7w/m^2 for GSM 900MHz and 182.8w/m^2 for GSM 1800MHz respectively. For general public, the ICNIRP reference levels are 20.1w/m^2 for GSM 900MHz and 36.6w/m^2 for GSM 1800MHz respectively [11].

VII. RESEARCH METHODOLOGY

This research work covered two study areas: Wunti Area and Abubakar Tafawa Balewa University (ATBU) Gubi Campus within Bauchi Local Government Area of Bauchi State, North Eastern Nigeria. All the GSM masts (both 900MHz and 1800MHz) of the four network providers of MTN, Glo, Airtel and 9Mobile were purposely selected as data source for the study.

The data for this research work was collected using TM-195 Meter and GPS dragon (2021) App respectively. TM-195 Meter is an isotropic electric field strength meter designed purposely for measuring and monitoring RF electromagnetic radiation in the frequency between 50MHz-3.5GHz. TM-195 Meter is calibrated to measure electric field strength, magnetic field strength, and power density from RF electromagnetic radiation sources with uncertainty of ±2.5dB. The GPS Dragon App (2021) measures the geographical coordinates and elevations of a place with respect to sea levels on Earth's surface. ARCGIS 10.8 (2021) was used to generate the electromagnetic pollution maps of Wunti Area and ATBU Gubi Campus respectively.

Using TM-195 Meter, measurements of electric field strength, magnetic field strength, and power density for both GSM 900MHz and 1800MHz were conducted in the vicinities of all the selected GSM masts in the study areas between 9:00AM to 4:00PM from 23 July 2021 to 26 July 2021. The Measurements were conducted radially away at distance intervals of 20m, 40m, 60m, 80m and 100m from the selected GSM masts. The geographical coordinates and elevations of each of the GSM masts were also determined using GPS Dragon App (2021). Using Universal Transverse Mercator (UTM) coordinates and maximum power densities of the GSM masts, electromagnetic pollution maps of the study areas were generated with ARCGIS 10.8 (2021). Figures 1 and 2 below show snapshot and picture of the GPS Dragon App and the TM-195 Meter respectively.

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Figure 1: Snapshot of GPS Dragon App

Figure 2: Picture of TM-195 Meter

VIII. RESULTS

The results obtained were presented below. Measured values of electric field strength, magnetic field strength and power density for both GSM 900MHz and 1800MHz in ATBU Gubi Campus and Wunti Area were tabulated. The geographical coordinates and elevations of all the GSM masts were also tabulated. Tables 1-2 contain the Universal Transverse Mercator (UTM) Coordinates and elevations of each of the GSM masts in the study areas.

Table 1.0: UTM Coordinates and Elevations of each of the GSM Masts in ATBU Gubi Campus

Location	Northings	Eastings	Elevation (m)
Adakawa: Airtel	589121	1154161	607
Lagashi: MTN	588222	1154564	605
RL4: MTN and Airtel	591132	1157256	587

Table 2.0: UTM Coordinates and Elevations of each of the GSM Masts in Wunti Area

Location	Northings	Eastings	Elevation (m)
Murtala Muhd Way: Glo	591225	1140240	619
Multipurpose Hall: Airtel	591034	1140551	617
'Yandoka Road: MTN	590753	1140863	617
ATBUTH: Airtel	591257	1141552	615
Bauchi Stadium-1: MTN	591587	1140920	622
Bauchi Stadium-2: 9Mobile	591581	1140903	622

Tables 3-5 below contain the measured values of electric field strength, magnetic field strength, and power density for all the GSM masts in ATBU Gubi Campus.

Table 3.0: Measured Values of Electric Field Strength, Magnetic Field Strength, and Power Density for Airtel GSM Mast at Adakawa

Distance (m)	Electric Field Strength (mv/m) ± 2.5dB	Magnetic Field Strength (mv/m) ± 2.5dB	Power Density (mv/m) ± 2.5dB
20.0	876.30	2.324	1.268
40.0	1090.60	2.893	2.306
60.0	853.30	2.263	1.281
80.0	631.20	1.674	0.686
100.0	549.00	1.456	0.569

Table 4.0: Measured Values of Electric Field Strength, Magnetic Field Strength, and Power Density for MTN GSM Mast at Lagashi

Distance (m)	Electric Field Strength (mv/m) ± 2.5Db	Magnetic Field Strength (mv/m) ± 2.5dB	Power Density (mv/m) ± 2.5dB
20.0	1384.50	4.311	4.900
40.0	2041.00	5.414	8.005
60.0	762.70	1.927	1.401
80.0	620.60	1.646	1.022
100.0	492.10	1.240	0.580

Table 5.0: Measured Values of Electric Field Strength, Magnetic Field Strength, and Power Density for MTN and Airtel GSM Mast at RL4

Distance (m)	Electric Field Strength (mv/m) ± 2.5dB	Magnetic Field Strength (mv/m) ± 2.5dB	Power Density (mv/m) ± 2.5dB
20.0	2613.00	6.931	14.568

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40.0	1577.90	4.185	4.284
60.0	1876.00	4.976	6.488
80.0	2285.00	6.060	11.293
100.0	3441.00	9.127	25.280

Table 6 contains location, type of network provider, and maximum power density in ATBU Gubi Campus.

Location	Network Provider	Maximum Computed Power Density (mw/m^2)± 2.5dB
Adakawa	Airtel	2.306
Lagashi	MTN	8.005
RL4	Glo	25.280

Table 6.0: Location, Network Provider, and Maximum Power Density in ATBU Gubi Campus

Tables 7 – 12 contain the measured values of electric field strength, magnetic field strength, and power density for all the GSM masts in Wunti Area

Distance (m)	Electric Field Strength (mv/m) ± 2.5dB	Magnetic Field Strength (mA/m) ± 2.5dB	Power Density (mw/m^2) ± 2.5dB
20.0	4632.00	12.286	44.510
40.0	4164.00	11.044	41.710
60.0	3585.00	9.509	26.620
80.0	1894.90	5.103	12.235
100.0	2546.00	7.486	19.062

Table 7.0: Measured Values of Electric Field Strength, Magnetic Field Strength, and Power Density for Glo GSM Mast at Murtala Muh'd Way

Table 8.0: Measured Values of Electric Field Strength, Magnetic Field Strength, and Power Density for Airtel GSM Mast at Multipurpose Hall

Distance (m)	Electric Field Strength (mv/m) ± 2.5dB	Magnetic Field Strength (mA/m) ± 2.5dB	Power Density (mw/m^2) ± 2.5dB
20.0	2430.00	6.937	20.610
40.0	1759.70	4.890	5.848
60.0	1672.60	4.416	7.396
80.0	1749.60	5.155	8.857
100.0	1103.40	2.927	1.962

Table 9.0: Measured Values of Electric Field Strength, Magnetic Field Strength, and Power Density for MTN GSM Mast at 'Yandoka Road

Distance (m)	Electric Field Strength (mv/m) ± 2.5dB	Magnetic Field Strength (mA/m) ± 2.5dB	Power Density (mw/m^2) ± 2.5Db
20.0	3354.00	6.444	10.304
40.0	1339.50	3.670	2.890
60.0	1429.90	3.758	2.020

80.0	1804.90	3.934	2.797
100.0	2149.00	6.765	11.530

Table 10.0: Measured Values of Electric Field Strength, Magnetic Field Strength, and Power Density for Glo GSM at ATBUTH

Distance (m)	Electric Field Strength (mv/m) ± 2.5dB	Magnetic Field Strength (mA/m) ± 2.5dB	Power Density (mw/m^2) ± 2.5dB
20.0.	1064.40	2.490	15.041
40.0	1031.70	2.702	1.834
60.0	1781.20	3.989	2.582
80.0	2493.00	5.960	10.374
100.0	3848.00	8.208	13.315

Table 11.0: Measured Values of Electric Field Strength, Magnetic Field Strength, and Power Density for MTN GSM Mast at Bauchi Stadium

Distance	Electric Field Strength (mv/m) ± 2.5dB	Magnetic Field Strength (mA/m) ± 2.5dB	Power Density (mw/m^2) ± 2.5dB
20.0	4332.00	13.911	54.340
40.0	30827.00	8.180	49.220
60.0	1454.90	3.850	6.274
80.0	2210.00	5.862	12.135
100.0	2410.00	7.092	16.421

Table 12.0: Measured Values of Electric Field Strength, Magnetic Field Strength, and Power Density for 9Mobile GSM Mast at Bauchi Stadium

Distance (m)	Electric Field Strength (mv/m) ± 2.5dB	Magnetic Field Strength (mA/m) ± 2.5dB	Power Density (mw/m^2) ± 2.5dB
20.0	4744.00	12.584	44.010
40.0	2785.00	7.388	17.642
60.0	4140.00	11.723	47.970
80.0	4403.00	11.685	55.520
100.0	3176.00	8.425	23.320

Table 13 contains location, type of network provider, and maximum power density of all the GSM masts in Wunti Area.

Table 13.0: Location, Network Provider, and Maximum Power Density in Wunti Area

Location	Network Provider	Maximum Computed Power Density (mw/m^2) ± 2.5dB
Murtala Muh'd Way	Glo	44.510
Multipurpose Hall	Airtel	20.610
'Yandoka Road	MTN	11.530
ATBUTH	Glo	13.315
Bauchi Stadium 1	9Mobile	54.340
Bauchi Stadium 2	MTN	55.520

IX. DISCUSSION

Using the Universal Transverse Mercator (UTM) Coordinates and maximum power densities of all the GSM masts of the network providers, electromagnetic pollution maps of the study areas: Wunti Area and ATBU Gubi Campus were generated with ARCGIS 10.8 (2021). Figures 3 – 4 below show electromagnetic pollution maps of the study areas.

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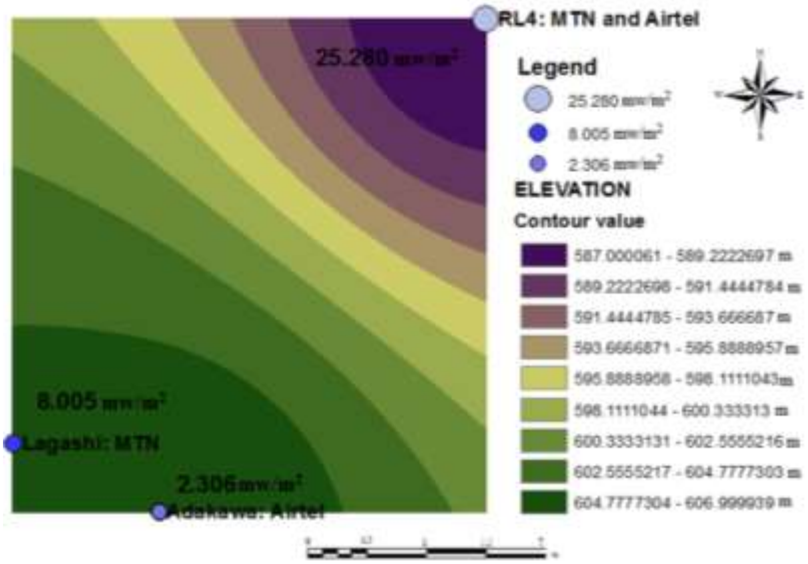

Figure 3.0: Electromagnetic Pollution Map Showing UTM Coordinates and Maximum Power Densities of the GSM Masts ATBU Gubi Campus

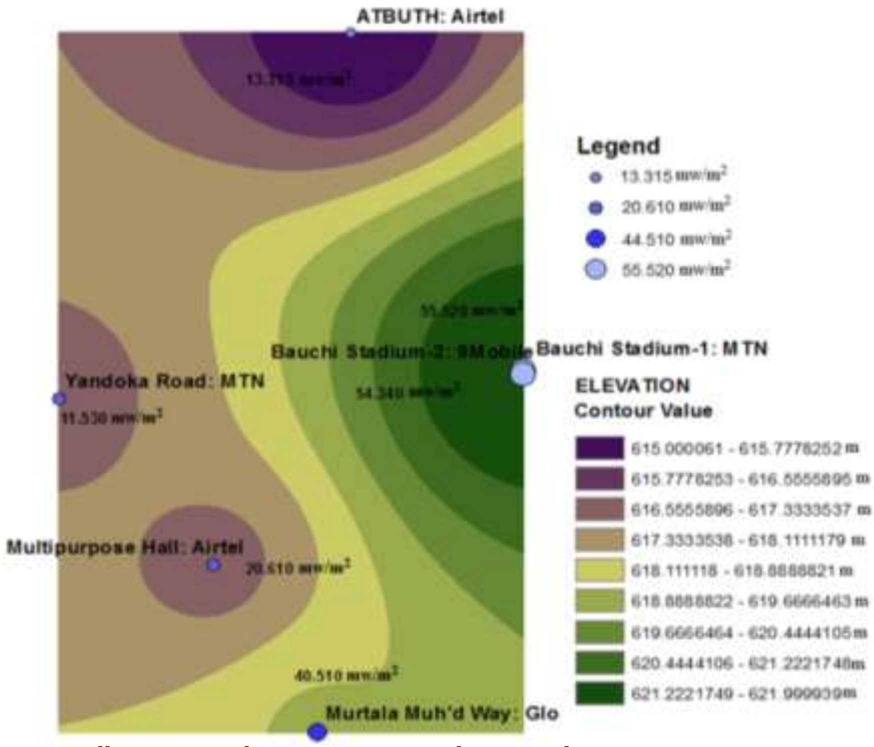

Figure 4.0: Electromagnetic Pollution Map Showing UTM Coordinates and Maximum Power Densities of the GSM Masts in Wunti Are

In ATBU Gubi Campus, a maximum power density of power density of 25.280mw/m^2 was registered at distance of 100m from a double-network GSM mast of Airtel and MTN situated at RL4 within the university campus (Figure 1). This finding indicates that the electromagnetic pollution level at RL4 is higher compared with those of Adakawa (power density of 2.306mw/m^2 [Airtel]) and Lagashi (power density of 8.005mw/m^2 [MTN]). For Wunti, a maximum power density of 55.520mw/m^2 was obtained at distance of 80m from a GSM mast of MTN Network Provider

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situated around Bauchi Stadium (figure 2).This finding suggests that the region around Bauchi Stadium has a higher electromagnetic pollution level compared with 'Yandoka Road (power density of 11.530mw/m^2 [MTN]), Murtala Muhammad Way (power density of 44.510mw/m^2 [Glo]), Multipurpose Hall (power density of 20.610mw/m^2 [Airtel]) and ATBUTH (power density of 13.315mw/m^2 [Glo]). A number of factors such as number and size of antennas on each of selected GSM masts, interference and diffraction phenomena, medium of propagation, types of building in the vicinity of the GSM masts, antenna distance and topography could be responsible for the variation of power density from the selected GSM Masts. For instance, the GSM masts around Bauchi Stadium in Wunti Area and RL4 in ATBU Gubi Campus where the maximum power densities were registered have the highest number of antennas on them. The maximum power densities of 55.520mw/m^2 and 25.280mw/m^2 obtained in the study areas are all below the Institute of Electrical and Electronics Engineering [IEEE] 2019 Reference Levels of 1-10w/m^2 and 1-50w/m^2 for the whole-body exposure of persons in unrestricted and restricted environments to electromagnetic fields [100kHz – 300GHz] averaged over 30minutes respectively. Also these maximum power densities are below the International Commissions on Non-ionizing Radiation Protection (ICNIRP) 2020 Reference Levels for whole body exposure of persons in unrestricted and restricted environments to electromagnetic fields from 100kHz to 300GHz of 1-50w/m^2 and 1-40w/m^2 averaged over 6minutes respectively.

X. CONCLUSION

Analysis of electromagnetic pollution levels from GSM masts of MTN, Glo, Airtel and 9Mobile Network Providers were conducted in ATBU Gubi Campus and Wunti Area within Bauchi Local Government Area of Bauchi State, North eastern Nigeria using TM-195 Meter and GPS Dragon App respectively. Measured values of electric field strength, magnetic field strength, and power density were measured with TM-195 Meter at certain distance intervals from the selected GSM masts of MTN, Glo, Airtel, and 9Mobile. Electromagnetic pollution maps of the study areas were produced with ARCGIS 10.8 using the UTM coordinates and maximum power densities of each of the GSM masts. In ATBU Gubi Campus, a maximum power density of 25.280mw/m^2 was registered at distance of 100m from a double-network GSM mast of Airtel and MTN situated within the university campus. In Wunti Area, a maximum power density of 55.520mw/m^2 was obtained at distance of 80m from a GSM mast of MTN situated around Bauchi Stadium. Number and size of antennas, their power and orientation, medium of propagation of RF radiation, topography, buildings, absorption, refraction and interference phenomena are some of the factors that could be attributed to these variations. The study concludes that the measured power density varied radially away from the selected GSM masts. The study further concludes that the highest values of the power density obtained in the study areas are all found to be below the Institute of Electrical and Electronics Engineering [IEEE] 2019 Reference Levels. The maximum power densities are also below the International Commissions on Non-ionizing Radiation Protection (ICNIRP) 2020 Reference Levels respectively.

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International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 2 Feb 2022, pp: 1170-1179 www.ijaem.net ISSN: 2395-5252

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