ASSESSMENT OF POWER DENSITY RADIATION FROM TELECOMMUNICATION MASTS IN THE NORTHERN PART OF DELTA STATE, NIGERIA

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Abstract
The number of mobile phone users has significantly grown in recent years, hence more base stations are required. These base stations are mostly found in urbanized or highly populated areas which have become an issue of concern to the public's health. In this research, a Trifield EMF meter was used to take the measurements of power density at 1.5 and 1.7 m height above the ground level for a distance of 100 m at 20 m intervals from 45 masts distributed throughout the northern part of Delta State, Nigeria. The distance of the masts from the nearest buildings was also measured. The results obtained range from 0.248 mWm^{-2} to 17.914 mWm^{-2} at 1.5 m and 0.369 to 20.000 mWm^{-2} at 1.7 m. These results assert that the measured values are relatively low compared to the 2.0 – 10.0 Wm^{-2} for >400 – 2000 MHz radiofrequency range stipulated by International Commission on Non-Ionising Radiation Protection (ICNIRP). This shows that there is no significant health concern from non-ionizing radiation (NIR) exposure to the population in the study area. 46.6% of the masts in this research breached safety requirements set by the National Environmental Standards and Regulations Enforcement Agency and the Nigerian Communication Commission.

Keywords: Power Density (PD), Radiofrequency exposure, Distance variation, Mobile base mast, Health risk

INTRODUCTION

The tremendous advancement in telecommunication has made the world and even Nigeria, a global village. Mobile telecommunication is a very substantial business and a key economic driver in many nations. This exceptional rise in the use of the Global System for Mobile (GSM) Communications has even more support due to the advances in wireless telecommunication that allows mobile phone users to access the Internet (among other uses) using the mobile phone. (Briggs *et al.*, 2018). Due to the advancement of technology from the 1st generation to the present 5th generation, concerns about a potential health risk brought on by human exposure to radiofrequency radiation in general and radiation released by base stations, in particular, is growing as mobile phone towers become more prevalent. (Siba, 2016). Universal Mobile Telecommunication systems (UMTS) are the major and prevalent mobile systems (Koprivica et al., 2015). Radiofrequency (RF) is used in mobile communication, just like in every other wireless technology, to transmit data. The term "RF" refers to all frequencies that transmit signals between 3 kHz and 300 GHz. (Akpolile et al., 2014). Due to repeated exposure to RF signals and RF radiation from mobile towers, the rising use of mobile phones has raised serious concerns for human health. Although mobile base station RF radiation exposure is low strength, it is a continual process. Since they don't break chemical bonds or knock electrons off, electromagnetic radiations were once thought to be quite harmless. However, several new kinds of research on

exposure to mobile base stations (MBS) show that even non-ionizing radiations are harmful. As a result, it is anticipated that exposure to non-ionizing radiation (NIR) may affect a person's health if they live close to a base station. (Sinik et al., 2013; Ibrahim, 2016; Syaza et al., 2017; Belpomme et al., 2019; Siba, 2016). Many people think that EM radiation exposure is the cause of numerous illnesses and hereditary disorders. There may be somatic and hereditary effects. Somatic impacts result in injuries that only the person who was exposed to radiation would experience since the body's normal cells are damaged. However, damage to genital organ germ cells can also occur. This has a genetic or hereditary repercussion that may affect subsequent generations (Mokobia and Akpan, 1997). The study's findings will serve as a baseline of reference for regulatory actions and the development of a national safety standard for the general public's exposure to RF radiation from the environment by concerned regulatory authorities. This study is also part of the investigation of power density conducted in twenty-three Local Government areas of Delta State, Nigeria.

MATERIALS AND METHODS

This study was carried out in the North part of Delta state, Nigeria which is located between latitude 5°30.000°E and longitude 6°30.000°N. The study area consists of nine local government areas (Figure 1). The local governments are Aniocha South, Aniocha North, Oshimili North, Oshimili South, Ika south, Ika north east, Ndokwa East, Ndokwa West, and Ukwani. The BTS operated by the four main telecommunication service providers in Nigeria were randomly selected. Forty-five (45) BTS, Five (5) from each local government area were assessed, building proximity and base station accessibility were important factors considered during selection. The sectoral antenna on the majority of BTS spans an area of roughly 1200 meters. A Trifield EMF meter (Model, TF2) was used to measure the power density of the radiofrequency radiation from the base stations. The meter is a broadband instrument with a sensitivity of 0.001 mWm^{-2} to a maximum of 20.000 mWm^{-2} and covers a frequency range of 20 MHz to 6 GHz. This frequency range covers most of the wireless communication frequency spectrum. Measurements of PD in milliwatts per square meter (mWm^{-2}), of RF radiation from selected BTS, were made at 1.5 and 1.7 m above ground level starting from the base of the BTS to a distance of 100 m at 20 m intervals. This height falls within the range of an average adult, enabling the RF radiation to be intercepted in an upright position from the ground up. Measurement set-up as shown in Orogodo et al, 2022. To preserve a clear line of sight with the RF radiation source, these heights were used (Orogodo et al, 2022). An arbitrary distance of 0 meters was chosen, which was quite close to the base of each BTS, and readings were taken in handy directions around the BTS at intervals of 20 meters for a radius of 100 meters. The RF meter was put at a consistent height of 1.5 and 1.7 m above the ground level using an adjustable tripod stand that was designed for this study. After a short period, when the meter's readings at the two heights were stable and consistent, the power density value was obtained and recorded. For each height above the ground, an average of five readings were recorded at each measurement site, 60 measurements were performed at each location, and 2700 measurements were for the 45 base stations that were evaluated. The identification number, Proximity to the Nearest Building and coordinates of the site using the GPS Route finder application were also entered for proper documentation as shown in Table 1.

RESULTS AND DISCUSSION

Table 2-10 illustrate the PD levels measured at different distances from the BTS at 1.5 and 1.7 m heights.The maximum PD was

determined to be 20.000 mWm^{-2} at 20 m at 1.7 m above ground level from UKWA 5. The minimal PD was determined to be 0.270 mWm^{-2} at 60 m from NDEA 3 at 1.7 m above ground level as shown in table 11. Most of the measured PD values at a height of 1.7 m were all noted to be higher than those measured at 1.5 m, implying a direct proportion of the PD with height. This indicates that human interception of the RF radiation from the base stations at 1.7 m height and above has a higher chance of exposure to high PD levels. Test of significance by one-way analysis of variance (ANOVA) shows no significant differences ($p \geq 0.05$) exist between the obtained average PD data, except for the ICNIRP references. As observed in figure 2, Oshimli South Local Government Area has the highest power density is can be as a result of the most of the BTS investigated in the LGA operating at high frequency of 1800MHz and above while Ika North has the lowest power density which can also be as a result of the BTS operating at low frequency. Table 1 shows the proximity of the MBS to the nearest building and the locations. As observed, the PD variation with distance follows a polynomial trend of order 5 as against the inverse square rule which can be attributed to scattering, additional RF emission devices that may be nearby electromagnetic radiation sources such as receivers, TV antennas, moving objects, as well as other MBS clustered around. The observed was also noted in a related study Orogodo et al, (2022) in which the power density value increased at a few greater distances before falling once more. Also, the observed fluctuation of the PD cannot be ruled out with structures like buildings, and trees that are within the radius of measurements (Ajiboye and Osiele, 2013). Generally, the obtained PD values of identified base masts in all the study locations are far less than the ICNIRP (1998) recommended general public exposure limit of 4.5 Wm^{-2} for GSM 900 AND 9 Wm^{-2} for GSM 1800, respectively for the general public exposure. However, continuous long-term exposure to RF radiation PD by people living close to the base stations may result in cumulative health effects in later years. This study also discovered that approximately 46.6% of the masts assessed in the study area violated the Nigerian Communication Commission (NCC) and National Environmental Standards and Regulations Enforcement Agency (NESREA) safety regulations of 5 m and 10 m away from residential or official buildings, respectively. Therefore, the measured PD in the studied area are very much below the values capable of initiating any noticeable health risk to the general public.

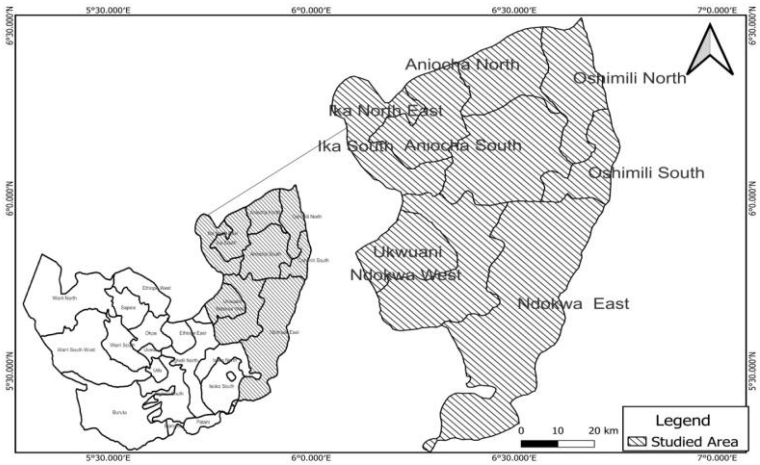

Figure 1: Map of the Northern Part of Delta State showing the study locations

Table 1: Proximity of BTS to Nearest Building

Code	LGA	Proximity to Nearest Building (m)	Identification No	Latitude	Longitude
OSHS 1		5.0	T2729	6.194525	6.7122116
OSHS 2		7.0	DT/047	6.192186	6.711043
OSHS 3	Oshimili South	4.0	IHS DEL 1170A	6.192535	6.710186
OSHS 4		2.0		6.195217	6.712318
OSHS 5		5.0	DL0615	5.7898983	6.098159
OSHN 1		10.0	T0280	6.177727	6.628243
OSHN 2	Oshimili North	6.0	B4536	6.176660	6.629264
OSHN 3		10.0		6.179258	6.626118
OSHN 4		3.0	DL0744	6.178521	6.625325
OSHN 5		15.0	DL0117	6.1818316	6.627355
ANIS 1		12.0		6.248320	6.607748
ANIS 2		10.0	T2787	6.238752	6.603741
ANIS 3	Aniocha South	30.0	DL0011	6.219809	6.567656
ANIS 4		150.0		6.224266	6.567863
ANIS 5		15.0	DL0856	6.247873	6.605718
ANIN 1		40.0		6.303250	6.468253
ANIN 2		25.0	DL0044	6.318446	6.477751
ANIN 3	Aniocha North	20.0		6.316958	6.478111
ANIN 4		20.0		6.315726	6.476250
ANIN 5		20.0	DL0864	6.305368	6.469718
NDOW 1		10.0	T2699	5.688582	6.429821
NDOW 2		20.0	DL0001	5.688250	6.426330
NDOW 3	Ndokwa West	7.0		5.685985	6.426383
NDOW 4		5.0		5.683816	6.425335
NDOW 5		10.0	T2950	5.710706	6.435056
NDEA 1		5.0	T2734	5.640673	6.391110
NDEA 2		10.0	DL4068	5.631201	6.404548
NDEA 3	Ndokwa East	5.0		5.627229	6.406983
NDEA 4		12.0		5.637975	6.400724
NDEA 5		5.0	DL4069	5.671844	6.417844
UKWA 1		15.0	DL0701	5.850447	6.161549
UKWA 2		20.0		5.843785	6.155689
UKWA 3	Ukwani	7.0		5.843722	6.154546
UKWA 4		3.0	DL0106	5.845604	6.152728
UKWA 5		8.0	DL0700	5.834435	6.148897
IKAN 1		10.0	401324	6.223422	6.567373
IKAN 2		6.0	B6624	6.273052	6.300439
IKAN 3		2.0		6.273611	6.308867
IKAN 4	Ika North	2.0	T4402	6.253607	6.209148
IKAN 5		5.0		6.254255	6.201832
IKAS 1		17.0		6.253607	6.209148
IKAS 2		7.0		6.261237	6.201606
IKAS 3	Ika South	10.0	DL1019	6.261926	6.197774
IKAS 4		8.0		6.256727	6.202186
IKAS 5		10.0	DL0102	6.254551	6.201947

Table 2 : Measured PD (mWm^{-2}) Values in Oshimli North

Code	Height above ground level (m)	Measured PD at varying distances from Mast (m)						
		0	20	40	60	80	100	Average
OSHN 1	1.5	3.045	7.242	2.566	7.705	3.374	5.377	4.885±2.227
	1.7	7.948	6.089	7.580	7.557	2.416	3.900	5.915±2.277
OSHN 2	1.5	1.008	4.831	0.321	1.872	0.248	2.041	1.720±1.732
	1.7	1.521	4.003	0.369	1.543	1.181	0.945	1.594±1.257
OSHN 3	1.5	1.159	2.225	9.574	0.628	2.404	6.467	3.743±3.519
	1.7	0.416	3.175	14.025	0.979	3.807	6.194	4.766±4.990
OSHN 4	1.5	3.880	15.018	14.761	3.746	1.509	1.347	6.710±6.426
	1.7	9.460	11.921	15.041	4.934	4.626	9.230	9.202±4.018
OSHN 5	1.5	7.025	16.754	17.606	10.972	9.384		12.348±6.529
	1.7	5.172	16.200	11.396	10.665	10.706		10.828±5.638

Table 3 : Measured PD (mWm^{-2}) Values in Oshimli South

Code	Height above ground level (m)	Measured PD at varying distances from Mast (m)						
		0	20	40	60	80	100	Average
OSHS 1	1.5	15.973	10.668	15.172	12.136	14.413	16.495	14.143±2.285
	1.7	14.482	14.350	13.490	9.953	18.470	13.338	14.014±2.735
OSHS 2	1.5	6.145	4.872	13.391	11.962	1.957	1.274	6.600±5.059
	1.7	7.194	4.483	16.899	3.934	5.145	4.564	7.036±4.962
OSHS 3	1.5	13. 390	16.295	14.308	13.926	14.494	15.069	14.581±.950
	1.7	18.702	16.485	15.508	11.636	15.213	16.073	15.603±2.302
OSHS 4	1.5	9.831	16.182	8.986	4.476	4.557	4.635	8.111±4.622
	1.7	16.723	17.5784	13.8914	4.9978	5.3934	6.9456	10.922±5.801
OSHS 5	1.5		16.920	15.595	7.311			13.276±7.983
	1.7		15.038	15.784	15.627			15.483±8.484

Table 4 : Measured PD (mWm^{-2}) Values in Ika North East

Height above ground level (m)	Measured PD at varying distances from Mast (m)						
	0	20	40	60	80	100	Average
1.5	3.972	1.658	4.947	1.898	6.553	2.363	3.565±1.942
1.7	0.644	0.756	1.567	1.104	12.054	2.742	3.145±4.431
1.5	2.288	0.485	2.782	1.264	0.792	1.999	1.602±.899
1.7	0.939	0.512	4.211	0.860	0.929	2.141	1.599±1.395
1.5	16.238	1.726	7.137	1.863	1.573	2.058	5.099±5.861
1.7	15.742	1.382	2.491	2.675	2.909	1.486	4.448±5.569
1.5	11.744	1.738	11.751	6.539	11.397	2.925	7.683±4.607
1.7	14.985	1.399	18.426	6.349	11.431	7.881	10.078±6.159
1.5	1.837	1.885	2.553	1.808	0.968	0.522	1.596±.728
1.7	1.576	2.295	3.017	2.029	1.130	0.665	1.785±.844

Table 5 : Measured PD (mWm^{-2}) Values in Aniocha South

Code	Height above ground level (m)	Measured PD at varying distances from Mast (m)						
		0	20	40	60	80	100	Average
ANIS 1	1.5	1.051	6.519	12.121	2.592	2.840	2.121	4.541±4.150
	1.7	1.814	6.291	18.068	1.555	3.682	1.540	5.492±6.430
ANIS 2	1.5	3.858	3.159	5.382	9.861	6.312	3.949	5.420±2.459
	1.7	3.768	3.425	11.593	9.177	3.728	4.804	6.083±3.451
ANIS 3	1.5	13.882	12.643	5.474	16.408	1.659	3.809	8.979±6.087
	1.7	14.310	13.207	14.901	17.309	3.138	2.399	10.877±6.427
ANIS 4	1.5	0.855	3.090	1.766	0.897	2.334	3.799	2.123±1.186
	1.7	1.219	2.041	4.070	0.939	1.687	4.175	2.355±1.421
ANIS 5	1.5	3.420	7.105	11.482	4.209	4.916	1.389	5.420±3.509
	1.7	7.483	12.422	16.314	5.458	2.098	2.183	7.660±5.716

Table 6 : Measured PD (mWm^{-2}) Values in Ika South

Height above the ground level (m)	Measured PD at varying distances from Mast (m)						
	0	20	40	60	80	100	Average
1.5	13.667	1.742	0.815	11.951	3.064	4.781	6.003±5.422
1.7	13.899	1.090	1.333	5.157	3.905	4.948	5.055±4.672
1.5	12.475	17.914	13.374	11.186	5.046	7.319	11.219±4.569
1.7	15.290	13.138	17.530	11.248	8.559	7.667	12.239±3.835
1.5	2.135	3.115	15.323	3.164	2.387	2.678	4.800±5.171
1.7	10.075	5.547	15.157	5.460	5.364	4.618	7.703±4.144
1.5	14.527	17.818	6.679	12.131	17.008	15.933	14.016±4.117
1.7	16.042	14.936	12.295	17.144	19.416	17.134	16.161±2.407
1.5	11.950	10.338	2.777	14.176	15.249	10.985	10.913±4.406
1.7	9.581	17.937	12.521	12.213	15.390	14.803	13.741±2.918

Table 7 : Measured PD (mWm^{-2}) Values in Ndokwa East

Height above the ground level (m)	Measured PD at varying distances from Mast (m)						
	0	20	40	60	80	100	Average
1.5	0.331	0.915	4.175	1.122	2.197	3.005	1.958±1.449
1.7	0.617	0.793	12.807	4.896	1.654	2.546	3.886±4.640
1.5	5.301	5.391	14.369	11.676	15.078	6.685	9.750±4.508
1.7	4.944	6.375	11.650	6.634	13.136	15.879	9.770±4.401
1.5	0.501	0.840	1.328	0.291	0.348	0.347	0.609±.405
1.7	1.024	0.888	0.556	0.272	0.291	0.283	0.552±.333
1.5	1.365	3.694	3.850	0.999	2.799	0.406	2.186±1.461
1.7	0.865	0.891	5.137	0.575	3.040	0.614	1.854±1.858
1.5	1.684	15.319	3.975	6.122	4.601	2.436	5.690±4.973
1.7	2.387	12.807	6.382	5.824	6.022	3.527	6.158±3.620

Table 8 : Measured PD (mWm^{-2}) Values in Aniocha North

Code	Height above ground level	Measured PD at varying distances from Mast (m)						
		0	20	40	60	80	100	Average
ANIN 1	1.5	1.153	1.063	3.993	10.835	1.761	3.381	3.698±3.848
	1.7	1.354	2.826	2.698	12.665	1.191	2.056	3.798±4.395
ANIN 2	1.5	2.002	4.089	10.369	11.176	4.113	0.972	5.453±4.303
	1.7	2.820	2.278	11.401	10.201	2.758	1.855	5.219±4.354
ANIN 3	1.5	4.483	1.681	4.182	3.034	2.301	3.529	3.202±1.083
	1.7	5.161	3.998	2.668	5.585	4.866	3.756	4.339±1.073
ANIN 4	1.5	8.555	1.834	2.626	4.314	3.541	1.995	3.811±2.508
	1.7	7.378	1.352	14.202	3.317	1.883	2.666	5.133±4.930
ANIN5	1.5	1.776	4.256	5.244	4.278	4.316		3.974±1.995
	1.7	0.785	3.963	4.263	5.643	2.190		3.369±2.184

Table 9 : Measured PD (mWm^{-2}) Values in Ukwani LGA

Code	Height above the ground level (m)	Measured PD at varying distances from Mast (m)						
		0	20	40	60	80	100	Average
UKWA 1	1.5	9.550	15.712	14.064	3.997	5.495	4.797	8.936±5.019
	1.7	6.599	17.379	8.266	5.026	12.722	4.845	9.140±4.966
UKWA 2	1.5	1.915	6.570	5.517	2.573	8.375	5.948	5.150±2.461
	1.7	0.962	2.569	5.250	2.384	15.807	6.946	5.653±5.272
UKWA 3	1.5	2.388	3.195	10.095	3.308	5.391	11.508	5.981±3.889
	1.7	2.930	4.976	11.563	4.797	5.444	12.434	7.024±3.957
UKWA 4	1.5	2.260	9.644	12.981	5.745	4.708	4.530	6.645±3.935
	1.7	2.256	16.259	13.308	11.721	6.346	7.387	9.546±3.789
UKWA5	1.5	8.933	16.223	15.680	15.051	15.571	6.294	12.959±4.240
	1.7	11.378	20.00	17.293	8.501	7.194	5.065	11.572±5.912

Table 10 : Measured PD (mWm^{-2}) Values in Ndokwa West

Code	Height above ground level (m)	Measured PD at varying distances from Mast (m)						
		0m	20m	40m	60m	80m	100m	Average
NDOW 1	1.5	7.989	6.658	14.836	5.492	6.628	1.796	7.233±4.282
	1.7	2.662	8.247	18.294	7.096	11.468	1.969	8.290±6.054
NDOW 2	1.5	1.966	14.583	5.448	5.093	5.549	8.645	6.881±4.327
	1.7	5.577	16.974	10.423	4.236	15.880	5.613	9.784±5.570
NDOW 3	1.5	10.021	7.516	5.978	7.872	10.998	1.971	7.393±3.211
	1.7	6.054	12.162	12.857	8.886	12.151	3.591	9.284±3.802
NDOW 4	1.5	2.198	0.883	1.083	2.849	1.692	6.009	2.452±1.886
	1.7	1.010	1.352	1.918	1.082	2.630	3.473	1.911±.961
NDOW5	1.5	10.951	16.0522	10.082	4.532	5.646	10.641	9.651±4.149
	1.7	18.636	12.068	12.656	7.610	7.666	15.708	12.391±4.367

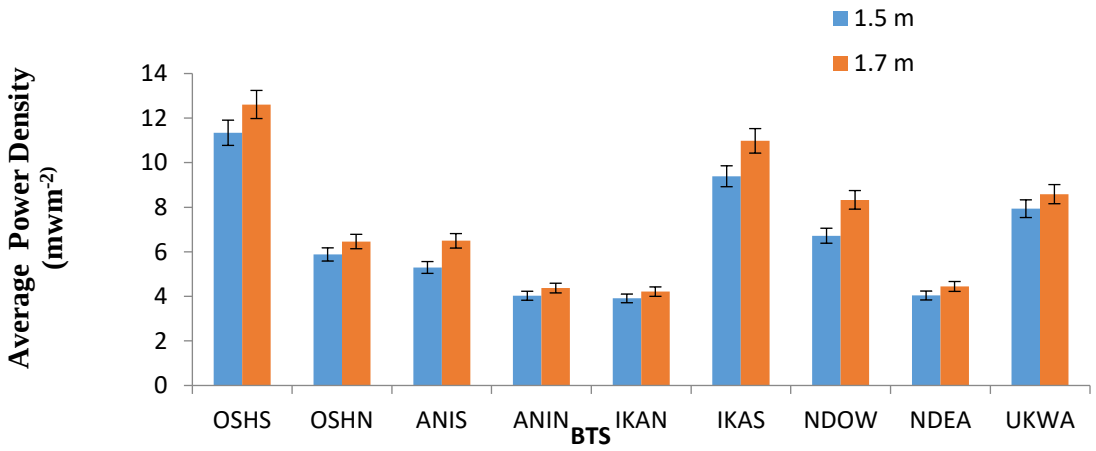

Figure 2: Average Power Density (mwm-2)

Table 11: Power Density Descripitive Statistics at 1.7 and 1.5 m height

11a. Descriptive Statistics at 1.7 m

Distance (m)	N	Range	Minimum	Maximum	Sum	Mean	Std. Erro	Std. Deviation	Variance
0.0	44	18.280	0.420	18.700	294.390	6.690	0.881	5.849	34.214
20.0	45	19.490	0.510	20.000	353.900	7.864	0.944	6.332	40.105
40.0	45	18.060	0.370	18.430	461.090	10.246	0.850	5.707	32.574
60.0	45	17.040	0.270	17.310	287.490	6.388	0.669	4.494	20.197
80.0	44	19.130	0.290	19.420	296.740	6.744	0.809	5.369	28.827
100.0	42	16.850	0.280	17.130	240.620	5.729	0.734	4.757	22.636

11b. Descriptive Statistics at 1.5 m

0.0	43	15.910	0.330	16.240	247.330	5.751	0.745	4.890	23.917
20.0	45	17.420	0.490	17.910	338.080	7.512	0.896	6.012	36.145
40.0	45	17.290	0.320	17.610	366.540	8.145	0.771	5.175	26.788
60.0	45	16.120	0.290	16.410	285.060	6.334	0.684	4.590	21.072
80.0	44	16.760	0.250	17.010	245.560	5.580	0.705	4.679	21.893
100.0	42	16.150	0.350	16.500	204.290	4.864	0.641	4.157	17.283

CONCLUSION

The assessment of the power density of 45 base stations belonging to the major network provider in Nigeria were randomly selected within North part of Delta State Nigeria was carried out using a Trifield EMF. The UKWA 5 was found to have a maximum power density (PD) of 20.000 mWm-2 at 20 m at 1.7 m above the ground and a minimum PD of 0.270 mWm-2 at 60 m from NDEA 3 at 1.7 m above the ground. All values of the power density investigated in this research work were found to be below 4.5 W/m^2 and 9 W/m^2 and standard limit set by ICNIRP for GSM 900 MHz and GSM 1800 MHz, respectively. The people who live in the homes close to the base stations under investigation in this work will not be adversely affected by the radiation emitted from these base stations. The majority of the chosen BTS were situated close to commercial and residential structures, in violation of the 5 and 10 m of the Nigeria communication commission (NCC) and National environmental standards and regulation enforcement agency (NESREA) respectively.

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