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Determination of Power Density from Radiofrequency Exposure by Base Transceiver Stations and Implications for Ado-Ekiti Residents

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ABSTRACT
The non-ionizing (RF) energy from base transceiver stations (BTS) is radiated into space through its antennas. The Human Body Surface Area (HBSA) can significantly influence the coupling of electromagnetic fields with the body, thereby resulting to energy absorption, increase in body temperature and possibly affect some physiological parameters. The health implications of RF exposure from telecommunication mast are becoming important as base stations get increasingly installed. In this study, the power density (PD) was measured using Pro Triple Axis RF/High Frequency Meter (HF-B8G) at distance (10 – 110 m) in thirty (30) active base transceiver stations (BTS) in Ado-Ekiti. Parameters of health importance such as blood pressure (BP), body temperature and body mass index (BMI) of 300 subjects around the base stations were monitored for 30 days using calibrated instruments. These measurements were recorded at a minimum of six symmetric locations around each individual BTS, with the coordinates of each location noted using portable Global Positioning System (GPS) device. The correlations among PD, HBSA and physiological parameters of nutritional/health importance were done using SPSS Vs 18 at 0.01 and 0.05 levels of significance. The results indicated that PD ranged from 0.32 to 96.89 mW/m^2 while the average radiation received by HBSA ranged from 19.62 to 40.95 mWm^{-2}. For the three classes of subjects (adult male, adult female and children), the power density in the observed active 30 base stations were below ICNIRP recommended limits (4.7 W/m^2). At 0.05 level of significance, PD correlated positively with diastolic blood pressure (DBP, r = 0.695), HBSA (r = 0.661- 0.904) and at 0.01 level, BMI also correlated with Age, HBSA and PD (r = 0.688 – 0.948). This suggested the possibility of the influence of these physiological parameters by exposure to RF which could cause potential health risk to the residents.

Keywords:
Non-ionizing radiation,
Health effect,
Human body surface area,
Body temperature.

INTRODUCTION

Base Transceiver Stations (BTS) have proliferated in Ado-Ekiti, Ekiti State, Nigeria, as a result of the quick development of mobile communication infrastructure. Residents in the vicinity may be exposed to electromagnetic radiation from BTS antennas in the radio frequency (RF) spectrum. Public concerns about potential health dangers continue, despite the fact that international organizations like the ICNIRP (2020) and WHO (2024) deem these exposures to be usually safe when below recommended limits.

Worldwide, there is a substantial concern about the radiation risk posed by base transceiver stations' proximity to populated areas and other public spaces. The radiation from telecommunication masts is not good for the environment since it increases background radiation and has an adverse impact on human being, plants and animals (Girish, 2010). A base transceiver stations (BTS) is a part of a wireless communication infrastructure that contains the radio that establishes a cell and manages the radio link protocols with portable devices like GSM phones (Godfrey, 2015). According to numerous scientific assessments, the largest man-made source of ambient radioactivity is presently electromagnetic radiation from mobile telephony, Scientists have noted that non-ionizing radiation has harmful effects. Living near a mobile phone antenna has been linked to more health problems in children than in any other age group, including cancer, memory loss, focus and concentration problems, sleep problems, behavioral disorders, and hyperactivity (Eltiti *et al*., 2016). After 11 infants received cancer diagnoses in a short period in Valladolid, Spain, a cellular telecommunications antenna had to be taken down. Due to potential health risks like brain tumors and learning problems, cell phone towers are not allowed to be built close to schools in New Zealand. (Santini *et al.,* 2002) among others, conducted investigations that demonstrated the existence of the so-called microwave syndrome which is characterized by disease symptoms that appear within a range of 10 to 400 meters from mobile phone transmitters. In addition to tinnitus, hot sensations in the ears, headaches, fatigue and sleep difficulties, there are numerous more consequences as well (Eltiti *et al.,* 20016). Since radiation has been present everywhere in our surroundings like the sky, the ground and even our own bodies, in other words, from the time of conception till the time of death, we are naturally exposed to radiation. Additionally, scientists have discovered that electromagnetic energy particles exist practically everywhere. We cannot completely remove radiation from our surroundings because it is a natural part of everything. However, by limiting our exposure, we can lower the threats to our health (EAP, 2012). NIR has been associated with dielectric heating, in which polar molecule rotation caused by an electromagnetic field heats biological tissue.

Living near mobile phone base stations has been linked to headaches, sleep difficulties, tremors, dizziness, headaches, and the sad syndrome (Bevelaqua, 2015). Radiation, both ionizing and non-ionizing can pose health risk to humans and the environment. In certain ways, ultraviolet radiation falls between ionizing and non-ionizing radiation, occupying a middle ground (Bevelaqua, 2015). The potential non-heating effects of low-power non-ionizing radiation, including exposure to non-heating microwaves and radio waves on human body surface, continue to be a source of debate.

However, human body surface area is the measured or calculated surface area of the human body. It is used to calculate cardiac index which is a critical parameter used to evaluate cardiac function, estimate percentage body fat. It is a function of weight and can be used to assess disease severity (Zhou *et al.*, 2024; Nazerian *et al*., 2025). A number of biological effects and established adverse health effects from acute exposure to RF fields have been documented (ICNIRP, 2019; WHO, 2007).

HBSA can significantly influence the coupling of electromagnetic fields with the body, thereby resulting to energy absorption, and increase in body temperature and possibly affect some physiological parameters (Teerapot and Phodungsak, 2018).

The purpose of this study was to measure the RF power density levels from BTS in Ado-Ekiti and assess its influence on some physiological parameters. As at the moment, few (which covered just few stations) or no data is available. This study provided not only the baseline levels of the RF exposure parameters for thirty transceiver base stations but also established their links with some parameters of nutritional and health importance.

MATERIALS AND METHODS

Study Area

Ado-Ekiti is the capital city of Ekiti State, Nigeria. Ado-Ekiti is the largest city in terms of population and land mass in Ekiti-state, Southwestern Nigeria. It is also the headquarter of the Ekiti Central Senatorial district, Southwest, Nigeria. Ado has land mass area of 293 km^2 with an elevation of 455 m (1493 ft) with the number of residents close to a half a million. The latitude of Ado-Ekiti, Nigeria is 7.621111, and the longitude is 5.221389. Ado Local Government of Ekiti State, Nigeria is located at Nigeria with the GPS coordinates of 7° 37' 15.9996" N and 5° 13' 17.0004" E. It is also a center of education, with few large universities and Polytechnics.

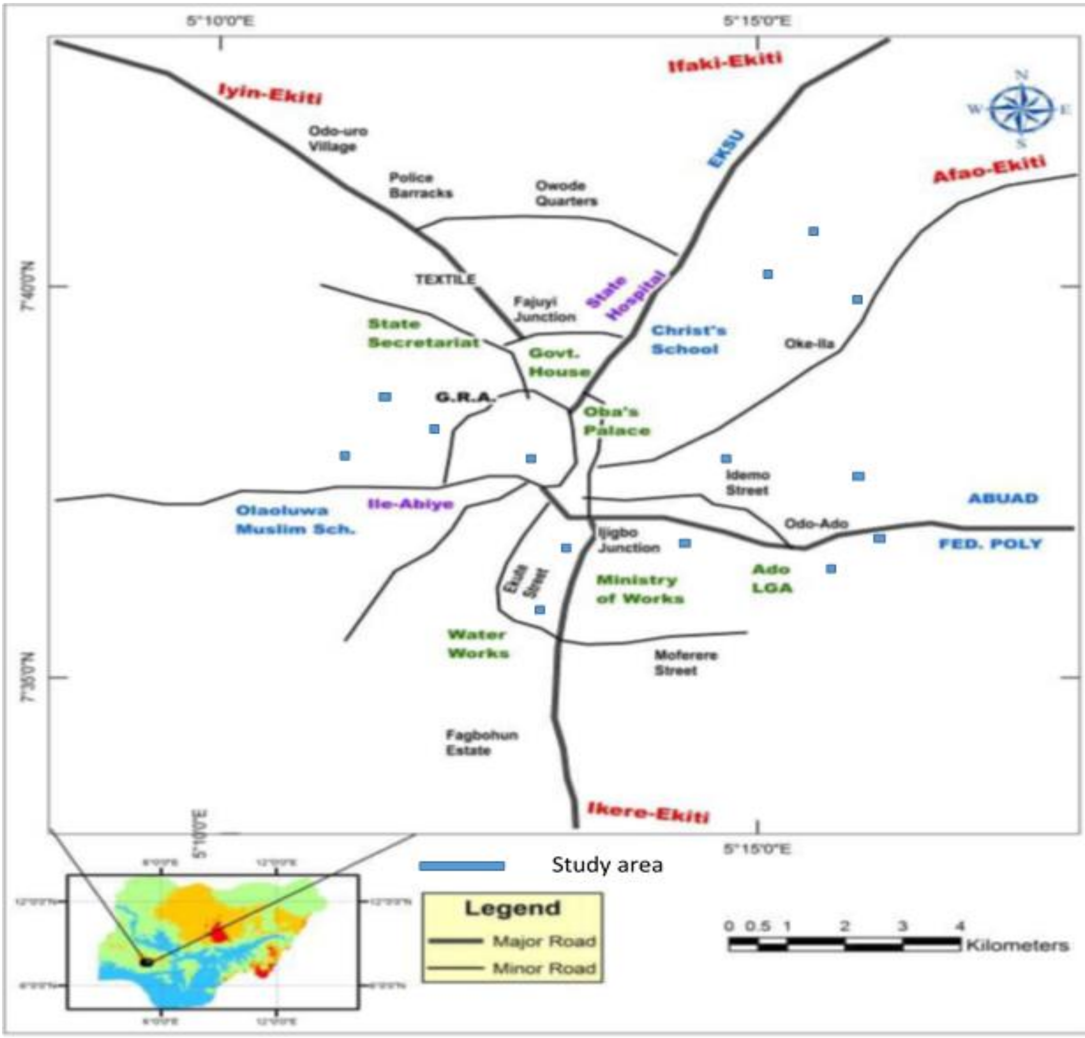

Figure 1: Location map of the study area (Akinola, 2019)

Ado-Ekiti was chosen for this study based on the proximity and also a place where a reasonable numbers of base transceivers stations are erected close to suburban residential buildings, Schools, Hospitals and Market can be captured, dense urban center (high-rise residential area), reconnaissance to identify 30 BTSs that cover different operator (MTN, Airtel, Glo and 9 mobile) and diverse environment. The sampling was random which covered the entire Ado-Ekiti Local Government Area.

Data Collection

The weights (kg) and heights of the subjects were determined using well calibrated weighing scale and tape rule (m) respectively The power density was measured in triplicates at distances 10, 30, 50, 70, 90 and 110 m. This was monitored for 30 days to observe if there is any significant variation in the values obtained. At 20 m intervals around a 110 m radius from the base of each communication tower, measurements were made in a convenient direction around the base stations. All the measurements were taken during early hour of the day to avoid interrupted radiation from the sun. This was taken into consideration throughout the field work for this research. One hundred and eighty (180) measurements were taken in all. Six (6) measurements were taken at different distance from 30 randomly selected base stations. Pro Triple Axis RF/High Frequency Meter (HF-B8G model) was used to measure radiation power received in mW/m^2, $\mu W/cm^2$ $\mu W/m^2$. The Pro Triple Axis RF/High Frequency Meter (HF-B8G model) was used to take the tri-axial and maximum power density from each base station by holding the RF meter at arm's length, pointing it away from the body and about 1.5 meters above the ground. After a short period of time, when the meter's reading was stable and constant, the power density values were taken and recorded. Precautions were taken to ensure that no additional radiation sources affected the measured values. Each measurement was taken three times and the mean values

were obtained to ensure precision and accuracy. Proper calibration of the meter was also ensured before use.
The Body Mass Index (BMI) was calculated using

$$BMI = \frac{W}{Ht^2} \left(\frac{kg}{m^2}\right) \quad (1)$$

while Human Body Surface Area (HBSA) was obtained using

$$HBSA = \sqrt{\frac{WxH}{T}} \quad (2)$$

Where w = weight (kg), Ht = height (m) and T = time per hour. (Looney *et al,* 2023)
The average radiation power received by the human body from an external, far-field electromagnetic (EM) source was estimated using

$$P_{absorbed} = P_{density} \times HBSA \quad (3)$$

Where
$P_{absorbed}$ = Average power absorbed by the body (Watts)
$P_{density}$ = Incident power density of the radiation (W/m^2)
$HBSA$ = Human body Surface Area (m^2) (Redlarski et *al*., 2024).

Data/Statistical Analysis
The data acquired in this study were subjected to descriptive statistics. The mean and standard deviations were obtained for each parameter measured. The statistical package for social scientists (SPSS Vs 15) was used to find the links or correlations among the observed parameters at 0.01 and 0.05 levels of significance. The same software was also used to plot the graphs or charts.

RESULTS AND DISCUSSION
Tables 1 depicts the variation of power density with respect to distances (m) from the source (10 – 110 m) for the observed base stations. Table 2 gives the average power density on the basis of the distances from the sourced while Table 3 shows human body surface area for the three categories of subjects (Adult male, adult female and children) used for this study.

Table 1: Variations of mean power density (mWm^{-2}) with distances (10 – 110 m) for base stations 1 – 30 respectively

S/N	10 m	30 m	50 m	70 m	90 m	110 m
BTS 1	33.95	2.83	4.97	1.44	21.45	12.15
BTS 2	12.96	11.21	7.19	2.35	44.23	83.06
BTS 3	24.32	25.61	11.23	12.56	13.84	24.52
BTS4	11.34	21.09	46.91	55.63	51.37	55.73
BTS5	1.151	19.01	34.66	19.81	2.59	2.21
BTS 6	22.59	3.48	3.19	3.41	2.11	2.35
BTS 7	14.47	28.02	24.74	14.38	32.11	19.37
BTS 8	3.95	2.83	4.97	1.44	21.45	12.15
BTS 9	15.61	25.73	20.41	20.43	17.28	26.54
BTS 10	10.68	12.03	13.04	20.21	24.89	28.21
BTS 11	12.34	12.48	12.4	11.89	13.95	14.32
BTS 12	13.45	15.25	22.11	16.24	18.36	20.25
BTS 13	18.12	16.88	25.67	15.12	22.62	14.23
BTS 14	33.82	21.59	15.09	13.64	12.01	10.89
BTS 15	10.16	31.78	21.42	20.01	16.24	10.24
BTS 16	22.91	44.39	44.94	39.45	36.23	35.51
BTS 17	3.33	2.45	1.79	1.15	0.78	2.46
BTS 18	2.16	2.01	3.12	1.35	1.01	0.32
BTS 19	62.14	70.81	93.71	88.41	14.79	8.68
BTS 20	19.85	11.82	5.05	2.06	2.64	1.76
BTS 21	2.65	3.03	0.47	6.13	3.61	5.74
BTS 22	2.25	1.71	2.13	1.41	2.73	3.04
BTS 23	1.31	2.46	1.73	1.41	0.92	1.49
BTS 24	31.24	20.64	21.25	12.64	9.38	2.41
BTS 25	2.66	3.52	2.01	0.48	0.66	4.44
BTS 26	9.59	26.46	4.32	3.04	1.11	14.54
BTS 27	20.88	80.56	52.22	10.87	96.89	75.61
BTS 28	54.01	47.84	41.91	40.61	44.47	53.26
BTS 29	41.04	49.54	50.73	51.27	61.77	41.04
BTS 30	20.18	12.59	24.18	13.81	18.13	60.09

Table 2: Average power density with respect to distances from the source

Distance (m)	Power Density (mWm^{-2}) Mean ± SD
10	17.84 ± 3.24
30	20.99 ± 2.85
50	20.59 ± 2.57
70	20.02 ± 4.46
90	20.32 ± 4.34
110	21.55 ± 6.32

Table 3: Average radiation received at various distances (mWm^{-2}) (based on HBSA) from BTS 1- BTS 30

	10 m	**30 m**	**50 m**	**70 m**	**90 m**	**110 m**
HBSA (m^2)	**17.84**	**20.99**	**20.59**	**20.02**	**20.32**	**21.55**
Adult male 1.9	33.90	39.88	39.12	38.04	38.61	40.95
Adult female 1.7	30.33	35.68	35.00	34.03	34.54	36.64
Children 1.1	19.62	23.09	22.65	22.02	22.35	23.71

Table 4: Body Mass Index stratification of the subjects

Variable	Classification	No of Subjects	Percentage
Body Mass Index (BMI)	Less than 18.5	9	Underweight
	18.5 – 24.9	179	Normal
	25 – 29.9	101	Overweight
	30 above	11	Obese

Discussion

The results indicated that average power density ranged from 0.32 – 10.87 mW/m^2 while the human body surface area ranged from 19.62 - 40.95 m^2. The values obtained for power density over the observed active 30 base stations were below 2018 ICNRP recommended limits of 4.7 W/m^2. This result was in line with (Akinyemi *et al.,* 2014) with lower power density than the International Commission on Non-Ionizing Radiation Protection (ICNIRP , 2020) exposure limit for BTS mask operation at almost the same frequency range (and for values of radiating power of the base station antenna ranging between 33 Watts to 100 Watts). Out of the 300 subjects used in this study, the BMI stratification based on nutritional status shows that 3 % of the subjects were underweight, 59.6 % were normal while 33.7 % and 3.7 % were overweight and obese respectively.

Variation of Average Power Density with Distances from Base Stations

Figure 2 shows the variation of the average with distances from the source of the base stations while Figure 3a and 3b depict the power densities at the observed distances for the base stations 1 – 15 and 16 – 30 respectively. In most cases, the variation of the average power density with distances (10, 30, 50, 70, 70 and 110 m) from the foot of the base stations obeyed inverse square law (66.66%) as obtained by (Ilesanmi *et al.,* 2021) and (Akinyemi *et al.,* 2014). However, for 33.33 % of the base stations, there was deviation from inverse square law due to environmental factors such as obstruction from buildings and trees. This is in line with the study by (Oluwafemi *et al*., 2019). This deviation from the normal could be as a result of interference from mobile and immobile objects while taking readings, undulating nature of the land, non-uniformity in BTSs height, the number of antenna and value of frequency contributing to the radiation at a particular distance, weather condition and other phenomena. (Bello *et al.,* 2023); (Taiwo *et al*., 2023); (Samaila *et al.,* 2023) & (Olawale *et al.,* 2021).

Table 5: Physiological parameters of the residents around the base stations

Category	Age (yrs)		HT (cm)		SBP (mmHg)		DBP (mmHg)		BMI (Kg/m^2)		BT (^{0}C)	
	Range	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD
Children (n = 29)	0-14	10.00 ± 0.12	107.76-120.24	114.00 ± 6.24	105.37-113.45	113.45 ± 4.04	75.47-82.87	79.17 ± 3.70	13.20	21.17 ± 0.70	34.21-40.09	37.15 ± 2.94
Male Adult (n = 125)	15-65	31.20 ± 0.40	158.45-170.55	164.52 ± 6.03	111.10-100.36	110.73 ± 0.37	56.67-64.53	60.60 ± 3.93	19.30	24.21 ± 2.43	34.57-37.89	36.23 ± 1.66
Female Adult (n = 146)	15-65	35.28 ± 0.45	155.87-167.01	161.44 ± 5.57	108.02-117.24	112.63 ± 4.61	68.82-75.82	72.32 ± 3.50	16.80	24.73 ± 2.47	37.40	36.15 ± 1.65

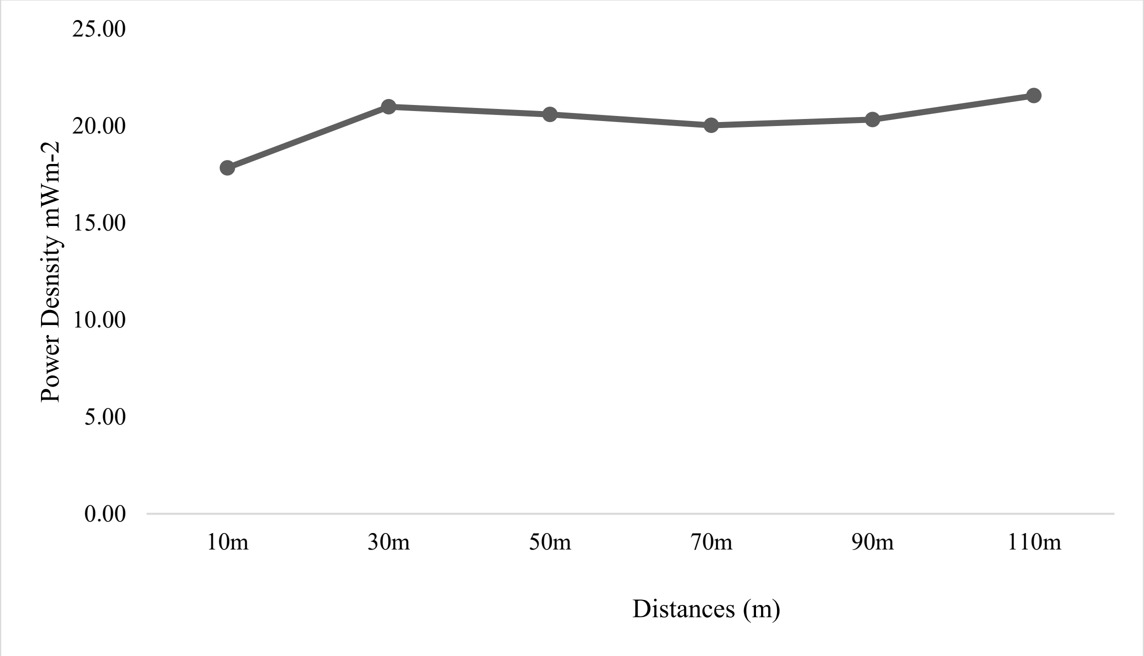

Figure 2: Average power density with respect to distances from the source

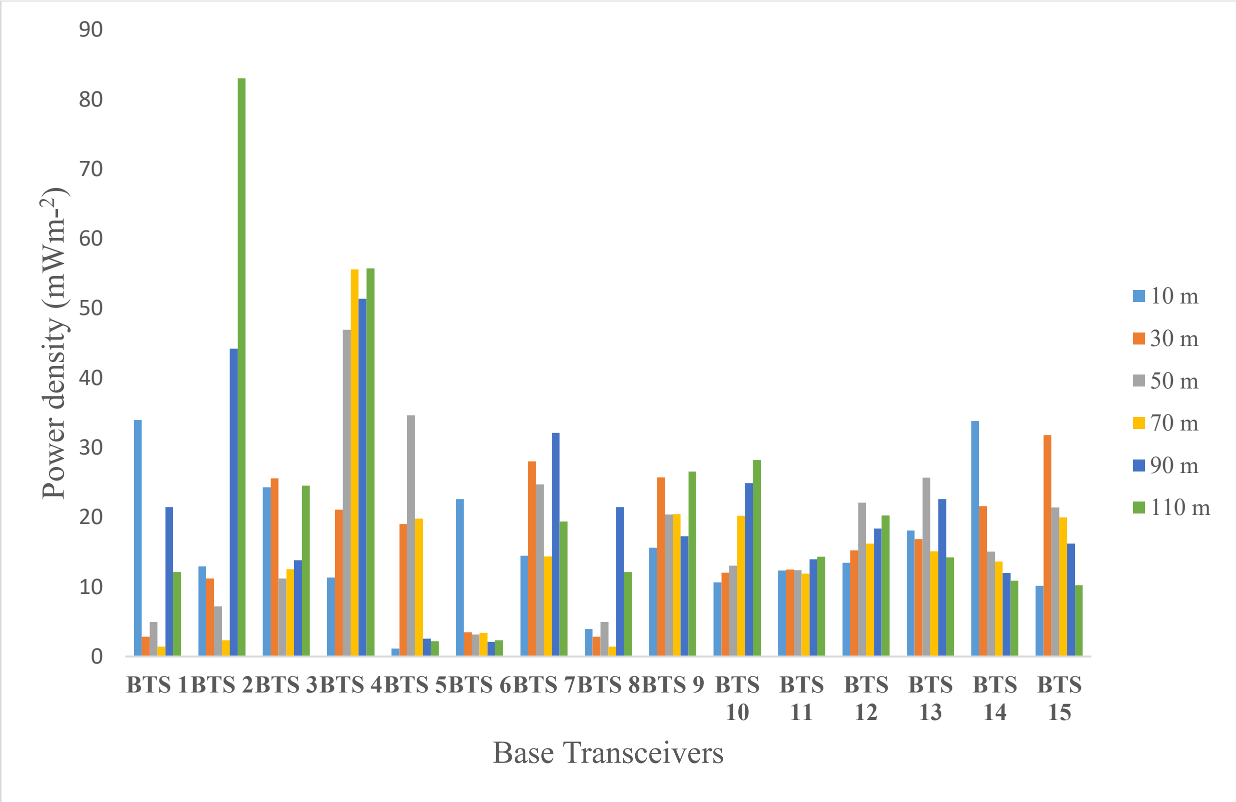

Figure 3a: Power density at different distances for BTS 1- BTS 15

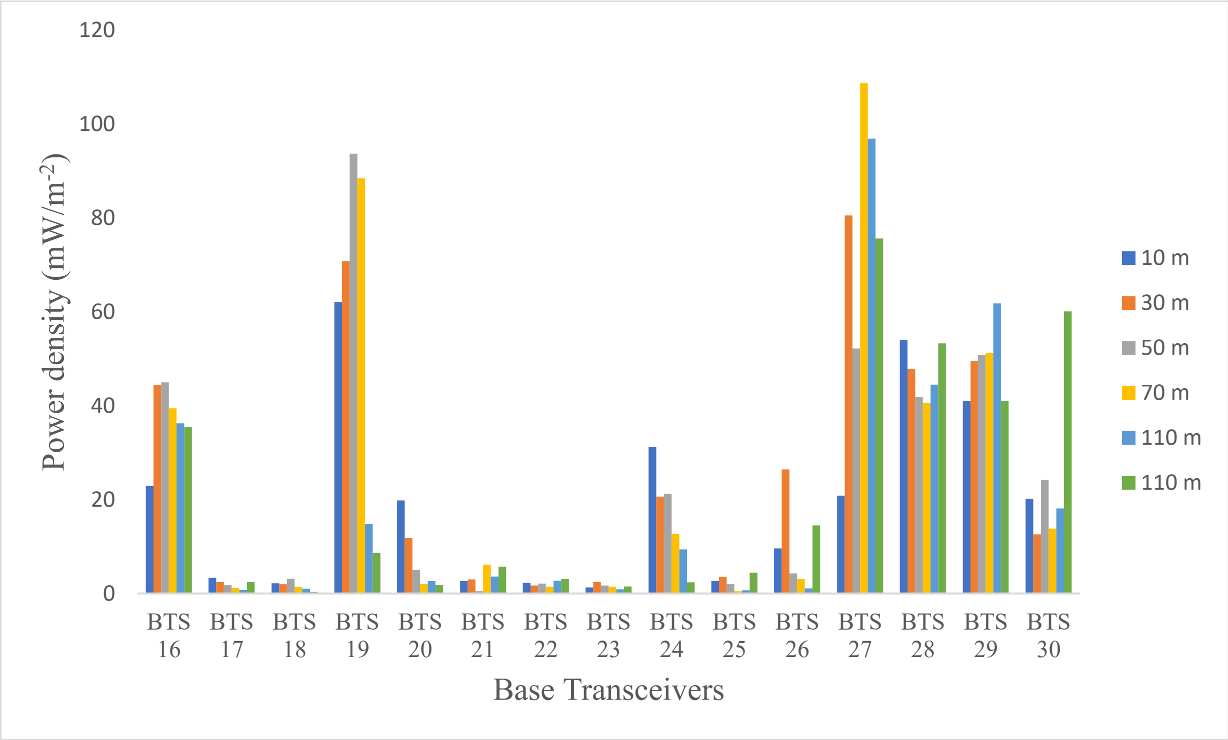

Figure 3b: Power density at different distances for BTS 1- BTS 30

Power Density and Nutritional Status

Using t-test, Significant differences ($t < 0.05$) exist between power density of the normal and overweight ($t = 0.04$) and obese ($t = 0.025$) but not for underweight. This indicated that power density can either directly or indirectly affect the nutritional status of the residents around the base stations. It was mentioned that being overweight may increase one's chance of developing cancer in a variety of ways. Some of which may be unique to a given type of cancer. Furthermore, these issues have been linked to an increased vulnerability to a number of diseases, such as Type 2 diabetes, cardiovascular disease, high blood pressure, sleep disorders, and specific musculoskeletal conditions. In addition, given that radiofrequency (RF) exposure is identified as a potential source of health risks, especially with females being the predominant group in this study. Maintaining a healthy BMI may reduce the risk of exposure to cancers and other associated diseases that may arise from RF exposure (Islami *et al.,* 2020), (ACS, 2019), (WCRF, 2020).

Power density and other observed physiological parameters

The correlation between the power density and physiological parameters of nutritional and health importance were sought for using SPSS Vs 18 at 0.01 and 0.05 levels of significance. Table 5 gives the summary of the descriptive statistics of subjects' observed physiological parameters residing around the base stations. At 0.05 level of significance, for some of the base stations, power density correlated positively with diastolic blood pressure (DBP, $r = 0.695$), HBSA ($r = 0.661$- 0.904) and at 0.01 level, BMI also correlated with subjects' Age, HBSA and Power density ($r = 0.688$ – 0.948). This indicated the possibility of the alteration of BMI and blood pressure by power density of the subjects/residents in the neighborhood and also buttress the fact that radiation received from the base stations could influence some of these parameters as pointed or raised by (Bevelagna, 2015).

CONCLUSION

In this study, the power density at 30 active based stations (and with respect to some distances from their sources) have been measured using a well calibrated Radio frequency meter with a view to determining the baseline levels and possible effects on residents in the neighborhood of these stations. Findings from these results indicated that power density ranged from 0.32 – 96.89 mW/m^2 while the human body surface area ranged from 22.02 - 40.95 m^2. At 0.01 level, BMI correlated with Age, HBSA and Power density ($r = 0.688 – 0.948$). These results established the fact that thermal effect could be the primary mechanism behind the impacts of RF exposure on the biological and physiological quantities observed in this study (as reported by Bevelagna (2015). The results obtained also indicated the possibility of the alteration of BMI and blood pressure by power density of the subjects/residents in the neighborhood. In the meantime, following safety guidelines by health authorities and limiting exposure can be a good precautionary measure.

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