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ORIGINAL RESEARCH ARTICLE

RESIDENTIAL EXPOSURE OF ELECTROMAGNETIC FIELDS RADIATED FROM MOBILE BASE STATIONS AND BROADCAST TRANSMITTERS

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ABSTRACT

This paper presents the cellular base station electromagnetic radiation and its effects on human body. Due to technological advancement, human life is subjected to high level of electromagnetic emission. The effect of electromagnetic radiation (EMR) is recognized from health risk associated with exposure to it. The research work was performed in two Communication companies, namely COMPA and COMPB located in Owerri, Imo State, in two geographical areas of Onitsha – Owerri Road and Owerri Municipal. The study was conducted to ascertain power density measurement using SureCall signal meter in 72 houses within a distance of 200 - 2500 meters from the base stations. Results obtained revealed that the average cumulative power density at different distances of 200m, 500m, 800m, 1200m, 1700m, and 2500m were 1.54005627200μW/m^2, 0.319382647200μW/m^2, 0.171062647200μW/m^2, 0.139667752800μW/m^2, 0.028675447200μW/m^2, and 0.001429063200μW/m^2, respectively. These results were compared with International Standard and World Health Organization (WHO) allowable limits. In conclusion, it was observed that the power density varied with distance from tower and is highest at the shortest distance. Power density also varied from place to place depending on the infrastructure obstruction, like buildings or internal obstructions

1.0 Introduction

Electromagnetic Radiation (EMR) is made up of both the electric and magnetic field components, where both occur in a fixed ratio of intensity to each other, oscillating in phase at right angle to the direction of energy and wave propagation (Viel et al., 2009).

In free space, electromagnetic radiation travels at the speed of light. In addition, Electromagnetic radiation is classified based on the frequency of its wave. The electromagnetic spectrum, in order of its increasing frequency and diminishing wavelength consists of the radio waves, microwaves, infrared, white light, ultraviolet radiation, x-rays and gamma rays (Alhekail, 2012).

In general, Electromagnetic Fields (EMF) and waves are media for carrying signals through specific medium. The transmitted signal can be in form of voice, data, or image. The electromagnetic field is transmitting at the speed of light in a vacuum at 300,000 km/s and this can be modulated, transmitted and received while the required information is being conveyed (Sauter et al., 2010).

In classical physics, electromagnetic radiation is considered to be produced when electrically charged particles are speed up by forces acting on them. Electrons are the causes of emission by most electromagnetic radiation, because they possess low mass of weight and are therefore easily moved by various varieties of mechanism. Rapidly moving electrons are speed up when they come in contact with a region of force (Joseph, 2016).

The cell towers are located randomly in different places and some are cited within living homes, churches, schools, market places and office premises. In most developing countries, most leading mobile service provider would like to cite their cell towers in a suitable area so as to serve the users using their networks. The number of cell phones and cell towers are increasing without due consideration to its disadvantages especially to the humans and the environment (Miclaus and Bechet, 2006).

Biological consequences due to these fields arise from power and transmission lines, electronic devices inside our residence and work places, electrical cable splices, distribution networks and associated devices such as cellular telephones and wireless communication tower (Danielle, 2017).

1.1 Ionizing and Non-Ionizing

Electromagnetic Radiation of high frequencies (ultraviolet, x-rays and gamma rays) are called ionizing radiation, since individual photons of such high frequency have enough energy to ionize molecules or breaks chemical bonds. These radiations have the ability to cause chemical reactions and damage living cells, beyond that resulting from simple heating and can be a health hazard (Ankur and Mandeep, 2012).

Electromagnetic Radiation of visible or lower frequencies (visible light, infrared, microwaves, and radio waves) is called non-ionizing radiation, because its photons do not individually have enough energy to ionize atoms or molecules or break chemical bonds. The effects of these radiations on chemical systems and living tissue are caused primarily by heating effects from the combined energy transfer of many photons (Bortkiewicz et al., 2014).

Most of the researches on the health effects of adverse non-ionizing radiation has been done that consists of one general type of anthropogenic non-ionizing EMR, where there are microwave and radio frequency from wireless telecommunication devices such as wireless telephones, cell towers, antennas as well as broadcast transmission towers (Cho et al., 2016).

1.2 Cellular Base Stations

Telephone cellular site is where antennas and electronic communications gadgets are placed on a radio mast, tower, structures or high places to create a cell in a cellular network. The raised platform normally supports antennas and one or more sets of transmitters and receivers, control electronics, a GPS receiver for timing and digital signal processor (Catarinucci, 2003).

The base station uses microwave radio communication. It consists of several antennas placed on a tower and a building with electronics in it. When one makes a call on a cell phone, the cell phone and base station communicate back and forth by radio, and the radio waves they use are in the microwave region of the electromagnetic spectrum. The antenna components of a base station are mostly less than ten centimeters but can be classified into clusters or arrays with heights of about one meter. They need to be mounted on towers against obstacles like hills, trees or tall buildings that possess barriers to our cell phone and the base station (Blanch and Romeu, 2002).

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The two types of cellular antennas used are Sector and Omni-directional antennas. Omni directional antenna exhibits a circular radiation pattern and operates in virtually all directions while sector or directional antennas operate in a specific direction. Sector antenna normally covers an arc of 120 degrees or less depending on capacity requirements.

The statement of problem is that most stations radiate different levels of electromagnetic signals so as to actualize their planned coverage and stable network, without considering the possible health hazard an increased radiated power can cause to the human body. The objective is to investigate residential exposure of electromagnetic fields radiated from mobile base stations.

2.0 Materials and Method

The materials used in this study are Mobile Spectrum Analyzer, SureCall Signal meter, radio frequency meter, Global Position System (GPS) and MATLAB Software. The mobile spectrum analyzer was used to detect signal, frequency and radio frequency signal strength in the two geographical areas.

A SureCall Signal meter was used to detect and study the cellular signal strength to enable the network providers to determine the areas of weak signal which require boasting.

The radio frequency meter records signal frequencies including Long Term Evaluation and Cellular. Data was obtained from two base stations of communication companies, namely COMPA and COMPB located within Onitsha – Owerri road (site 1) and Owerri municipal area (site 2).

Onitsha – Owerri road is situated where the base station transmitters were located far away from the residential buildings between Owerri and Onitsha town. Owerri municipal is situated where the residential buildings were located very close to the base station transmitters within Owerri town.

Absolute power measurement was conducted in seventy two different houses in close proximity to the base stations. No mobile phone was turned on in the vicinity while taking readings.

Background radiation of -50dBm was measured and at the same time absolute power (dBm) was taken at each geographical area in the two companies for a period of three days. The average signal power was also calculated throughout the period.

The measurement was performed to ensure that radio frequency field emission from each geographical area did not exceed the safe public limits and to find whether there was correlation between the health complaints and the measured power densities (Mouaaz and Mohammed, 2011).

Frequency spectrum of the mobile tower was determined at different places and it was observed that the peak frequency changes at different places over time. This change in peak was due to varying nature of the wave (Martinez-Gonzalez and Fernandez-Pascual, 2002).

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3.0 Results and Discussion

The experimental results of the measured power from the base stations of two companies at various distances of 200m, 500m, 800m, 1200m, 1700m and 2500m within two geographical areas along Onitsha - Owerri road and Owerri municipal were recorded.

The measured power was used to calculate the average received power for the two mobile providers. The radiation levels absorbed by different areas of the body were obtained due to the received signal power measured at various distances where the human body exists.

Tables 1 shows the received signal power for COMPA (site 1). The distance measured and average signal power (dBm) for the period of three days between 7am – 7pm each day at a frequency of 900MHz were tabulated. When the distance was 200m, the average signal power (dBm) for 3 days was -68.30, -67.50 and -67.20. It was observed that when the distance was small, the average signal power gave a small value but when the distance was high, the average signal power gave a high value.

Table 2 indicates the received power for COMPA (site 2). When the distance was 800m, the average signal power (dBm) was -77.50, -77.50 and -77.00.

Table 3 shows the received signal power for COMPB (site 1). When the distance was 500m, the average signal power (dBm) for 3 days was -76.75, -77.00 and -75.51 respectively. It was observed that when the distance was small, the average signal power was small but when the distance was high, the average signal power was high.

Table 4 reveals that when the distance was 1700m, the average signal power (dBm) for 3 days was -85.50, -83.50, and -85.50.

Table 5 – Table 6 indicates that when the distance was small, the power absorbed became high whereas at higher distance, the power absorbed became small. For instance, in table 5, when the distance was 200m for an area of $0.243m^2$, the power absorbed was $0.000044659008\mu W/m^2$ compared to when the distance was $2500m$, the power absorbed was $0.000000026317\mu W/m^2$.

Table 7 shows the cumulative power absorbed by the human body from one second to one hour. It was observed that when the distance was small, the power absorbed became high but when the distance was high, the power absorbed became small.

Table 8 reveals that at smaller distances from the base station, more power is absorbed but when the distance increases, the power absorbed decreases from 1 day to 1 year.

Table 9 shows the average area of human body and the power absorbed. It was observed that people within ages of 2 – 18 years absorbed more power than those above ages 18 years.

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Table 1: Received Signal Power for COMPA (Site 1)

S/N	Distance (m)	Average Signal Power (dBm) for day 1	Average Signal Power (dBm) for day 2	Average Signal Power (dBm) for day 3	Average Signal Power
1	200	-68.30	-67.50	-67.20	-67.66
2	500	-74.60	-72.50	-74.67	-73.92
3	800	-87.25	-77.50	-86.25	-83.66
4	1200	-88.00	-86.00	-87.25	-87.08
5	1700	-92.30	-90.00	-90.50	-90.93
6	2500	-100.00	-100.00	-99.04	-99.68

Table 2: Received Signal Power for COMPA (Site 2)

S/N	Distance(m)	Average Signal Power (dBm) for day 1	Average Signal Power (dBm) for day 2	Average Signal Power (dBm) for day 3	Average Signal Power
1	200	-67.94	-67.00	-67.50	-67.48
2	500	-72.75	-72.75	-72.50	-72.66
3	800	-77.50	-77.50	-77.00	-77.33
4	1200	-79.50	-79.50	-78.00	-79.00
5	1700	-89.00	-86.00	-87.00	-87.33
6	2500	-103.45	-103.50	-103.80	-103.58

Table 3: Received Signal Power for COMPB (Site 1)

S/N	Distance (m)	Average Signal Power (dBm) for day 1	Average Signal Power (dBm) for day 2	Average Signal Power (dBm) for day 3	Average Signal Power
1	200	-66.70	-66.60	-67.21	-66.84
2	500	-73.50	-74.00	-73.50	-73.66
3	800	-76.75	-77.00	-75.51	-76.42
4	1200	-77.00	-77.60	-77.20	-77.26
5	1700	-84.50	-84.00	-83.90	-84.13
6	2500	-97.57	-97.01	-96.90	-97.16

Table 4: Received Signal Power for COMPB (Site 2)

S/N	Distance (m)	Average Signal Power (dBm) for day 1	Average Signal Power (dBm) for day 2	Average Signal Power (dBm) for day 3	Average Signal Power
1	200	-67.50	-67.01	-68.01	-67.50
2	500	-71.20	-71.50	-71.50	-71.40
3	800	-77.00	-77.00	-77.00	-77.00
4	1200	-79.10	-81.00	-80.00	-80.03
5	1700	-85.50	-83.50	-85.50	-84.16
6	2500	-97.00	-95.00	-96.00	-96.00

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Table 5: Power Absorbed by Human Body with Area of 0.243m^2 from COMPA (Site 1)

Distance (m)	Power received in (μW)	Area (m^2)	Power Absorbed (μW/m^2)
200	0.00017967	0.243	0.000043659008
500	0.00004167	0.243	0.000010125008
800	0.00000735	0.243	0.000001786050
1200	0.00000199	0.243	0.000000483570
1700	0.00000083	0.243	0.000000200888
2500	0.00000011	0.243	0.000000026317

Table 6: Power Absorbed by Human Body with Area of 0.243m^2 from COMPB (Site 1)

Distance (m)	Power received in (μW)	Area (m^2)	Power Absorbed (μW/m^2)
200	0.0002076667	0.243	0.000050463008
500	0.0000430667	0.243	0.000010465208
800	0.0000230667	0.243	0.000005605208
1200	0.0000188333	0.243	0.000004576492
1700	0.0000038667	0.243	0.000000939608
2500	0.0000001927	0.243	0.000000046826

Table 7: Cumulative Power Absorbed by the Human Body from 1sec to 1hr

Dist. (m)	Power Absorbed (μW/m^2) for 1 Sec	Power Absorbed (μW/m^2) for 1 Min	Power Absorbed (μW/m^2) for 1 Hr
200	0.000427793402	0.025667604120	1.540056247200
500	0.000088717402	0.005323044120	0.319382647200
800	0.000047517402	0.002851044120	0.171062647200
1200	0.000038796598	0.002327795880	0.139667752800
1700	0.000007965402	0.000477924120	0.028675447200
2500	0.000000396962	0.000023817720	0.001429063200

Table 8: Cumulative Power Absorbed by the Human Body from 1 Day to 1 Year

Dist. (m)	Power Absorbed (μW/m^2) for 1 Day	Power Absorbed (μW/m^2) for 1 Week	Power Absorbed (μW/m^2) for 1 Month	Power Absorbed (μW/m^2) for 1 Year
200	36.96135	258.7294	1034.9180	12419.01
500	7.665184	53.65628	214.6251	2575.502
800	4.105504	28.73852	114.9541	1379.449
1200	3.352026	23.46418	93.85673	1126.281
1700	0.688211	4.817475	19.26990	231.2388
2500	0.034298	0.420083	0.96033	11.52397

Table 9: Average Area of Human Body with The Power Absorbed

Age or Age Group (Year)	Area (m^2)	Power Absorbed (μW)
2	0.563	38.00
5	0.787	7.50
10	1.236	4.20
13	1.603	2.50
18	1.980	1.20
20-79	2.060	0.1

Figure 1 shows the graph of radiation level against distance. When the distance was 250 meters, the radiation level increases to 4.0 x 10^{-5}Gy. When the distance was 500 meters, the radiation level reduces to 1.0 x 10^{-5}Gy. When the distance was 1000 meters, the radiation level reduces to 0.2 x 10^{-5} Gy. Also, when the distance increases to 2500 meters, the radiation level further reduces to 0.1 x 10^{-5}Gy.

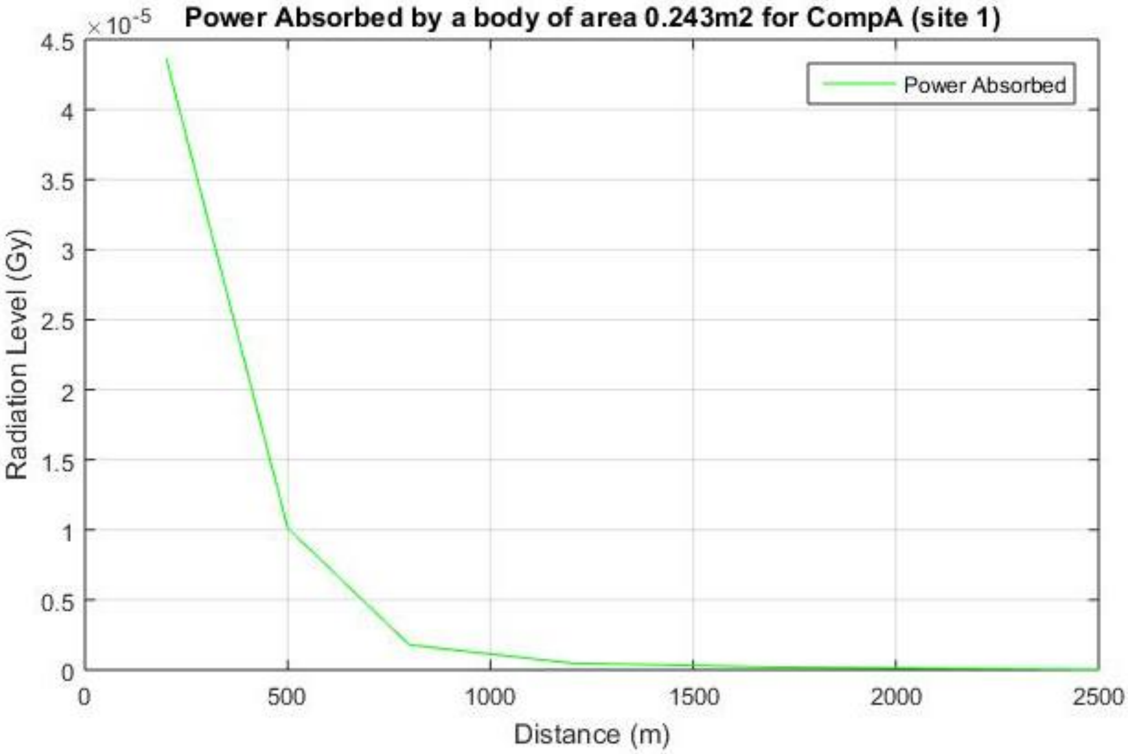

Figure 1: Radiation power level against distance by a body with area of $0.243m^2$ from COMPA (site 1)

Figure 2 indicates the graph of radiation level against distance. When the distance was 250 meters, the radiation level was 1.0 x 10^{-5}Gy and when the distance increases to 1500 meters, the radiation level reduces to 0.2 x 10^{-5}Gy. Also, when the distance increases to 2500 meters, the radiation level further reduces to 0.01 x 10^{-5}Gy.

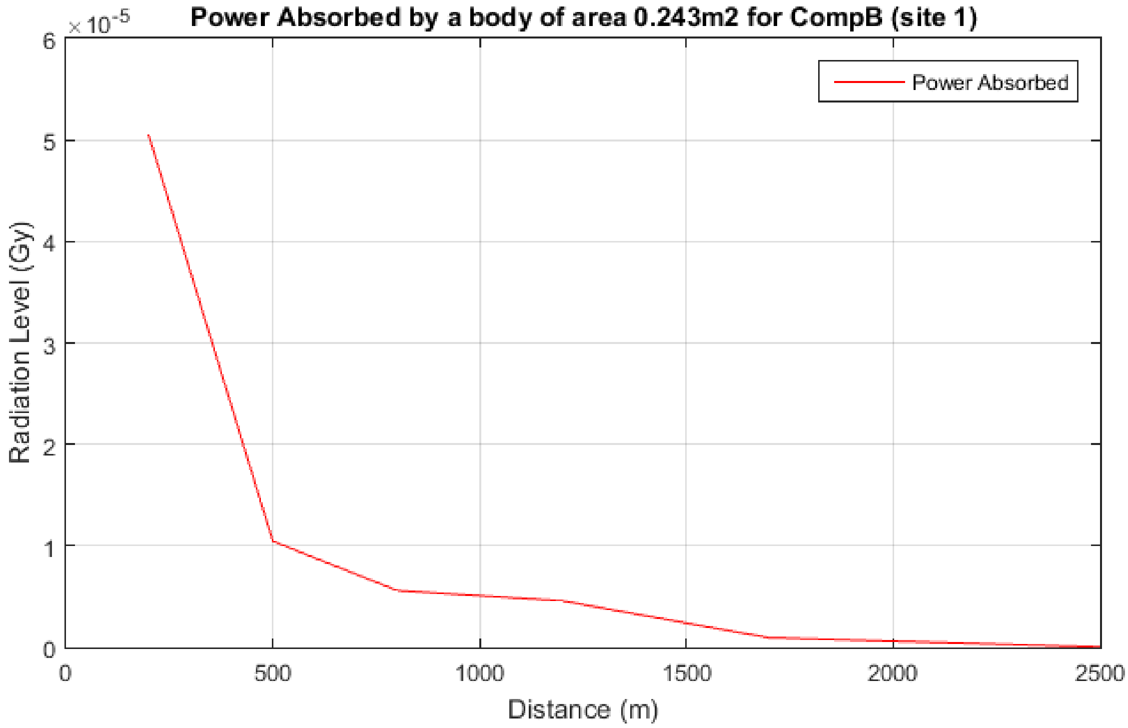

Figure 2: Radiation power level against distance by a body with area of 0.243m^2 from COMPB (site 1).

Figure 3 reveals the power absorbed by human body against age. When the age of human being was 5 years, the power absorbed was 8μW and when the age was 20years, the power absorbed was 1μW. It was observed that when the age of human being was small, the body absorbed more power but when the age of human being was large, the body absorbed less power.

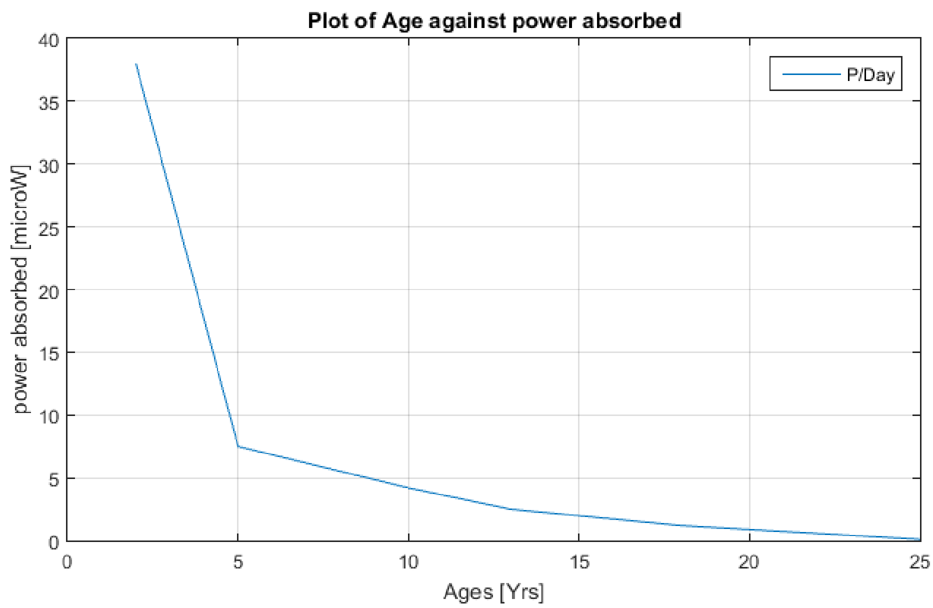

Figure 3: Power absorbed by the human body between the ages of 2-25 year per day.

Figure 4 indicates the radiation level against distance. The power absorbed in one month shows a linear result from 200 - 500 meters with high radiation levels of 1025.725Gy and 0.250Gy. The radiation levels gradually drops between 500 - 2500 meters. The power absorbed in one year also shows a linear result with radiation levels of 2481.413Gy and 12238.10Gy. The radiation levels therefore drop gradually till 2500 meters.

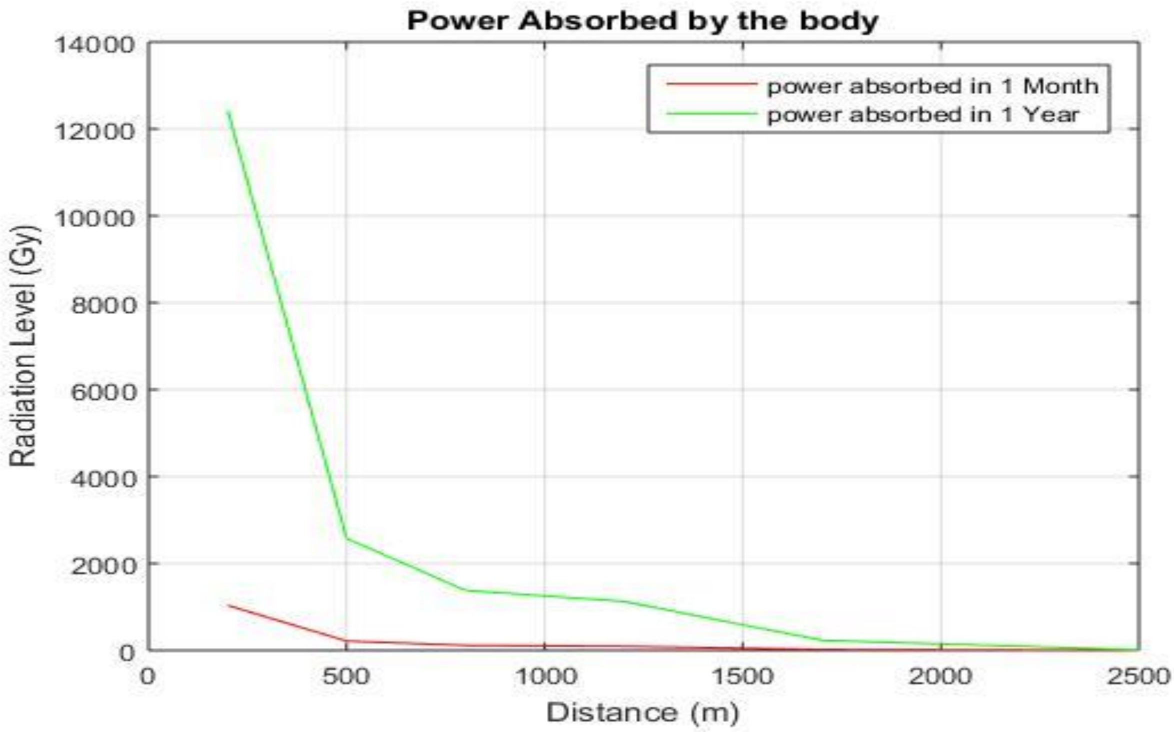

Figure 4: Cumulative power absorbed in 1month and 1 year

4.0 Conclusion

In this paper, measurements on received signal power was used to identify the level of electromagnetic radiation at distances close to the base station transmitters and to determine the level of radiation absorbed by the human body. Some of the base station transmitters are located very close to the residential houses and business areas, thereby exposing people to the danger of electromagnetic radiation from the base stations.

However, the results obtained indicates that the average cumulative radiated power for one hour at 200 meters was 1.54005624700μW/m^2 which is within the range of recommended standard for electromagnetic radiation effect of 0.1 - 10 μW/m^2. Also, the average cumulative radiated power for 24 hours at 200 meters was 36.96135μW/m^2 which is of severe concern and exceeded the recommended standard. It is concluded that cellular base stations transmitters should not be located within 200 meters from the residential buildings.

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