Estimation of Radiofrequency Power Density around GSM Base Stations in Some Selected Parts of Lagos State

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Abstract
There have been growing concerns among members of the public about the health hazards that may be associated with radiofrequency emissions from GSM base stations which are sited in the public domain. This study estimates the level of maximum power density to which the populace living within 200 m radius of GSM base stations of different service providers in some parts of Lagos are exposed to. A total number of 200 masts randomly selected across 6 local Government Areas were considered for this study. Measurements were made at an interval of 20 m starting from the foot of each base station to 200 m at 1.5 m above the ground level, using a handheld TES-92 Electrosmog meter, in which the calibration factors provided by the manufacturer were used accordingly. The measured power density ranged between 2.4 μW/m^2 and 71530 μW/m^2. The mean value of the measured power density was 2113.96 μW/m^2. Result of the study shows that the maximum power density of 71530 μW/m^2 is by far less than the International Commission on Nonionizing Radiation Protection (ICNIRP) values of 4.5 W/m^2 and 9.0 W/m^2 for GSM 900 and GSM 1800 respectively. It is therefore concluded that RF emission from GSM base stations in the selected parts of Lagos State may pose no health risk to members of the public within this area.
Keywords: Radiofrequency emissions, Health hazards, Base stations

1. Introduction

The need to communicate with people far away has necessitated the development of various forms of technology in the field of telecommunications; consequently, there has been massive erection of telecommunication antennas in public places. The erection of GSM masts in public places including residential areas has however become a source of concern to the members of the public. This is due to the suspected health effects that have been attributed to the radiofrequency radiation emitted by the antennas.

Radiation is generally believed to be dangerous; this may be due to the level of health hazard which some forms of radiation poses. It would therefore be necessary that the concept of radiofrequency radiation is well understood. There have been reported cases of bio effects as a result of exposure to radiofrequency fields. Hutter *et al.* (2005), found a significant relation of some health symptoms to measured power density around GSM base stations. However, international agencies like the World Health Organization (WHO) are of the opinion that the level of RF radiation emitted by these base stations is too small to pose any health risk. Despite this fact, more environmental assessments of RF radiation exposure are needed for environmental monitoring.

2. Quantification of RF Exposure

The intensity (Power intensity) of radiofrequency radiation in the environment is measured in units such as W/cm^2 or W/m^2. However, the intensity provides little information on the biological consequence unless the amount of energy absorbed by the irradiated object is known (Lai, 1998). The physical quantity which is used to express the amount of energy absorbed by body tissues when exposed to radio frequency fields in the frequency range used by mobile phones is the specific absorption rate (SAR). Specific absorption rate is a measure of the rate at which energy is absorbed by the body when exposed to a radiofrequency (RF) electromagnetic field. It is expressed as the rate of energy absorbed per unit mass, and is measured in watts per kilogram (W/kg).
The specific absorption rate can be calculated from the electric field within the tissue as:

$$SAR = \frac{\sigma E^2}{\rho}$$

Where σ is the sample electrical conductivity, *E* is the RMS electric field strength and ρ is the mass density of the sample.

2.1 Possible Health effects associated with RF exposure

The hypothesis that radio frequency exposure might produce health damage has been analyzed mainly from several epidemiological studies (Navarro *et al.*, 2003). Although the energy absorbed by the human body from RF radiation is not sufficient to cause ionization, some researches however have suggested that the frequency of an RF radiation may be the determining factor of the biological response of exposure to RF radiation (Lai, 1998). To this end, the biological responses have been grouped as either thermal or non-thermal effects. The thermal effects are associated with exposures greater than 10 mW/m^2 while the non-thermal effects are associated with exposures less than 10 mW/m^2 (Cember, 1998).

Animal studies have shown that RF radiation, in frequencies ranging between 200 to 24000 MHz is lethal if the product of exposure intensity and time is sufficient enough to increase the body temperature beyond the body's homeostatic capabilities ($> \sim 5^o$ C). Insomnia, cancer, leukemia in children, and brain tumors are the clinical entities more frequently associated with RF exposure (Dolk *et al*., 1997).

Ayinmode and Farai (2012), in a comparative assay of some selected epidemiological studies on RF exposure found that common symptoms like headache, fatigue, irritability, sleep disorders and nausea can be associated with exposures ranging from 20 $\mu W/m^2$ to 13.2 W/m^2 at distances less than 350 m.

Moreover, the clinical consequence of being exposed to microwave radiation such as radar has been evaluated from military and occupational studies. A specific symtomatology, linked to radar exposure at low levels of RF has been termed "microwave sickness" or "RF syndrome" (Johnson, 1998) with few exceptions, functional disturbances of the central nervous system have been described as a kind of radiowave sickness, neurasthenic or asthenic syndrome.

2.2. Thermal and nonthermal effects of RF exposure

The biological effects that result from heating of tissue by RF energy are often referred to as "thermal" effects. Tissue damage in humans could occur during exposure to high RF levels because of the body's inability to cope with or dissipate the excessive heat that could be generated. Two areas of the body, the eyes and the testes, are particularly prone to RF heating because they are ischemic, that is, there is relative lack of available blood flow to dissipate the excessive heat load. Thermal effects depend upon the frequency of the energy, the power density of the RF field that strikes the body, and even on factors such as the polarization of the wave.

At relatively low levels of exposure to RF radiation, that is, levels lower than those that would produce significant heating; the evidence for harmful biological effects is ambiguous and unproven (Repacholi, 1998). Such effects have sometimes been referred to as "nonthermal" effects. There can be two meanings to the term "nonthermal" effect. It could mean that an effect occur under the condition of no apparent change in temperature in the exposed tissue, suggesting that the body maintains a constant temperature. The second meaning is that somehow RF radiation can cause biological effects without the involvement of heat energy (or temperature independent). This is sometimes referred to as 'athermal effect' (Lai, 1998).

3. Materials and Methods

3.1 Study area

This research work was carried out across six local government areas out of the 20 local government areas of Lagos state. The study covered some areas within Latitude N 6° 30' 59" to N 6° 38' 51" and Longitude E 3° 14' 11" to E 3° 23' 28". According to the 2006 population census, Lagos has a total population of 9,013,534. It covers an area of about 1292 Sq.mi (3345 Km^2) and with a population density of 6977/Sq.mi (2695/Km^2). The teledensity of Lagos State is high due to the communication demands by its large population; therefore, making the selected part of the state suitable for this research. A total of 200 base stations were surveyed in the study area.

3.2 Measurements

All the base stations surveyed had at least 3 antennas on them with each antenna covering a sector of 120^0. Thus, it was possible for measurement to be taken in any convenient direction within a particular sector. Measurements were taken at an interval of 20 m starting from the foot of each of the base station up to a distance of 200 m at 1.5 m above the ground level. The power density at each base station was measured with the aid of the TES-92 Electrosmog Meter (which can measure in the range of 50 MHz to 3.5 GHz) and the geographic coordinates of each base station was determined using the Etrex Vista Global Positioning System (GPS).

4. Results and Discussion

The results of measurements from locations where the maximum and minimum values were obtained are presented in Table 1 while the values of the average power densities and standard deviations at 20 m interval over all locations are presented in Table 2. Figure 1 shows a plot of the Average power density at 20 m interval for all locations.

Table 1. Power Densities at locations where maximum and minimum values were obtained.

Distance (m)	L_x (µW/m^2)	L_y (µW/m^2)
20.00	1199.00	4.30
40.00	1212.00	17.90
60.00	1478.00	6.70
80.00	26480.00	2.70
100.00	37580.00	2.40
120.00	67610.00	6.40
140.00	71530.00	12.80
160.00	48580.00	14.20
180.00	489.30	35.60
200.00	579.70	21.10

Table 2. Average power densities and Standard deviations at 20 m intervals over all locations.

Distance (m)	Average (µW/m^2)	Standard Deviation (µW/m^2)
20	1412.43	1460.73
40	1834.26	3510.24
60	1959.96	4093.70
80	2147.69	3868.02
100	2049.45	4333.08
120	2684.13	6699.39
140	2353.58	6476.88
160	2698.65	6777.78
180	1867.87	2841.49
200	2131.59	4692.05

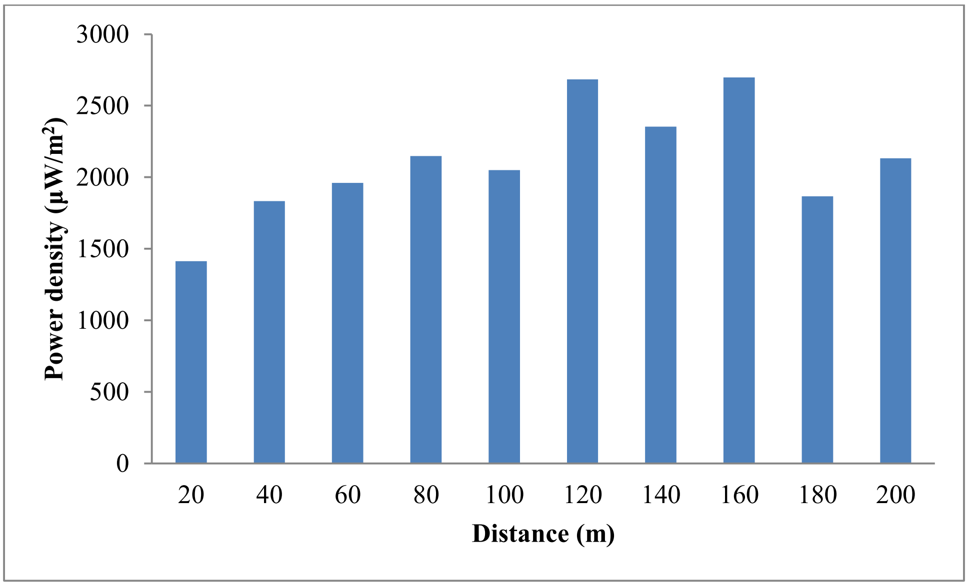

Figure 1. Average power density at 20 m interval for all locations.

The results obtained from this study as presented in Table 1 showed that the level of RF radiation which an individual can be exposed to ranges between 2.4 µW/m^2 to 71530 µW/m^2. In far field conditions, it is expected that the variation of the power density with distance obeys the inverse-square-law; the measured power densities however deviated from the inverse square law, this deviations may be due to interference from one of the nearby and distant masts.

For some of the intervals, it was observed that the values of the standard deviation greatly exceeded the average. This only indicates the level of spread of the measured values where very high values were obtained at some points.

5. Conclusion

Power densities around 200 GSM base stations across six Local Government areas of Lagos State were measured. A total number of 2,000 measurements were made, 10 samples for each base station. The maximum power density was found to be 71530 $\mu W/m^2$ and it was obtained at a distance of 140 m from one of the locations. The average power density over all locations was evaluated to be 2113.96 $\mu W/m^2$. The corresponding SAR value for the human brain in each case was found to be 0.02 W/Kg and 0.59 mW/Kg for the case of GSM 900; and 0.03 W/Kg and 0.89 mW/Kg for the case of GSM 1800.

The measured value of the maximum power density as well as its average value is by far less than the maximum level of 4.5 W/m^2 and 9.0 W/m^2 for GSM 900 and 1800 respectively as recommended by the ICNIRP. Thus, the level of RF radiation within a distance of 200 m from the foot of GSM base stations in the selected part of Lagos state may pose no health risk to the populace living within this interval to the base station.

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