IOSR Journal of Applied Physics (IOSR-JAP)
e-ISSN: 2278-4861.Volume 7, Issue 4 Ver. II (Jul. - Aug. 2015), PP 01-06
www.iosrjournals.org

Determination of Electromagnetic Pollution level from GSM antennas in Ado-Ekiti, Nigeria

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Abstract: *Despite the continuously increasing use of mobile phones and the consequent proliferation of GSM antenna masts, few studies on the health effects of the radiofrequency (RF) radiation from the antennas have been carried out in Nigeria and none in Ado-Ekiti, Nigeria. A baseline RF radiation assessment survey of thirty base stations was carried out in Ado-Ekiti to assess the level of radiofrequency pollution from their antennas. Power density measurements were undertaken using a calibrated Spectrum Analyzer. Exposure measurements at distances 50m, 100m, 150m and 200m from the foot of the base stations yield average values of* $0.31\,\mu W/m^2$, $3.87\,\mu W/m^2$, $6.91\,\mu W/m^2$ *and* $10.26\,\mu W/m^2$ *for GSM 900 and* $1.95\,\mu W/m^2$, $10.69\,\mu W/m^2$, $31.90\,\mu W/m^2$ *and* $22.83\,\mu W/m^2$ *for GSM 1800 respectively. The maximum specific energy absorption rate (SAR) obtained is* $8.966 \times 10^5\ W/Kg$. *The exposure to RF radiation due to GSM in Ado-Ekiti does not follow any specific trend with respect to distance from the base stations. This is attributable to the rocky terrain of the town. RF radiation level from GSM in Ado-Ekiti is generally below the International Commission on Non-Ionizing Radiation Protection (ICNIRP) safety limit for exposure.*

Keywords*: Radiofrequency, antenna, power density, SAR, GSM*

I. Introduction

The increase in natural radiation levels as a result of human activities is generally referred to as radiation pollution. Radiofrequency radiation level across the globe has increased since the advent of mobile telephony. Mobile phones are fast becoming increasingly important aspect of everyday life as members of the public not only rely on the devices for making calls alone, but the devices have now become a mini mobile office which can be deployed anywhere for sending and receiving electronic mails, writing reports, perform internet surfing among others.

In Nigeria, the most populous black nation in the world, there has been a phenomenal rise in mobile phone subscription. Between the advent of the GSM in Nigeria in 2001 and 2013, the number of fixed lines was put at around one hundred and seventeen million as reported by Babatunde et. al. [1]. About a billion subscription was estimated for India for the year 2013 [2]. This rapid growth in the number of subscribers has necessitated the increase of the erection of base station antennas, and consequently, increased level of radiofrequency electromagnetic radiation in the environment.

Electromagnetic radiation is broadly classified according to the frequency of its wave. This classification in order of frequency is referred to as the Electromagnetic Spectrum. In order of increasing frequency and decreasing wavelength, electromagnetic spectrum consists of radiowaves, microwaves, infrared, visible light, UV radiation, x-rays and gamma rays. Electromagnetic radiation mayalso be classified as ionizing and non-ionizing radiations considering the biological effect of the radiation. Ionizing radiation is that which has enough energy to remove electron from an atom such that the atom becomes an ionized atom whereas the non - ionizing radiation does not have the sufficient energy to ionize the atoms. The radiowaves, microwaves, infrared and visible light are all classified as non-ionizing radiation while the UV radiation, x-rays and gamma rays are classified as ionizing radiation.

The radio waves employed in mobile communications are also electromagnetic waves like visible light and X-ray and they also propagate in the same speed of light. The Global System for mobile communication (GSM) designated frequency bands of operation ranges between 400-1900MHz which is considered as part of the microwave range of the electromagnetic spectrum. This radiofrequency electromagnetic radiation has both electric and magnetic field components. In determining the strength of the radiofrequency field, the electric field intensity, also called electric field strength $\vec{E}$ of the electric field component may be measured or the magnetic field strength $\vec{H}$ of the magnetic field component. The unit of electric field strength is volts per metre (V/m) and the unit of magnetic field strength is amperes per metre (A/m). In the far field, the power density S, which is the rate of flow of energy per unit area normal to the direction of propagation, of the radiofrequency radiation field may be calculated using the relation:

$$S = \vec{E}\vec{H} = \frac{E^2}{377} = 377H^2 \qquad (1)$$

It is measured in watt per square meter (W/m^2). In free space, the ratio of the amplitudes of the electric field strength and magnetic field strength equals 377 ohm which is the characteristic impedance of free space [3], that is

$$\frac{E}{H} = 377\Omega \qquad (2)$$

Radiation survey meters are usually calibrated to read the far field power density corresponding to the measured electric field intensity. In the near field, both electric and magnetic fields must be measured [4].

When radiofrequency radiation passes through any biological medium, some of the energy from the radiation field is absorbed by the medium. The dosimetric quantity used to determine the absorbed energy from radiation field is the specific absorption rate (SAR). It is a measure of the time rate of energy absorption per unit mass and is usually expressed in units of watts per kilogram (W/kg). The SAR is expressed as:

$$SAR = \frac{\Delta E/t}{\Delta m}(W/Kg) \qquad (3)$$

In terms of electrical parameters, the SAR can be calculated using:

$$SAR = \frac{\sigma E^2}{\rho} \qquad (4)$$

where σ is the conductivity of the tissue, E is the rms electric field strength in the tissue, and ρ is the density of the tissue.

1.1 Biological Effects of Radiofrequency Radiation

The possible health effects due to exposure to electromagnetic radiations from the ever-increasing number of base-stations have been a source of concern to users of the GSM technology and to the general public. Health effects due to long term whole-body exposure to radiofrequency radiation from base station antennas have not been explained beyond reasonable doubt, and in most cases such studies are deficient of infallible evidence[3]. However, there have been many reports which suggest various biological effects even at low exposure levels - levels that can be thousand times below public safety limits.In an experiment to determine the effect of exposure from radiofrequency radiation from mobile phone on human pulse rate, an insignificant pulse rate change was observed[5]. Hutter et al. suggested individuals exposed to microwave frequency from GSM antenna mast showed symptoms such as headache and difficulty in concentration which is attributed to the radiation exposure[6]. On the possible carcinogenicity of radiofrequency radiation, it has been suggested that early case control studies is less informative since population considered had low cumulative exposure[7]. In general, it is difficult to come to a conclusion on the health effects of radiofrequency radiation from GSM antenna as most studies that have been conducted did not provide convincing proof linking exposure to adverse health effect.

II. Materials And Methods

2.1 The Study Area

The study was conducted in Ado-Ekiti which is the state capital of Ekiti state, located in the South-West geo-political zone of Nigeria. Ado- Ekiti is situated on latitude $7°37'16"N$ of the equator and longitude $5°13'17"E$ of the Greenwich Meridian. The people of Ado-Ekiti are mainly the of the Ekiti sub-ethnic group of Yoruba. The Ado-Ekiti township, for the purpose of this study, is divided into five (5) axes. The axes are as follows: (1) Ado-Ijan axis, (2) Ado-Ikere Axis, (3) Ado-Ilawe Axis, (4) Ado-Iyin axis, and (5) Ado-EKSU. The study site locations are shown in the Table 1. Sites S1 -S9 are within Ado -Ijan axis, sites S10 - S13 are within Ado -Ikere axis, sites S14 -S20 are within Ado - Ilawe axis, sites S21 -S25 are within Ado - Iyin axis and sites S26 - S30 are within Ado - EKSU axis.

Ado-Ekiti, Ekiti State, Nigeria being a hilly terrain, provides a bit of difficulty for broadcasting of radiofrequency. This may sometimes necessitate broadcasting at higher power so as to be able to reach a wider range of users. These factors therefore necessitate the assessment of the level of radiation pollution of Ado-Ekiti.

2.2 Measurement

Radiofrequency radiation measurements were conducted at 30 selected base stations within Ado-Ekiti with the use of a spectrum Analyser- SPECTRAN HF 60105 (AARONIA AG) with a calibrated omnilog 90200 antenna with frequency range 700MHz to 2.5GHz and a Global Positioning System (GPS) for geographical coordinate measurement. A line of site measurement was used throughout, taking the measurement at 50m, 100m,150m and 200m, by so doing, eight (8) measurements were taken at each base station site for both GSM 900 and GSM 1800.Spectral measurements were taken for GSM 900 and GSM 1800 bands. Frequencies bands for GSM were set on the analyzer as allocated by the Nigeria Communication Commission. The analyzer was mounted on a tripod stand of height 1.5m – this is about the height of the trunk of an average human.

2.3 Data Acquisition

The spectrum analyzer is connected to the PC with a pre-installed data acquisition software - Aaronia spectrum analyzer software. The spectrum analyzer has a limited memory for recording of data spectrum, thus, the data is recorded directly on the PC in the field. The data are later retrieved with the aid of the software for the purpose of analysis. Fig. 1 and Fig.2 show the set-up of the spectrum analyzer on field and a typical spectrum obtained from the software respectively.

Table 1 Features of Study Area (Location 1 - 30)

Site No.	Location	Coordinate	
		North	East
S1	ABUAD Mast 1	$7^o36'16''$	$5^o18'22''$
S2	ABUAD Mast 2	$7^o36'23''$	$5^o18'26''$
S3	Polytechnic Masts	$7^o35'48''$	$5^o17'34''$
S4	Aba Igbira	$7^o36'30''$	$5^o16'58''$
S5	Aba Oyinbo	$7^o36'37''$	$5^o15'44''$
S6	Nigerian Immigration	$7^o36'40''$	$5^o15'7''$
S7	Matthew (Olokuta Street)	$7^o36'44''$	$5^o13'32''$
S8	Matthew (Aiyegunle Street)	$7^o36'52''$	$5^o13'33''$
S9	St. Patrick School	$7^o36'59''$	$5^o13'36''$
S10	Ajebamidele	$7^o34'32''$	$5^o12'39''$
S11	Ologede	$7^o34'48''$	$5^o12'50''$
S12	Cocacola (Olujoda Street)	$7^o35'9''$	$5^o13'7''$
S13	Master Energy	$7^o35'10''$	$5^o13'2''$
S14	Falana Street	$7^o36'37''$	$5^o13'12''$
S15	Odo Ijigbo	$7^o36'26''$	$5^o13'22''$
S16	Isato-Oke	$7^o36'54''$	$5^o12'53''$
S17	Egbewa Street, Ilawe Road	$7^o37'12''$	$5^o12'7''$
S18	Falegan Street	$7^o37'4''$	$5^o12'7''$
S19	CAC Ilawe Road	$7^o36'59''$	$5^o11'29''$
S20	NTA	$7^o39'57''$	$5^o11'37''$
S21	Bank Road	$7^o37'42''$	$5^o12'34''$
S22	Basiri	$7^o39'37''$	$5^o12'22''$
S23	Basiri 2	$7^o39'6''$	$5^o12'19''$
S24	Safejo Street, Basiri	$7^o38'43''$	$5^o12'29''$
S25	Basiri 3	$7^o38'34''$	$5^o12'29''$
S26	Ayetoro	$7^o38'29''$	$5^o13'24''$
S27	Ore-Ofe Quarters	$7^o39'58''$	$5^o13'39''$
S28	Opopogbooro I	$7^o39'15''$	$5^o13'40''$
S29	Opopogbooro II	$7^o38'58''$	$5^o13'32''$
S30	Opopogbooro III	$7^o38'52''$	$5^o13'29''$

Figure 1 Set-up of the spectrum analyzer on field

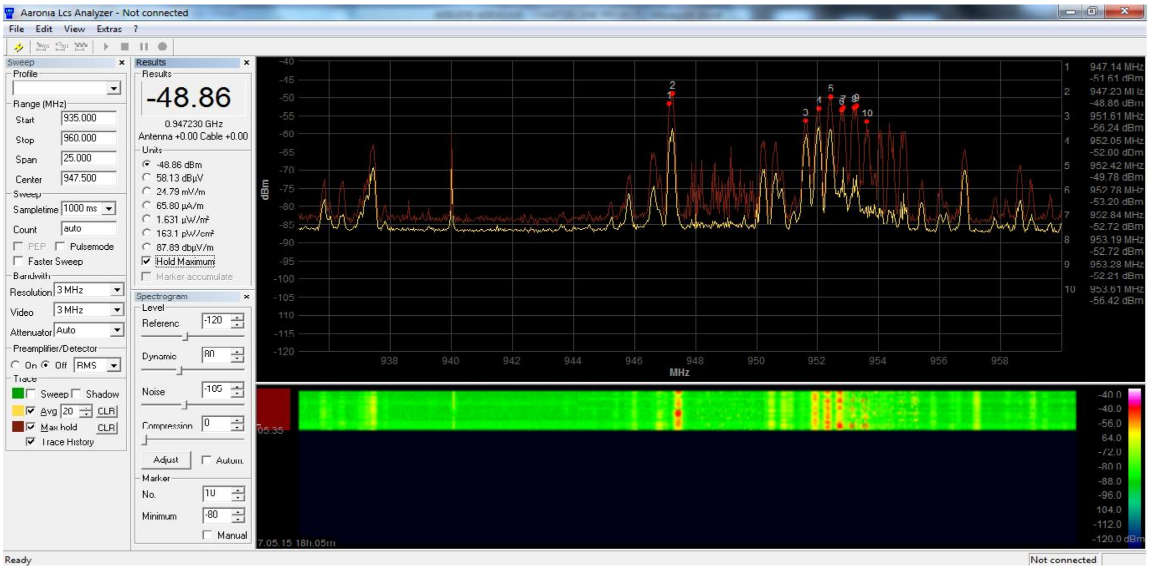

Figure 2A GSM 900 Spectrum of one of the sites

III. RESULTS AND DISCUSSION

Power density measurements were made at distances 50m, 100m, 150m and 200m. The exposure results are presented in microwatts per square meter $(\mu W/m^2)$ for GSM 900 and GSM 1800.

The exposure for GSM 900 ranges from $0.008\,\mu W/m^2$ to $101.00\,\mu W/m^2$ with the minimum and maximum values obtained at 100m from site S19 and 100m from site S15. The exposure for GSM 1800 ranges from $0.00\,\mu W/m^2$ to $511.80\,\mu W/m^2$ with minimum and maximum values obtained at 100m from site S6 and 150m of site S21 respectively.

The average values for the exposures in each site were calculated using the relation: $\boldsymbol{Average\ Exposure\ E_{avg} = (E_{50m} + E_{100m} + E_{150m} + E_{200m})/4}$. The results are presented in table 2 and figure 3. The average or mean exposures for GSM 900 ranges from $0.04\,\mu W/m^2$ to $67.34\,\mu W/m^2$ while that of GSM 1800 ranges from $0.05\,\mu W/m^2$ to $56.29\,\mu W/m^2$. Average exposure measurements at distances 50m, 100m, 150m and 200m from the foot of the base stations yield $0.31\,\mu W/m^2$, $3.87\,\mu W/m^2$, $6.91\,\mu W/m^2$and $10.26\,\mu W/m^2$ for GSM 900 and $1.95\,\mu W/m^2$, $10.69\,\mu W/m^2$, $31.90\,\mu W/m^2$and $22.83\,\mu W/m^2$ for GSM 1800 respectively.

In determining the absorbed energy by the brain, the specific absorption rate (SAR) was determined at 50m, 100m, 150m and 200m for GSM 900 and GSM 1800. The results obtained are presented in table 3.

3.1 Discussion

Radiofrequency radiation field obeys the inversely square law, that is, the strength of the field decreases with distance. Although, this law holds, many environmental conditions affect the distribution of radiofrequency field. Some of such factors include: distance to the antenna site; line of sight to the antenna site; type of antenna; number, power and orientation of antennas; capacity of antenna site; vertical distance between location and antenna site; type of building construction/type of window glass; total reflection of the environment among others.

Table 2 Mean Exposures $(\mu W/m^2)$ of GSM 900 and GSM 1800

Site No.	GSM 900 Mean Exposure $(\mu W/m^2)$	GSM 1800 Mean Exposure $(\mu W/m^2)$
S1	0.15	0.18
S2	6.54	6.65
S3	11.15	7.90
S4	0.64	0.48
S5	0.12	0.12
S6	0.24	0.25
S7	0.53	0.45
S8	0.36	0.36
S9	0.63	0.58
S10	0.18	0.16
S11	0.19	0.21
S12	38.96	27.35
S13	0.16	0.16
S14	0.15	0.15
S15	31.61	38.18
S16	48.54	36.86
S17	0.68	0.51
S18	0.59	0.79
S19	0.18	0.16
S20	0.19	0.20
S21	67.34	56.29
S22	0.12	0.14
S23	23.52	17.57
S24	0.38	0.40
S25	0.21	0.24
S26	0.11	0.13
S27	0.11	0.11
S28	0.04	0.05
S29	0.20	0.20
S30	0.19	0.20

Table 3 Specific Absorption Rate (SAR) at different distances from the Base Stations

	SPECIFIC ABSORPTION RATE $(\times 10^{-5}\,W/Kg)$	
Distance	GSM 900	GSM 1800
50m	0.087	0.549
100m	1.085	2.988
150m	1.942	8.966
200m	0.288	6.417

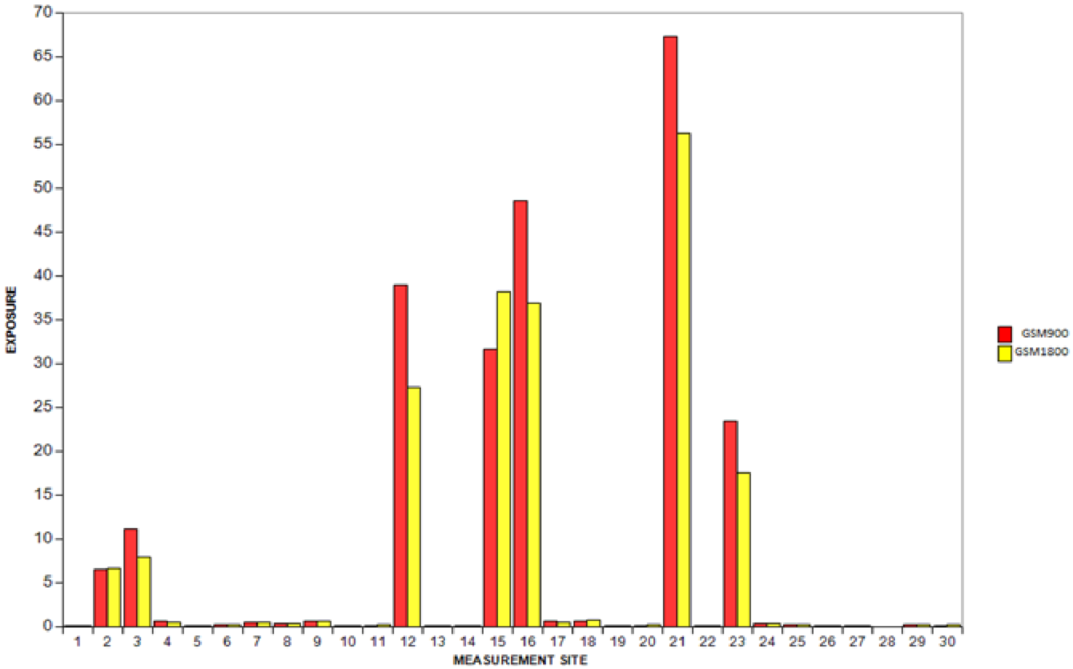

Figure 3 Mean Exposure $(\mu W/m^2)$ for GSM 900 and GSM 1800

IV. Conclusion And Recommendation

Power density measurements for GSM 900 and GSM 1800 were undertaken at thirty base stations sites within Ado-Ekiti township. Average exposure at each of the location was evaluated using the measurement values obtained at 50m, 100m, 150m and 200m for both GSM 900 and GSM 1800. It was observed generally, that the exposure values do not follow any specific trend, but varied from point to point depending on the environmental factor and broadcasting power of the base station antennas.

Further studies with respect to epidemiological studies from RF radiation from the GSM antennas is recommended to douse the tension of the general public with respect to the adverse health effect RF radiation.

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