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RESEARCH ARTICLE

PRELIMINARY INVESTIGATION OF RF EXPOSURE LEVELS FROM MOBILE TELEPHONE BASE STATIONS IN ABIA, SOUTH EAST NIGERIA

***Asiegbu, A. D. and Ogunlaja, O. O.**

Department of Physics, Micheal Okpara University of Agriculture, Umudike Abia State, Nigeria

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ABSTRACT

Health for all is one of the objectives of the millennium development goals. Our effort to secure a more enabling communication environment should not compromise the health of the people. This paper tries to obtain a clue to the health impact of radio frequency exposure to the general public. It therefore reports results of preliminary studies carried on radio frequency exposure level of electromagnetic energy originating from mobile telephone base station antennas in Aba, a city in south east Nigeria. Densitometric measurement of mainly CDMA 800 and GSM900 signals were performed at distances of over 10 to 100m from 8 base stations. The exposure levels obtained from these base stations were found to be well below the general public exposure limits recommended by ICNIRP. The highest recorded level from a single base station was $2.20\text{x}10^{-6}/\text{Wm}^{-2}$ which corresponds to $4.9\text{x}10^{-5}$ % of the general public exposure limit.

INTRODUCTION

Aba is a city in Abia state, southeast Nigeria, found within latitudes 5^0 26' and 5^0 43^lN and within longitudes 7^0 2^l and 7^0 35^lE (Ministry of Lands and Survey, 1999). As the industrial and commercial nerve center of Abia state, Aba is a beehive of voluminous activities of multiferous and multifaceted human enterprises most of which depend on the use of telecom facilities. Within its dense population, Aba houses a sizable number of foreigners who live and earn their living in the city. A host of others pay regular visits to the city due to their business and industrial appendages to it.

***Corresponding author:** Danasiegbu@yahoo.com

Rapid and indiscriminate siting of telecommunication masts and antennas close to residential and official quarters is beginning to raise fears in the minds of the people. Of particular concern is the possible health effects from exposure to radiofrequency electromagnetic energy (RF EME) radiating from mobile telephone base station antennas. Radio waves transmitted could be harmful to health (Mann *et al.,* 2000). This is because mobile telecommunications use electromagnetic waves in the microwave range. Lack of public information, the rapidity of base station deployment to meet increasing consumer demands and the lack of clear internationally accredited procedures for granting permits for installation of radio antennas have contributed to public concern that the perceived increase in exposure to radio frequency electromagnetic fields could be harmful to health (Charles and Micallef, 2006).

EXPOSURE SCENARIO

The exposure scenario comprises individuals of all ages and varying health status- the elderly, children, infants and people with disease conditions or under such therapy that may compromise thermal tolerance. Members of the public are not aware of their exposure to RF radiation and cannot possibly be expected to take precautions to avoid or minimize exposure (Charles and Micallef, 2006).

At the time of this study there is no systematic experimental study in Aba to ascertain the level of RF exposure of the general public. There is no reference data of measured power density of RF radiation from base station antennas in all of south east Nigeria. There is also no precautionary and environmental guideline in the location of base stations known to us. However the international reference standard for occupational and public exposure in terms unperturbed rms electromagnetic power density and applicable reference levels for RF radiation exposure are known.

The reference levels of exposure to electromagnetic fields (unperturbed rms value) for the general public as reported by the international commission on non-ionizing radiation protection, (ICNRP, 1998; Ericson, 2004) is shown in Table 1(a). Here the range of frequencies f, is as indicated in the frequency column. Applicable reference levels by ICNIRP according to Ericsson (2004) is shown in Table 1(b), while the applicable Italian law reference exposure level to RF radiation for the general public according to Paolo (2006) is shown in Table 1(c). Table 1(a-c) give the impression that there should be a limit to radiofrequency exposure. Tables 1(a - b) show that for GSM900 and CDMA800, applicable reference levels for the power density exposure to the general public

Table 1(a). Reference levels for exposure to EM fields (unperturbed RMS value)

Frequency Range	Electric Field Strength(E)	Magnetic Field Strength (H)	Magnetic Flux Density (B)	Equivalent Plane Wave Power Density
400 – 2000MHz	V/m	A/m	µT	W/m^2
Occupational	$3\ f^{1/2}$	$0.008\ f^{1/2}$	$0.01\ f^{1/2}$	f/40
Public	$1.375f^{1/2}$	$0.0037\ f^{1/2}$	$0.0046\ f^{1/2}$	f/200

Source: ICNIRP (1998); f=frequency

Table 1(b). Applicable ICNIRP reference levels to radio frequency radiation exposure for general public

Frequency (MHz)	Power Density(W/m^2)	Electric field Strength (V/m)	Magnetic Field Strength (A/m)
900.00	4.50	41.00	0.11
1800.00	9.00	58.00	0.15
> 2000.00	10.00	61.00	0.16

Source: Ericsson (2004)

Table 1(c). Applicable Italian law reference exposure level to Rf radiation for general public

Frequency Range	Power Density (W/m^2)	Electric field Strength (V/m)	Magnetic Field Strength (A/m)
100KHz – 3MHz	-	60.00	0.20
3MHz – 3GHz	1.00	20.00	0.05
3GHz – 300GHz	4.00	40.00	0.10

Source: Paolo (2006)

should not exceed 4.50 and 4.00Wm^{-2} respectively. Also Table 1(c) shows that for microwaves of up to 300GHz the power exposure limit should be 4.00Wm^{-2}.

THEORETICAL BACKGROUND

According to Mann *et al.* (2000), the radio link from the phone to the base station is known as the uplink and carries the speech from the mobile phone user. A separate radio link carries the speech from the person to whom the phone user is listening. Base station is the electric equipment contained in the plant room which is linked to antennas through cables. The antennas are mounted on masts or other suitable structures. Today it has become a common practice to describe the complete installation, including antennas and masts as the base station. Base stations contain a number of transmitters with each having the same maximum output power, P_{tx}. Outputs from individual transmitters are combined and fed to the antenna. Thus total output power fed into base station antenna is given by:

$$P_{out} = NP_{tx}10^{-L/10} \quad (1)$$

Where N is the number of transmitters and L, the loss in signal strength (dB)

Power fed into base station antenna is launched into radio waves traveling away from the tower with its strength decaying with distance according to inverse –square-law. The power density S in the beam thus varies with distance, d according to the expression.

$$S = NP_{tx} \cdot 10^{(G - L)/10}/4\pi d^2 \text{ ----------------------(2)}$$

where G, the antenna gain (db) is a measure of how much the antenna is able to focus the radiated power in the direction of the beam. Equation (2) is valid for distances greater than 10m only. Distances less, will over estimate the power density (Mann *et al.*, 2000). Depending on the type of service and source, power radiated by transmitting antennas range from about 1.0W or 0dBW (as in portable transmitter) to over 100kW or 50 dBW (as in radars and VLF transmitters). The maximum power density in the near field region realizable for reflecting antennas such as parabolic dishes can be expressed as:

$$S= 4P_a/A \quad (3)$$

Where P_a, is the power into the antenna and A, the aperture area. In the far field region, the power density on the antenna axis can be determined from the expression.

$$S = P_aG/4\pi d^2 \quad (4)$$

Where d is the distance from the antenna and G is antenna directive gain. However, antenna gain is related to the antenna dimension by the expression.

$$G= 4\pi A_e/\lambda^2 \quad (5)$$

Where λ is the wavelength and A_e is the effective area of the antenna. Also A_e =pA, where p is antenna efficiency and A , the physical surface area of the antenna.

The free space electric field strength (rms value) at a distance r from a source with effective radiating power P_e on the antenna axis is given by:

$$E = \frac{\sqrt{30Pe}}{r} \quad (6)$$

The beams formed by antennas used with microcellular base stations are narrow in the plane of elevation with typical widths between 5^0 and 10^0. The beams also are tilted slightly downwards so the edge of the main beam is approximately horizontal while the lower edge is directed about 10^0 below horizontal as in Fig 1. Considering the heights at which antennas are mounted (15-50m), it is expected that main beam from base station antenna s would then be of a mast. The major exposure would then be expected within this range of distance from a mast. However, antennas used with microcellular base stations have much broader beams in the plane of elevation because they are intended to communicate over much shorter distances (Mann *et al.*, 2000). In Fig. 1, *a* is the antenna on a base station mast while b is the beam radiated from it. Possible angle of the beam inclination to the horizontal is as indicated (5^0-10^0).

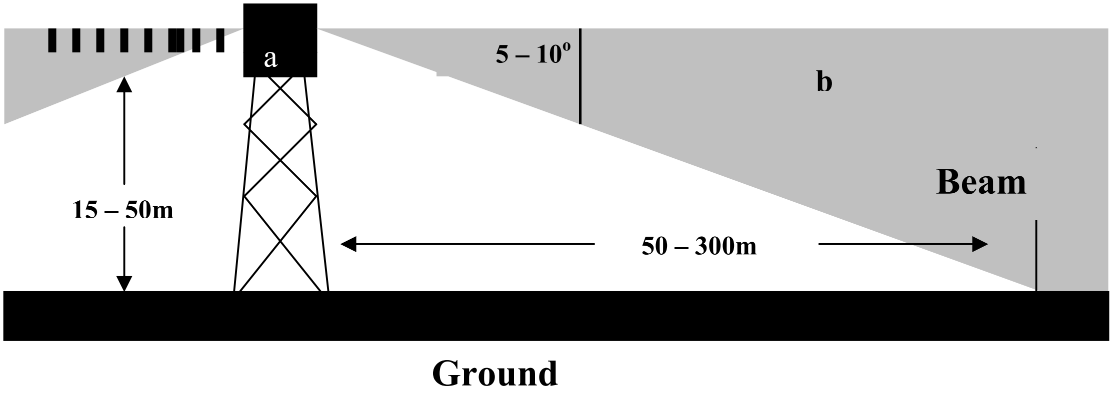

Fig. 1. A typical Base Station and its beam pattern

Densitometry of telecom devices depend on distance from the source. We have near and far-field densitometry. At the near field, emitted waves do not possess full wave characteristics, while electric and magnetic fields are relevant in the near-field, power density is more relevant in the far-field (Simunic, 2000; 2006). Following the coupling mechanism established for electromagnetic fields and the human body, the following quantities have been identified as being biologically effective:

*Induced current density, measured in amperes per square meter for internally induced electric currents by external magnetic fields (Paolo, 2006). This is used in the quantifications of experimentally induced effects.

*Specific absorptions rate (SAR) defined as the time derivative of the incremental energy absorbed or dissipated in an incremental mass contained in a volume element of a given density (Simunic, 2000; 2006).

This is measured in Watts per kilogramme and expressed as:

$$SAR=0\varepsilon^2/\rho \quad SAR=\varepsilon^2/\rho \qquad .... (7)$$

Where ε is the rms value of the electric field strength in the tissue in (V/m). o conductivity of body tissue in S/m and ρ in the density of body tissue in kg/m^3.

*Power density, measured in watts per square (W/m^2) for energy absorption localized at or near the body surface. This is the appropriate dosimetric quantity at frequencies between 10 and 300 GHZ (Paolo, 2006). It characterizes the external emf and can be experimentally measured or determined from measured electric or magnetic field strength.

MATERIALS AND METHODS

Materials used for this study include a standard Field Strength meter (ALRF 05) manufactured by Tomsgadget, United Kingdom with accuracy of ±20%, measuring tapes and height leveling platforms. Since it is not possible to measure the induced fields inside the human body directly under the exposure conditions, a densitometric approach rather than dosimetric was adopted for this study. This method is similar to that used by Henderson and Bangay (2006) and enables the exposure to electromagnetic field to be measured without the actual presence of a human body. It is based on correlating measured values with reference levels which are determined from the condition of maximum coupling of the electromagnetic field to the exposed individual (Simunic, 2000; 2006)

RESULTS AND DISCUSSION

Various sites measured include CDMA 800 and GSM 900 base stations. However measured power density received depends on the power of the transmitter at the mast. Measured power levels at each nominal distance were expressed as a fraction of the ICNIRP standard of exposure and plotted against distance in Fig. 2(a). This shows the

Table 2. Measured radiation S (μWm^{-2}) with respect to distance.

Distance(m)	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
10.00	0.12	0.19	0.14	0.01	0.07	0.08	0.10	0.14
20.00	0.15	0.17	0.17	0.02	0.14	0.11	0.28	0.10
30.00	0.06	0.18	0.14	0.03	0.12	0.09	0.15	0.40
40.00	0.25	0.15	0.08	0.03	0.01	0.05	0.79	0.06
50.00	1.74	0.14	0.07	0.05	0.10	0.10	0.10	0.08
60.00	1.25	0.11	0.06	0.05	0.13	0.09	0.06	0.08
70.00	1.40	0.14	0.05	0.05	0.08	0.11	0.10	0.10
80.00	0.57	0.16	0.08	0.04	0.07	0.10	0.10	0.10
90.00	2.00	0.06	0.04	0.05	0.01	0.07	0.05	0.04
100.00	2.20	0.08	0.07	0.04	0.02	0.04	0.04	0.03

Table 3. Mean of power density S (measured per distance)

Site	Mean S/m (mWm^{-2})
S_1	0.974
S_2	0.138
S_3	0.090
S_4	0.037
S_5	0.075
S_6	0.084
S_7	0.177
S_8	0.113

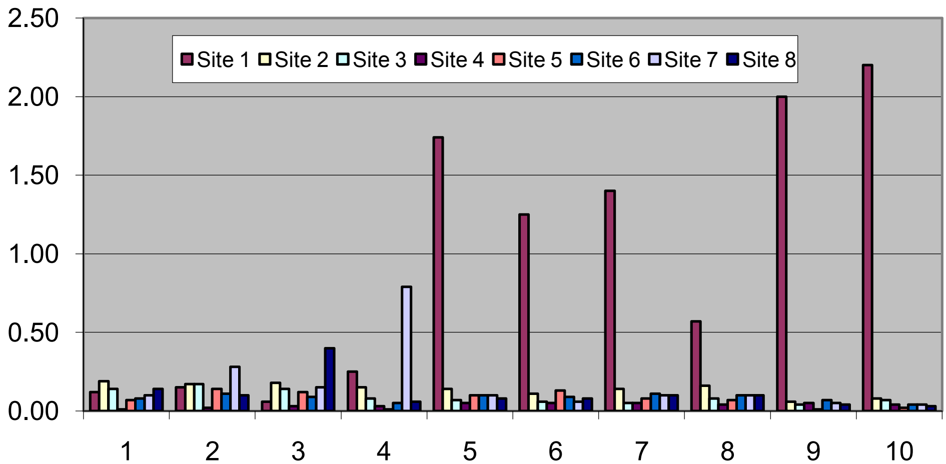

Fig. 2 (a). Graph of fraction of standard power density against distance from tower.

variation in the power density emission from different base stations. Sites 2 and 4 are CDMA 800 while the rest are GSM 900 sites. Fig 2(b) is a graphical presentation of fraction of standard (of mean value of total power density obtained per site) against each site. When compared with ICNIRP standard reference level of Table 1(b) and the applicable Italian law reference exposure standards of Table 1(c), we observe that the highest average power density recorded per distance for the

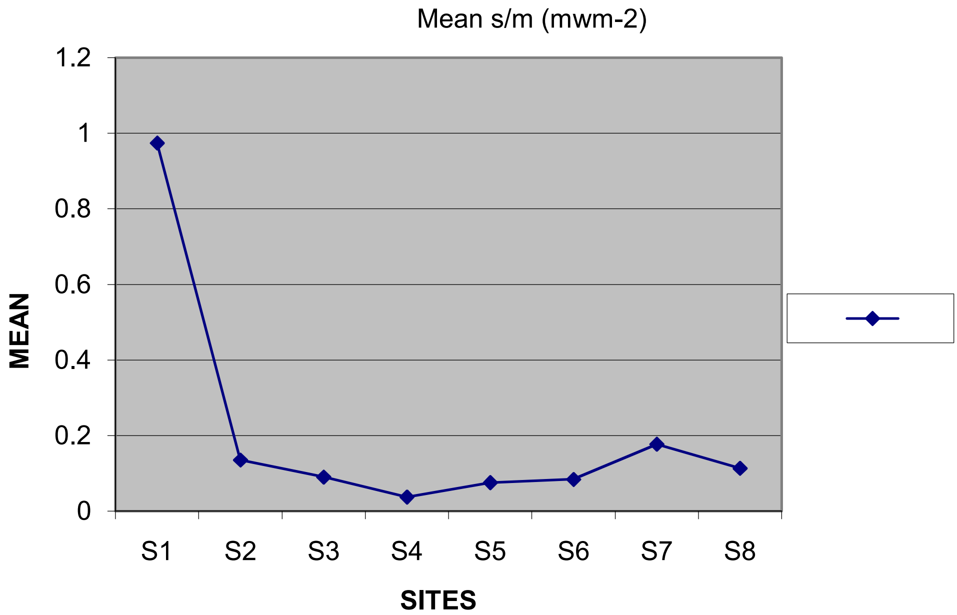

Fig. 2(b). Graph of fraction of standard mean power density obtained per site.

sites was about 1.0 mWm^{-2} which is lower than the 4.5Wm^{-2} reference of ICNIRP for GSM and CDMA range of frequencies.

CONCLUSION

Preliminary investigation of RF exposure levels from mobile telephone stations in Aba, south east Nigeria has been done. Average density of exposure to the general public within 100m range from the masts is 0.211 mWm^{-2}.

This is quite low compared with the ICNIRP reference standard of 4.5 Wm^{-2} for GSM and CDMA range of frequencies. Studies therefore reveal that the exposure scenario in the city is quite safe for now. However, telecommunication networks are dynamic systems which develop and grow daily, efforts should therefore be made to control and regulate indiscriminate siting of masts to save the city and indeed the entire nation from hitting the crisis period in future.

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