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Hazard estimation from Radiofrequency Radiation in a Nigerian Teaching Hospital from nearby GSM Base-Stations

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Abstract: *Increasing competition between GSM service providers and several calls for improvement of their quality of service from members of the public has led to proliferation of base station (BTS) masts in Nigeria. Consequently, there is an increase in the risk of radiation hazard due to exposure of the public to radiofrequency radiation from the BTS antennae. This study is aimed at estimating the radiation hazard due to electric field intensity from BTSs.Electric field intensity measurements due to different GSM Operators were taken at thirty sites in the 900MHz and 1800MHz frequency bands. The maximum instantaneous electricfield intensities of* $301.05 \pm 63.85 mV/m$ *and* $241.49 \pm 57.00 mV/m$ *were obtained for GSM900 and GSM1800 respectively. Estimation of the specific energy absorption rate (SAR) yield* $39.00 \mu W/kg$ *and* $34.80 \mu W/kg$ *for the skin, while that of the brain yield* $33.90 \mu W/kg$ *and* $32.70 \mu W/kg$ *for GSM 900 and GSM 1800 respectively. The skin penetration depth for the worst case of exposure was obtained as* $4.16 cm$*. Exposures in the study area are below the ICNIRP reference level.*

Keywords: *GSM, BTS, radiofrequency, SAR, Penetration depth*

I. Introduction

Performance evaluation of GSM operators in Nigeria have suggested the need for operators to build more base transceiver stations in order to increase their network coverage[1]. This development has necessitated the proliferation of the erection of base station antennas, and consequently, increased level of electromagnetic fields in the environment. The possible health effects of electromagnetic radiations have for some time now been a popular subject of interest. This is attributable to the fact that if there is any detectable detrimental effect, no matter how small, it could be very important due to the widespread use of mobile phones, the monumental numbers of people exposed to radiofrequency radiation on a daily basis, and the social, economic and health impacts this could have[2].

When electromagnetic radiations (EMRs) in the microwave region pass through a medium, they lose energy to the medium. The intensity of the electromagnetic field decreases exponentially with respect to the depth of the absorbing medium[3]. The effectiveness of absorbers for EMRs such as the human skin is determined by the depth of penetration of the radiation in the material. The penetration depth δ is the depth within the absorber at which the energy of the incident radiation decreases to one tenth of its incident value[4]. It is given as the inverse of the absorption coefficient α. That is:

$$\delta = \frac{1}{\alpha} \ldots \qquad (1)$$

such that

$$\alpha = \omega \sqrt{\frac{\mu\epsilon}{2}} \left[\left\{ 1 + \left(\frac{\sigma}{\omega\epsilon} \right)^2 \right\}^{1/2} - 1 \right]^{1/2} \ldots \qquad (2)$$

where$\omega = 2\pi f$ is the angular frequency, σ is the conductivity of the absorbent, ϵ and μ are permittivity and permeability of the absorbent respectively.

Various health effects have been associated with electromagnetic radiations. Several researches have chiefly identified the thermal effects of the EMR [4,5]. Although several studies have suggested a link between electromagnetic radiation and increased risk of health deficiencies such Leukaemia, testicular cancer, cancer of eye, etc., but collectively, no convincing evidence have been provided[6,7]. Many other reports have it that exposure of organisms to radiofrequency radiations do not have any significant effect on some major biological indices[8,9] while others observed some cellular alterations in exposed organisms but suggested need for further investigation[10].

Restrictions on exposure to time varying electromagnetic fields are set based on established health effects[7]. The physical quantities used in setting such restrictions are frequency dependent and include current density (J), specific energy absorption rate (SAR) and power density (S). For spatial exposure to the electromagnetic field in the far field of a radiating antenna, the power density, which is the rate of energy flow per unit area of space and measured in Watts per square meters, can readily be measured since the relationship between the electric and magnetic fields are known.

Radiation survey meters are usually calibrated to read the far field power density corresponding to the measured electric field intensity[11]. This relationship is given as:

$$S = \frac{|E|^2}{\eta} = \eta|H|^2 \ldots \qquad (3)$$

where E and H are the root mean square values of the electric and magnetic field strengths respectively and η is the wave impedance which is 377 Ohm in free space[12]. Table 1 presents the ICNIRP reference levels for general public exposure to time varying electromagnetic fields.

Table 1: ICNIRP reference levels for general public exposure to time varying electric and magnetic fields

Frequency (MHz)	Electric Field Strength (V/m)	Magnetic Field Strength (A/m)	Equivalent Power Density (W/m^2)
400-2000	$1.375\sqrt{f}$	$0.0037\sqrt{f}$	$f/200$
2000-3000	61	0.16	10

Animportant physical quantity used in setting restrictions on exposure to time varying electromagnetic fields is the specific energy absorption rate (SAR) expressed in watts per kilogram (W/Kg). The SAR is an important dosimetric quantity for non-ionizing radiations. It is the time derivative of dissipated energy per unit mass of an exposed body or the absorbed power per unit mass of tissue. It is usually averaged over the whole body or over a tissue mass of 1g or 10g. It is expressed mathematically as:

$$SAR = \frac{d}{dt}\left(\frac{dW}{dm}\right) = \frac{d}{dt}\left(\frac{dW}{\rho dV}\right) \ldots (4).$$

In terms of the electrical parameters, the SAR can be calculated by

$$SAR = \frac{\sigma}{2\rho}|E|^2 \ldots \qquad (5)$$

whereE is the amplitude of electric field (v/m), σ is the conductivity (s/m), and ρ is the mass density of the tissue. The electrical properties of a biological material vary with absorbed electromagnetic radiation frequency. Dielectric properties of skin and brain tissues are presented in Table 2.

Table 2: The relative permittivity, conductivity and mass density used at 900 and 1800MHz [13]

Properties of Tissue		Relative Permittivity ε_r	Conductivity σ (S/m)	Mass Density ρ (kg/m^3)
Skin	900MHz	43.8	0.86	1000
	1800MHz	38.87	1.19	1000
Brain	900MHz	45.8	0.77	1030
	1800MHz	43.5	1.15	1030

Several methods have been developed to guide against direct exposure of human beings to electromagnetic radiations which includes the development of phantom models fabricated with various tissue geometries and specially developed tissue equivalent materials and fitted measurement probes[14,15]. Another method used in the determination of SAR which has gained prominence over the years is the finite-difference time-domain (FDTF) method[16,17,18]. Many electromagnetic field simulators have been developed based on the FDTD method to investigate the interaction between human head models and incident plane wave source[19].

II. Materials And Methods

1. The Study Area

The study area is a hospital located in Ibadan, Nigeria, then the largest city in West Africa. It is located on coordinates $7^o24'07''$ Nand $03^o54'04''$ E. Measurements were taken in a representative manner at the study area to include clinical areas, residential areas, business areas and academic areas. The study area was chosen for this study more particularly to provide a baseline data for radiofrequency exposure in the study area. Although radiofrequency interference (RFI) has been observed in some medical device in close proximity with cell phone [20,21], a look at the level of radiofrequency field emanating from base stations and estimation of its potential hazard may also be useful for future studies.

2. Measurement

Electric field strengths were monitored via a spectrum analyzer for GSM radiofrequency radiation. The spectrum analyzer was used with an omni directional antenna which has the capacity for radial isotropic measurements between 700MHz to 2.5GHz. Measurements were taken for all GSM Operators in the study area taking into consideration the allocated frequency band by the Nigerian Communications Commission (NCC).There are five operators each in the 900 MHz and 1800 MHz frequency band. For the purpose of this study, the five operators in each band are coded (Op 1 to Op 5) as presented in the NCC frequency spectrum allocation in Table 3.

Table 3: NCC Frequency Spectrum Allocation

900 MHZ					
Operator	Etisalat	MTel	Glo	MTN	Zain
Transmitting	(Op 1)	(Op 2)	(Op 3)	(Op 4)	(Op 5)
Frequency	935-940	940-945	945-950	950-955	955-960
1800MHZ					
Operator	MTel	Glo	MTN	Zain	Etisalat
Transmitting	(Op 1)	(Op 2)	(Op 3)	(Op 4)	(Op 5)
Frequency	1805-1820	1820-1835	1835-1850	1850-1865	1865-1880

The field strength measurements were averaged over a six minute period in compliance with the ICNIRP reference level [7].

III. Results And Discussion

Measurement of GSM 900 and GSM 1800 field strengths took place within the premises of a teaching hospital in Ibadan, Nigeria. The maximum electric field strength values of 900 MHz Spectrum allocation and their distributions in thirty measurement sites for the five Operators within the spectrum are shown in Fig. 1.

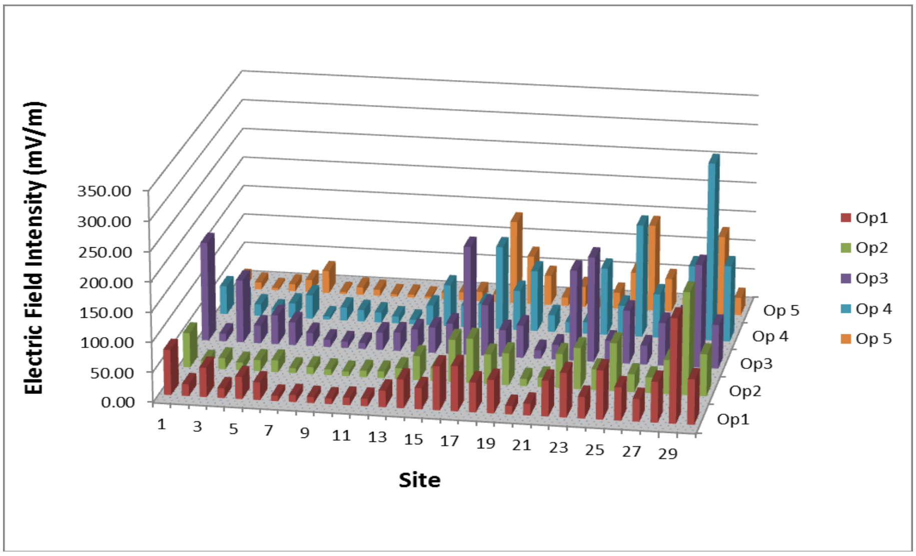

Figure 1: Electric Field strengths for Operators in the 900MHz Spectrum

In the 900 MHz spectrum allocation, Operator 4 radiates the most with maximum exposure of 301.05 mV/m and a mean exposure of 61.06mV/m while Operator 5 radiates the least with a maximum exposure of 146.91mV/m and a mean exposure of 33.95mV/m. Table 4 summarized the exposure levels in the 900 MHz spectrum allocation.

Variations in the radiofrequency fields are attributable to reflection, refraction and diffraction of electromagnetic radiation to a large number of scatterers and absorbing objects around the measurement site such as buildings, trees, vehicles etc. Buildings provide a strong shadowing effect to electromagnetic fields [22, 23].

Table 4: Exposure results obtained for 900MHz Spectrum allocation

	900 MHz				
Operator	**Minimum Exposure** (mV/m)	**Mean Exposure** (mV/m)	**Maximum Exposure** (mV/m)	**Standard Deviation** (mV/m)	**Percentage of Max Exposure to ICNIRP Reference Level**
Op 1	9.12	45.18	174.19	33.82	0.42%
Op 2	7.77	38.66	172.35	34.08	0.42%
Op 3	10.09	65.10	183.25	53.26	0.44%
Op 4	5.49	61.06	301.05	63.85	0.73%
Op 5	1.94	33.95	146.91	40.33	0.36%

Generally, Operators in the 1800MHz spectrum has lesser exposure compared to operators in the 900 MHz spectrum with the maximum exposure of 241.97mV/mand a mean exposure of 56.01mV/m obtained for operator 3 as shown in table 5. Figure 2 presents the exposures due to the five operators in the 1800MHz spectrum allocation. Operators 4 and 5 have the least exposure with average exposures of 32.49mV/m and 25.76mV/m respectively. At some measurement sites, the exposures due to these two operators were almost at the noise floor of the spectrum.

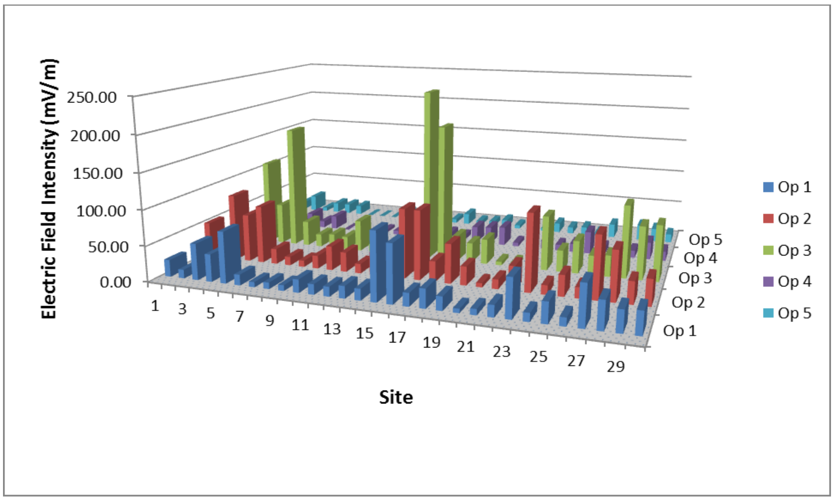

Figure 2: Electric Field Intensity by 5 Operators in the 1800MHz Spectrum

Overall assessment of the exposures in the 900MHz and 1800MHz spectrum allocation show that the power densities are much less than the ICNIRP reference level as shown in table 3 and table 4.

Table 5: Exposures results obtained for 1800MHz Spectrum allocation

	1800 MHz				
Operator	**Minimum Exposure** (mV/m)	**Mean Exposure** (mV/m)	**Maximum Exposure** (mV/m)	**Standard Deviation** (mV/m)	**Percentage of Max Exposure to ICNIRP Reference Level**
Op 1	5.82	28.40	94.98	22.84	0.16%
Op 2	5.82	41.73	107.97	30.81	0.19%
Op 3	5.14	56.01	241.97	57.00	0.41%
Op 4	0.00	12.15	32.49	8.32	0.06%
Op 5	0.00	10.99	25.76	8.32	0.04%

The estimated SARs due to each operator using the parameters for the skin and brain provided in table 2 are presented in table 6. Estimated SAR for the skin ranges from 0.63μW/kgto 39.00μW/kg, while the estimated SAR for the brain ranges from 0.59μW/kg to 33.90μW/kg.

Table 6: Estimated SAR to the skin and brain

		Estimated SAR $(\times 10^{-6}\mathrm{W/kg})$				
		Op 1	Op 2	Op 3	Op 4	Op 5
Skin	900 MHz	13.00	12.80	14.40	39.00	9.20
	1800 MHz	5.37	6.94	34.80	0.63	0.39
Brain	900 MHz	11.30	11.10	12.60	33.90	8.07
	1800 MHz	5.04	6.51	32.70	0.59	0.37

Using equations (1) and (2), the absorption coefficient and penetration depth in skin and brain tissues were obtained. These results are presented in table 7 for frequencies 900MHz and 1800MHz.

Table 7: Absorption Coefficients and penetration depth in Skin and Brain tissues

	Frequency	Absorption coefficient α (cm^{-1})	Penetration depth δ (cm)
Skin	900MHz	0.24	4.16
	1800 MHz	0.36	2.81
Brain	900MHz	0.21	4.72
	1800MHz	0.33	3.07

IV. Conclusion

The level of radiofrequency radiation in the measurement sites were found to be far below the ICNIRP reference level. The maximum instantaneous electric field intensities of 301.05 ± 63.85mV/m and 241.49 ± 57.00mV/m were obtained for GSM900 and GSM1800 respectively. Estimation of the specific energy absorption rate (SAR) yield 39.00μW/kg and 34.80μW/kg for the skin, while that of the brain yield 33.90μW/kg and 32.70μW/kg for GSM 900 and GSM 1800 respectively. The skin penetration depth for the worst case of exposure was obtained as 4.16cm. Exposures in the study area are below the ICNIRP reference level.

The study showed that worst case exposures in the 900MHz and 1800MHz spectraare 0.73% and 0.41% of the ICNIRP reference level respectively. Irrespective of the levels of radiofrequency radiation, there have been several reports on the biological effects of radiofrequency radiation. This calls for the need for protection against excessive exposure electromagnetic radiations.

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