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Measurement of radio frequency radiation (RFR) power levels from some GSM base stations and phones

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Abstract

With the upsurge in the number of network providers and the attendant increase in the installation of mast in Nigeria, the environment is being inundated with radiofrequency radiation (RFR). There is, therefore, increasing concern about the health implications of this development. In this study measurements of RFR output power densities were made in the mornings and afternoons at distances of 5 m, 15 m and 25 m respectively away from four selected mobile phone base stations belonging to MTN, Globacom, Zain and mast hosting Starcomms and Zoom network with all transmitting at a frequency of 1800 MHz. Using this as the baseline of study, measurements were again made in the afternoons at near-field zone of 15 m and far-field zone of 100 m away from the base stations. The RFR output power densities of mobile phones of different types were also measured while making or receiving calls with them.

The results obtained show that the lowest and highest RFR output power densities from the base stations were 0.139 ± 0.004 mW/m^2 and 2.300 ± 0.091 mw/m^2. RFR output power densities from mobile phones while making or receiving calls with them, ranged between 0.648 ± 0.013 mw/m^2 and 18.278 ± 1.031 mw/m^2. Comparing these values of RFR output power densities with that of the International Commission on Non- Ionizing Radiation Protection (ICNIRP) safety limit for exposure which is 9.0 w/m^2 shows that the RFR output power densities obtained in this study are relatively low and considered safe for the public.

Keywords: Radiofrequency radiation, power density levels, base stations, mobile phones.

1.0 INTRODUCTION

The proliferation of devices emitting RFR has elicited much public debate and scientific studies. Some familiar devices in this regard include mobile telephones, mobile phone base stations and their antennas. As cell phones usage becomes more common around the world, so do concern about their effect on human health. The concern exists because the antennas of these phones deliver much of their RFR energy to very small volume of the user body which is due to either the forces exerted on the molecules and ions or as a result of changing their energy states [19] and [22]. Significant exposure to RFR could be detrimental to health due to interactions with biological tissues [4] and [23]. The interactions may be described in several different ways depending on the area of interest and conditions [27].

Application of Linear Response Theory (LRT) shows that RFR may be absorbed at natural biotissues resonant freq`uencies. Performing some vector algebra and integrating over the volume, using the Poynting theorem for power flow in and out of a given volume lead to the relation:

$$\int_s \left(\vec{E}\ x\ \vec{H}\right).\, d\vec{s} = \frac{-\partial}{\partial t}\int_v \left(\frac{1}{2}\varepsilon_0 \vec{E}^{\,2} + \frac{1}{2}\mu_0 \vec{H}^{\,2}\right)\vec{d}v \qquad (1.1)$$

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where $d\vec{s}$ is the element of surface enclosing the volume $\vec{V}$, $\vec{E}$ *and* $\vec{H}$ are electric and magnetic field strengths respectively, ε_0, *and* μ_0 are the dielectric constant and magnetic permeability in free space. This treatment allows separation of power dissipated by the flow of free charges from that due to the motion of bound charges. In biological tissues, the dominant conduction mechanism is ion transport in which at low and moderate $\vec{E}$ – values, the current density $\vec{J}$ is

$$\vec{J} = \sigma\vec{E} = qn\mu'\vec{E} \qquad (1.2)$$

with σ being the conductivity, n is the carrier density and μ' the mobility. If the medium has conductivity σ, the electric field is able to penetrate a distance into the medium characterized by the skin depth δ, given by,

$$\delta \quad \left(\frac{2}{\omega\sigma\mu}\right)^{1/2} \qquad (1.3)$$

where the magnetic permeability of the medium is μ.

Although RFR do not give rise to the breaking of chemical bonds, it has been suggested [8] that change in topological factors can alter biological activity. A topological shift can result if the DNA strands twist as a result of the coupling of the large number of nitrogen atoms in genetic base pairs to the oscillator exogenous magnetic fields, via the Einstein – de Haas effect [13]. The dielectric constant and conductivity of tissue make propagation of electromagnetic waves in tissue different from that in free space. A number of workers have measured the dielectric properties of mammalian tissues and typical values for the dielectric constants and conductivities are found in [2] and [16]. From these works the conductivity values of 1 and 1000 S/m respectively were obtained at the frequencies ω = 314 rad/s and 5.0 x 10^9 rad/s. These frequencies are applicable for electromagnetic waves in the power lines and typical cell phones. Using these values in equation (1.3) and the fact that permeability $\mu = \mu_0 = 4\pi \; x \, 10^{-7} N / A^2$ since tissues are not ferromagnetic, the skin depth δ = 71m and δ = 5.6 x 10^{-4}m ≈ 1mm at the low and high frequencies respectively [22].

The rate at which radiation is absorbed by the human body is measured by the Specific Absorption Rate (SAR), and its maximum levels for modern handsets have been set by governmental regulating agencies in many countries. Specific absorption rate is a measure of the rate at which energy is absorbed by the body when exposed to a radiofrequency electromagnetic field. It is also defined as the time derivative of incremental energy (dw) absorbed by an incremental mass (dm) contained in a volume element (dv) of a given density ρ [17]. Mathematically, this is written as

$$SAR = \frac{d}{dt}\left(\frac{dw}{dm}\right) = \frac{d}{dt}\left(\frac{dw}{\rho dv}\right) \qquad (1.4)$$

where SAR is expressed in watts per kilogram (W/kg). SAR is usually averaged either over the whole body or over a sample volume. It can be calculated from the field within the tissue as

$$SAR = \frac{\sigma\vec{E}^{\,2}}{\rho} \qquad (1.5)$$

where σ is the sample electrical conductivity $\vec{E}$ is the RMS value of the electric field and ρ the sample density.

Absorption of electromagnetic field by human body can be divided into four ranges. At frequencies from about 100 kHz to less than 20 MHz significant absorption occurs in the neck and leg. Relatively high absorption can occur in the whole body at frequencies from about 20 MHz to 300 MHz. At frequencies in the range between about 300 MHz and several GHz, significant local (head, trunk and extremities), non-uniform absorption can occur. At frequencies above about 10 GHz, much energy absorption occurs primarily at the body surface such that the depth of penetration of the field into tissue is small and SAR is not a good measure for assessing the absorbed energy rather the power density of the field (in W/m^2) is a more appropriate dosimetric quantity [11].

Studies have been carried on the effects of electromagnetic field on those highly exposed to it, especially power line and telecommunication workers. Increased chronic lymphocytic leukemia was found among adults in electrical occupations [12]. Tynes and Andersen [25] and Martanoski et al, [18] reported a higher incidence of breast

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cancer in male telephone line workers. These findings aroused much attention because of the rarity of breast cancer in men. Experimental evidence indicates that the exposure of human to electromagnetic fields producing a whole body specific absorption rate (SAR) of between 1 and 4 W/kg results in thermal effect which is an increase in body temperature of about 1°C [10]. Laboratory studies by [10] with rodent and non-human primate models demonstrated the broad range of tissue damage resulting from either partial body or whole body heating, producing temperature increases in excess of 1 – 2 °C.

Many users of mobile handsets have reported feeling several unspecific symptoms during and after its use, such as burning and tingling sensations in the skin of the head and extremities, fatique, sleep disturbances, dizziness, loss of mental attention, reaction times and memory retentiveness, headaches, malaise, tachycardia and disturbances of the digestive systems [14]. However, the area of much concern about the effects of RFR on the population's health have been the radiation emitted by base stations, because in contrast to mobile handsets, it is emitted continuously and is much more powerful. Due to the attenuation of power with the square of distance, field intensities drop rapidly with distances away from the base of the antenna. A survey study by [24] found a variety of health effects for people who reported that they were living within 304.70 m of cell towers in rural areas; or within 91.44 m of base stations in urban areas. Fatique, headache, sleep disruption and loss of memory were among the effects found. There are studies published on health effects of radio and base stations in Switzerland, France, Spain, Austria and Egypt [1], [7], [9] and [21].

Even thus some studies had been carried out on the effects of the use of mobile phones [5], and which to our knowledge did not include mobile phones base stations in Nigeria, this study was undertaken to measure the RFR power levels for some Global System for Mobile Communication (GSM) base stations and some mobile phones to ascertain their possible implications to the general public.

2.0 Materials And Method

In this study the RFR power levels of four mobile phone base stations located in Ugbowo area of Benin City including the University of Benin campus were determined by means of an electrosmog meter model ED-25G. Also, the RFR power level of some selected mobile phones of different models were measured while they were being used to make or receive calls. The study was conducted in three phases. In phase one a survey of four mobile phone masts belonging to MTN, Globacom, Zain, and a mast hosting Starcomms and Zoom networks was carried out. Measurements of RFR were taken in the mornings and afternoons, at different distances of 5 m, 15 m, and 25 m away from each base station, transmitting at a frequency of 1800 MHz [6] in order to establish a baseline. Using phase one as the baseline for the study, measurements were made in the afternoons at the four masts and at different distances from that in phase one. Measurements were made at near-field zone and far-field zone of 15 m and 100 m respectively from each mast. This was done based on the observation from phase one which shows that RFR power levels were generally higher in the afternoon at 15 m away from the base stations. The measurements were repeated four times and a mean value was obtained for each position.

Values obtained from the first and second phases on a daily basis, were calculated to obtain the average measurement of RFR power levels emanating from the base stations. In phase three, the RFR power levels of some mobile phones of different models were determined while transmitting or receiving calls with them.

3.0 Results And Discussion

The results obtained are presented in Tables 1-5.

Table 1: Power level in mW/m^2 at 15 m and 100 m from MTN mast

Days / Distance	1	2	3	4	5	6	7	8
15 m	0.967 ±0.091	0.865 ±0.071	0.919 ±0.073	1.146 ±0.151	0.867 ±0.063	0.980 ±0.009	0.998 ±0.068	1.151 ±0.093
100 m	0.590 ±0.001	0.665 ±0.073	0.526 ±0.009	0.791 ±0.083	0.690 ±0.064	0.619 ±0.008	0.672 ±0.007	0.715 ±0.033

Table 2: Power level in mW/m^2 at 15 m and 100 m from Zain mast

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Days / Distance	1	2	3	4	5	6	7	8
15 m	1.709 ±0.051	1.879 ±0.008	1.095 ±0.032	1.623 ±0.025	1.423 ±0.005	1.850 ±0.038	1.624 ±0.021	2.300 ±0.091
100 m	0.192 ±0.003	0.695 ±0.058	0.188 ±0.007	0.209 ±0.007	0.148 ±0.004	0.172 ±0.004	0.308 ±0.017	0.148 ±0.020

Table 3: Power level in mW/m^2 at 15 m and 100 m from Globacom mast

Days / Distance	1	2	3	4	5	6	7	8
15 m	0.139 ±0.004	0.170 ±0.015	0.211 ±0.008	0.164 ±0.002	0.168 ±0.013	0.319 ±0.005	0.188 ±0.007	0.155 ±0.006
100 m	0.312 ±0.012	0.289 ±0.008	0.359 ±0.008	0.294 ±0.019	0.265 ±0.011	0.647 ±0.007	0.282 ±0.032	0.289 ±0.022

Table 4: Power level in mW/m^2 at 15 m and 100 m from Starcomms/Zoom mast

Days / Distance	1	2	3	4	5	6	7	8
15 m	0.164	0.153 ±0.008	0.160	0.320	0.165	0.149	0.773	0.170
100 m	0.787	1.344 ±0.007	0.645	1.364	0.697	0.621	0.621	0.671

Table 5: Power level in some popular cell phones

Call Phone model	**Power level in mW/m^2**
Nokia 1100	18.278 ± 1.031
Sagen MYX5-2V	11.533 ± 0.931
Haier (CDMA)	0.648 ± 0.013
Motorola L6	11.533 ± 0.732
Samsung X100	14.515 ± 0.072
Blackberry	11.512 ± 0.136

The data obtained show that the measured power levels at distances of 5 m, 15 m, and 25 m had its highest value at 15 m on the average, and decreases at 25 m. It was also observed that RFR was higher in the afternoons than in the mornings. Although the measurements of RFR power levels obtained from Globacom mast and the mast hosting Starcomms and Zoom networks, were constantly changing at the various distances and time of the day, however, some of the observations made above are in agreement with the WHO 1993 report on base stations which states that radiofrequency field intensity increases slightly as one moves away from the base station and decreases at greater distances from the antenna. Also, the high RFR power level observed in the afternoons may be attributed to peak periods when base stations are transmitting power more to the mobile phones.

Based on the measurements in phase one, the measurements in phase two were conducted at near-field zone of 15 m and far-field zone of 100 m from the base stations. Tables 1 and 2 contain data for MTN and Zain masts which clearly show that RFR was higher at near-field zone and lower at far-field zone. The measurements of RFR for Globacom, Starcomms and Zoom masts are presented in Tables 3 and 4. It is observed that at the near-field zone RFR was lower and then higher at the far-field zone. These findings seem contradictory. However, this may be attributed to a number of reasons such as a research conducted on mobile telecommunication base stations by a research group ‘short term mission within cost 244 bis” in Austria, France, Germany, Hungary and Sweden who

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reported that at sufficient distances from the antenna in base station, RFR decreases with square of distance. It was also reported that a number of reasons can be adduced for variations in measurements of RFR from base stations which includes variations in distances which may have strong influences in signal strength depending on the directionality of the antenna beam, and various propagation paths (reflection, diffraction and line sight of propagation), the presence of other objects (houses etc) which can best be described by the terms "fast fading" and "shadowing".

In the third phase of this study, the RFR power levels of different models of mobile phone were measured while transmitting or receiving calls with them. The data obtained are presented in Table 5 which shows the variations in RFR for the different models of the mobile phone investigated. Haier Code Division Multiple Access (CDMA) model had the lowest radiation while the Nokia model 1100 had the highest radiation. From the data on Tables 1-5, the lowest and highest RFR power level values of the base stations transmitting at a frequency of 1800 MHz were 0.139 ± 0.004 mW/m^2 and 2.300 ± 0.091 mW/m^2 respectively. The background RFR recorded in the area of study was 0.008 mW/m^2. RFR power levels from the mobile phones had its lowest at 0.648 ± 0.013 mW/m^2 and highest at 18.278 ± 1.031 mW/m^2.

Comparing the RFR power levels obtained in this study with that of the ICNIRP (1998) safety limits for exposure which is 9.0 W/m^2 at frequency of 1800 MHz, the RFR emission from both the base stations and the mobile phones studied is considered safe to the public. The report from the short term mission within cost 244 bis group for 152 measurements of all GSM frequencies available showed that exposure levels due to GSM base station varied in magnitude at different locations ranging from 0.000001 mW/m^2 to 48 mW/m^2, with a median of 0.2 mW/m^2. Despite this variation, compliance with ICNIRP (1998) in public places was safely confirmed. The values of RFR power level obtained in this study is in line with the evidence available from the above report indicating the safety of RFR emanating from the base stations and the mobile phone used in Benin City.

4.0 Conclusion

In this study, RFR from base stations and mobile phones was measured. The values obtained were compared with the safety limits recommended by national and international bodies. It was observed that the lowest and highest radiation levels recorded from the antennas of base stations operating at frequency 1800 MHz and the mobile phones investigated were within the recommended safety limits. Meanwhile, the prudent dispositions in the use and operations of GSM for now should be deliberate efforts to minimize RFR exposure. Some important ways of minimizing the health risks will include limiting phone calls as much as possible. Only essential calls should be made. As much as possible the calls should be in open space. One can also make use of wired headset that limits exposure to RFR, ideally, an air tube headset which conducts sound but prevents radiation from traveling up the wire to the brain. The wires should be shielded to prevent them from acting as antenna which could attract more information carrying radio waves directly to the brain. Use of the speaker phone instead of putting the phone close to the ear should be strongly encouraged. This is probably the single most important step to be taken other than not using cell phone. GSM phone dealers or manufacturers should be required to make it clear to consumers or customers that the SAR value declared on their product is only to the degree to which the RFR from the antenna can heat biological tissue, and is in no way related to non thermal effects that the RFR may have. Non emergency use of mobile phones by children and pre-adolescents should be strongly discouraged on account of their increased vulnerability to the potential adverse health effects of the use of GSM.

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