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Measurement of Electromagnetic Waves Radiated from Base Transceiver Stations (BTS) for Assessing Exposure Limit in Kaduna State

[1,]Ahmad Aminu , [2,]Danladi Agadi Tonga , [3,]Engr. Yahaya H. Abubakar , [4,]Zakariyya Hassan Abdullahi

[1,]Department of Electrical/Electronic Engineering, School of Technology Kano State Polytechnic, Kano Nigeria.
[2,]Department of Electrical/Electronic Engineering, Hussaini Adamu Federal Polytechnic, Kazaure, Jigawa Nigeria
[3,]Department of Electrical/Electronic Engineering, College of Engineering Kaduna Polytechnic, Kaduna Nigeria.
[4,]Department of Computer Engineering, Hussaini Adamu Federal Polytechnic, Kazaure, Jigawa Nigeria

---ABSTRACT---
Presently Nigeria is experiencing a steady growth in the telecommunication industry, with about twenty one (21) mobile wireless telecommunication services providers, about fifteen thousand (15,000) Base Transceiver Stations (BTS) spreads across the country, and also One Hundred and seventeen million lines actively connected[1]. There is growing concern among Nigerians about the possible health hazard of electromagnetic waves radiation from the BTS and the mobile handsets. This study focuses on measurement of Electromagnetic waves Radiation (w/m^2) radiated from Base Transceiver Stations (BTS). These measurements were carried out using handheld Spectrum Analyzer. Maximum radiation values were measured from (BTS) of the selected sites in Kaduna and the results were compared with the standard provided by the International Commission on Non-Ionizing Radiation Protection, (ICNIRP, 1998) and a good agreement was obtained.

KEYWORDS : *Electromagnetic waves Radiation, Measurement, Specific Absorption Rate (SAR), exposure limit, BTS, received power, Spectrum Analyzer*

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I. INTRODUCTION

Cellular wireless technology now allow the delivery of voice, text, images, music, video and other valuable services and it relies on an extensive network of base station to do this [6]. However, base stations have generated much public concern. They need to be high up, so they are often located on towers or masts or rooftops. Towers, which are usually 25 to 80 meters tall, are particularly often in the news when local residents object to their location, because of health concerns or simply because of their appearance. Electrical and electronic devices, wireless cellular telephones and other mobile personal communication services is the fastest growing field in the world. There is uncertainty about the health effects of radio frequencies (RF). A certain amount of energy from radiation is absorbed by the body and converted to heat. This is called thermal effect. It results in public concern about possible health effects of human exposure to electromagnetic energy [7]. Concerns about other possible thermal effects arising from exposure to RF include, suggestions of subtle effects on cells that could have an effect on cancer development or influences on electrically excitable tissue. It could influence the function of the brain and nervous tissue [5]. There has also been concern about whether there could be effects on brain function, with particular emphasis on headaches and memory loss. Few studies have yet investigated these possibilities [4]. The basic limit of exposure is expressed by the quantity called “specific absorption rate” (SAR). SAR is the time rate at which electromagnetic energy (EM) is absorbed/ dissipated by an element of biological body mass, and is expressed in units of watts per kilogram (W/kg) [4]. The maximum local SAR, which is the most critical quantity in the context of potential health effects of RF energy radiated, depends on a large number of factors [8].

The factors that influence how much RF an individual may be exposed to include: The power output, frequency and type of transmitter, the distance the person is from the transmitter, the location of the person with respect to the transmitted beam, the type of antenna and the direction of the transmitted beam; the presence of other structures near the person that may shield them or reflect the RF signals towards them; and the time spent in a particular area of the RF field.The most investigated effect of EM energy on biological tissues is the transformation of energy entering the tissues into increased kinetic energy of the absorbing molecules, thereby producing a general heating in the medium. The power absorbed by the tissues will produce a temperature rise that is dependent on the cooling mechanism of the tissue. The patterns of the fields producing the heating are complex functions of the frequency, source configuration, tissue geometry and dielectric properties of the tissues [7]. When the thermoregulatory capability of the system is exceeded tissue damage result, when a biological system is exposed to microwave radiation, an internal field is induced in the system. The calculation of this internal field is named as dosimetry [4]. The development of models to predict the absorption of electromagnetic energy and the physiologic thermoregulatory response for the human body has proceeded for several years**.** A large epidemiological study is being coordinated in over 10 countries by the International Agency for Research on Cancer (IARC), a specialized agency of the World Health Organization (WHO). The WHO established the International Electromagnetic Fields (EMF) Project, to assess the scientific evidence of possible health effects of EMF. There is also growing concern in Europe over such health effects. This initiated a European project within the European COST (Cooperation in the field of Scientific and Technical Research) program (COST 244). In this project a multi-disciplinary group of engineers, physicians and biologists are investigating the link between the fields absorbed by wireless-telephone users and possible health effects [4]. Many studies on the effects of microwaves on the Central Nervous System (CNS) were performed in Germany and France.

The properties of electromagnetic waves define neither the ionizing or non-ionizing radiation. Some electromagnetic waves carry so much energy per quantum that they have the ability to break bonds between molecules. In the electromagnetic spectrum, gamma rays are given off by radioactive materials, cosmic rays and X-rays carry this property and are called 'ionizing radiation'. Fields whose quanta are insufficient to break molecular bonds are called 'non-ionizing radiation'. Man-made sources of electromagnetic fields are found at the relatively long wavelength and low frequency end of the electromagnetic spectrum and their quanta are unable to break chemical bonds. Mobile phones have non-ionizing radiation. Frequencies between about 30 kHz and 300GHz are widely used for telecommunication [2], including broadcast radio and television, and comprise the radio frequency (RF) band. Cellular mobile phone services operate within the frequency ranges 872-960 MHz and 1710-1875 MHz Waves at higher frequencies but within the RF region. The SAR can be applicable to mobile phones and it is a way of measuring the RF that is absorbed by the tissue. Determination of SAR can be made either by using sophisticated computer modeling techniques or by performing tests on a model called a "phantom". Years of research have gone into understanding and developing ways to calculate the complexities involved in determining SAR values for products that produce radio frequency emissions. The results of that research are the current and recently revised Federal Communication Commission(FCC) RF emissions guidelines based on the American National Standard Institute/Institute of Electrical and Electronics Engineering(ANSI/IEEE) and National Commission on Radiation Protection(NCRP) standards[2, 3]. SAR testing on wireless phones is done at the maximum power output level for the phone. Wireless phones though, typically operate at power levels below peak power and often at just 25% their allowable power. Phones operate at constantly varying power levels due to many factors such as distance from the nearest base station and also to conserve battery power.

Specific Absorption Rate (SAR) is defined as;

$$\text{SAR} = \sigma \frac{E_i^2}{\rho} \quad (1)$$

or

$$\text{SAR} = C_i \frac{dT}{dt} \quad (2)$$

or

$$\text{SAR} = \frac{J^2}{\rho\sigma} \quad (3)$$

σ = conductivity of body tissue s/m,
ρ = density of body tissue in kg/m^3
E_i = rms value of electric field in the tissue V/m
C_i = heat capacity of body tissue in J/kgK,
T = temperature,
J = magnitude of the induced current density in the body tissue A/m^2

II. SAFETY AND STANDARDS

There are two main exposure guidelines for RF radiation in Europe. The National Radiological Protection Board (NRPB) published the first guideline in 1993 and the International Commission on Non-Ionizing Radiation Protection (ICNIRP) published the second one in 1998. The guidelines published by the NRPB were based on the potential of RF radiation to cause illness or injury through heating of body tissues. While some research had suggested that adverse health effects might occur from exposures lower than those needed to produce significant heating [3], the evidence for this was not considered sufficient to form a basis for the derivation of exposure guidelines which incorporate basic restrictions on the SAR. The SAR is averaged over an exposure time and a specified mass tissue, depending on the tissue region. Average times are specified because of the time taken for the temperature of tissues to equilibrate when they are exposed to the radiation. The fields are assumed to be in the far-field region. The second guidelines on exposure to RF radiation were also published by the ICNIRP, in 1998. These were designed to prevent illness and injury through heating effects. Their starting point is the behavioral changes found when experimental animals that were exposed to RF radiation at levels that produced a rise in whole body temperature in excess of 1 °C. An SAR of 1-4 W/kg or higher is needed to cause these changes. The ICNIRP guidelines feature a two-tier system with lower limits (five times lower) for exposure to the general public than for occupational exposure. Table 1 and 2 below show ICNIRP basic restrictions on occupational exposure and general public exposure (in brackets) in the frequency range 1 MHz to 3 GHz [2] respectively.

Table 1.ICNIRP Basic Restrictions on Occupational Exposure

Tissue region	SAR Limit (W/Kg)	Mass (g)	Time (s)
Whole body	0.4 (0.08)	-	6
Head,Trunk	10 (2)	10	6
Limbs	20 (4)	10	6

Table 2 ICNIRP Reference Level for Public Exposure to Mobile Telecommunication Frequencies

Frequencies (MHz)	Electric Field strength (V/M)	Magnetic field strength (A/M)
1-2	$87/\sqrt{F}$	$0.73/\sqrt{F}$
10-400	27.5	0.073
400-2000	$1.375*\sqrt{F}$	$0.0037*\sqrt{F}$
2000-3000	61	0.16

The ICNIRP guidelines for the public have been adopted in a European Council Recommendation (1999), which has been agreed to in principle by all countries in the European Union.

III. METHODOLOGY AND INSTRUMENTATION

This investigation was arranged in two phases, the physical measurement and analysis. It covers some sampled BTS of the four major telecommunication operators in three selected areas in Kaduna, namely, Mando, Kabala Costain and Malali, For the selected BTS, received power (dBm) and exposure limit (μw\m^2), were measured at distances ranging from 25-200 (meters) away from the BTS using Spectrum Analyzer, type: SPECTRAN hf 2025e with a frequency range of 700MHz to 2.5GHz. The instrument was obtained from the Electronics and Telecommunication Engineering Laboratory of the Nigerian Defense Academy Kaduna. The spectrum analyzer is a handheld instrument and as such was held in the hand during measurements for all the selected BTS. The results are depicted in tables below.

Table 3A Power received and Exposure limit for GLO NETWORK at FARIN GIDA-MANDO

FARIN GIDA-MANDO		
GLO NETWORK		
Distance in 'm'	Power received in dBm	Exposure limit in µw/m^2
25	-27	100.39
50	-31	81.1
75	-36	68.3
100	-34	48.96
125	-33	39.18
150	-30	23.41
175	-29	18.54
200	-38	5.34

Table 3B Power received and Exposure limit for AIRTEL NETWORK at FARIN GIDA-MANDO

FARIN GIDA-MANDO		
AIRTEL NETWORK		
Distance in 'm'	Power received in dBm	Exposure limit in µw\m^2
25	-26	96.11
50	-27	87.35
75	-28	32.98
100	-32	19.38
125	-33	18.35
150	-34	13.86
175	-36	12.48
200	-38	2.69

Table 3C Power received and Exposure limit for MTN NETWORK at FARIN GIDA-MANDO

FARIN GIDA-MANDO		
MTN NETWORK		
Distance in 'm'	Power received in dBm	Exposure limit in' µw/m^2
25	-27	100.89
50	-27	97.33
75	-28	86.74
100	-32	35.48
125	-35	18.58
150	-38	14.27
175	-39	6.33
200	-41	4.13

Table 4A Power received and Exposure limit for AIRTEL NETWORK at KABALA COSTAIN

KABALA COSTAIN		
AIRTEL NETWORK		
Distance in 'm'	Power received in dBm	Exposure in µw/m^2
25	-32	30.95
50	-34	18.24
75	-35	16.67
100	-35	16.33
125	-36	11.51
150	-37	9.67
175	-37	9.16
200	-41	4.47

Table 4B Power received and Exposure limit for MTN NETWORK at KABALA COSTAIN

KABALA COSTAIN		
MTN NETWORK		
Distance in ‘m’	Power received in‘dBm	Exposure limit in µw/m^2
25	-35	16.49
50	-37	10.97
75	-38	8.44
100	-41	4.26
125	-42	3.27
150	-43	2.71
175	-44	2.17
200	-45	1.77

Table 4C Power received and Exposure limit for ETISALAT NETWORK at KABALA COSTAIN

KABALA COSTAIN		
ETISALAT NETWORK		
Distance in ‘m’	Power received in dBm	Exposure limit in µwm^2
25	-33	23.92
50	-37	9.95
75	-40	5.20
100	-42	5.12
125	-43	4.79
150	-44	4.41
175	-47	2.66
200	-49	2.29

Table 4D Power received and Exposure limit for GLO NETWORK at KABALA COSTAIN

KABALA COSTAIN		
GLO NETWORK		
Distance in ‘m’	Power received in dBm	Exposure limit in µw/m^2
25	-26	19.72
50	-29	16.33
75	-30	11.80
100	-36	10.49
125	-37	8.68
150	-38	8.09
175	-39	7.56
200	-40	4.62

Table 5A Power received and Exposure limit for AIRTEL NETWORK at KABALA COSTAIN

MALALI LOW-COST/G.R.A		
AIRTEL NETWORK		
Distance in ‘m’	Power received in dBm	Exposure limit in µw/m^2
25	-33	24.29
50	-35	15.69
75	-36	13.7
100	-37	11.70
125	-38	8.79
150	-39	7.15
175	-42	2.96
200	-43	2.65

Table 5B Power received and Exposure limit for MTN NETWORK at KABALA COSTAIN

MALALI LOW-COST/G.R.A		
MTN NETWORK		
Distance in 'm'	Power received in dBm	Exposure limit in µw/m^2
25	-29	56.64
50	-32	32.16
75	-33	27.99
100	-34	21.21
125	-36	12.98
150	-39	6.30
175	-41	4.76
200	-44	4.37

Table 5C Power received and Exposure limit for ETISALAT NETWORK at KABALA COSTAIN

MALALI LOW-COST/G.R.A		
ETISALAT NETWORK		
Distance in 'm'	Power received in dBm	Exposure limit in µw/m^2
25	-27	89.54
50	-28	73.42
75	-32	42.50
100	-31	32.74
125	-34	24.89
150	-36	13.25
175	-37	12.43
200	-38	10.98

IV. RESULT AND DISCUSSIONS

Figure1shows the plot of exposure limits (µw/m^2) values measured at some distance (m) from the BTSs of the four major operators namely Airtel, MTN, Etisalat and Glo. Among the BTSs, subjected to measurements, MTN and Etisalat BTSs are the BTSs that radiated the lowest radiation of 2.3and 2.4µw/m^2 at a distance of 200m respectively. Airtel and Glo BTSs are the BTSs that radiated the highest radiation of 4µw/m^2 at a distance of 200m. On the other hand, MTN and Glo BTSs are the BTSs that radiated the lowest radiation of 16 and 19µw/m^2 at a distance of 25m respectively, while, Etisalat and Airtel BTSs are the BTSs that radiated the highest radiation of 24and 31µw/m^2 at a distance of 25m respectively. Measurements with distance show that the decreasing rate of radiation with distance is different for each BTS. The results of radiation values obtained for all the BTS used in this FARIN GIDA-MANDO, falls within the safety limit of 10 mW/cm^2or 100W/m^2 specified by the International Commission on Non-Ionizing Radiation Protection [2]. Therefore, these BTS are safe for use as far as electromagnetic radiation safety guide lines are concerned.

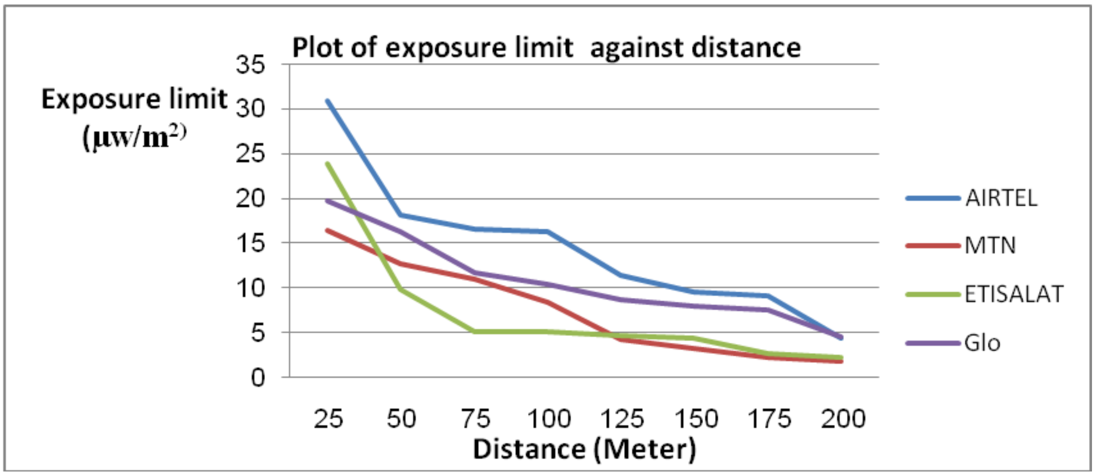

Figure 1: The plot of exposure limit values measured at some distance from the BTS.

V. CONCLUSIONS

In conclusion, this study focuses on measurement and evaluation of Electromagnetic Radiation (w/m^2) radiated from Base Transceiver Stations (BTS) in Kaduna state. These measurements were carried out using handheld Spectrum Analyzer. Maximum radiation values were measured from (BTS) of the selected sites in Kaduna and the results were compared with the standard provided by the International Commission on Non-Ionizing Radiation Protection [2], and a good agreement was obtained (standard exposure not exceeded). Therefore, these BTS are safe for use.

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