American Journal of Electrical and Computer Engineering
2021; 5(1): 14-24
http://www.sciencepublishinggroup.com/j/ajece
doi: 10.11648/j.ajece.20210501.13
ISSN: 2640-0480 (Print); ISSN: 2640-0502 (Online)

Electromagnetic Radiation (EMR) and Human Health: A Study on the Health Effect of EMR from GSM Base Stations in North-Western Nigeria

Jazuli Sanusi Kazaure[1, *], Ugochukwu Okwudili Matthew[2]

[1]Electrical Electronics Engineering, Hussaini Adamu Federal Polytechnic, Kazaure, Nigeria

[2]Computer Science, Hussaini Adamu Federal Polytechnic, Kazaure, Nigeria

Email address:

sakjazulisak@gmail.com (J. S. Kazaure), macdon4ru2003@gmail.com (U. O. Matthew)

[*]Corresponding author

To cite this article:

Jazuli Sanusi Kazaure, Ugochukwu Okwudili Matthew. Electromagnetic Radiation (EMR) and Human Health: A Study on the Health Effect of EMR from GSM Base Stations in North-Western Nigeria. *American Journal of Electrical and Computer Engineering*. Vol. 5, No. 1, 2021, pp. 14-24. doi: 10.11648/j.ajece.20210501.13

Received: December 12, 2020; **Accepted**: December 19, 2020; **Published**: March 17, 2021

Abstract: Nigeria had maintained substantial intensification in the perspective of the mobile communication utilization, services improvement and sustainable broadband regime and this development is presumed to persist into the conceivable future with the evolution of the contemporary 6G, 5G, 4G and 3G mobile communication technologies. The current mobile communication technologies intensification had equally brought the unavoidable multiplications in the ratio of the base service stations which also had raised the public concern over the considerable health hazards of the radioactive emissions from the communication systems. Notwithstanding the assurances of the several regulatory agencies, the World Health Organization and service providers, confirming compliance and strict observance to the international exposure standards in implementation, the apprehension over the electromagnetic spectrum emission is increasing. To that effect, the International Commission on Non-Ionizing Radiation Protection (ICNIRP) had made recommendations that established the intensities of the radio frequency (RF) exposures which are considered harmless to the community of users. This paper assessed the radio frequency radiation from mobile base stations in some selected states in north western Nigeria. The methodology employed for the study is measurement and instrumentation method. Handheld spectrum analyzer (Aaronia HF 4040V3) and a wheel meter were used for the measurement of electromagnetic emissions from selected Airtel, Glo, MTN and Etisalat base stations at capital city of Kano, Jigawa and Katsina states respectively. It was found from the study that 17 to 70mW/m^2 is the average electromagnetic radiation emitted in the study area, which showed total compliance of exposure limit by the GSM service providers in the selected states. The result confirmed the environmental safety level of the RF energy maintained within the general public and that are predictably low to produce any significant health hazards to human.

Keywords: Radio Frequency, Wireless Network Transmission, GSM Base Stations, Electromagnetic Radiation, Field Measurements, and Compliance Assessment

1. Introduction

The Radio Frequency (RF) base stations are critical in supporting mobile phone communication, data transmission and communication exchanges through the process of packet switching and circuit switching which fundamentally involves voice call communication, data transfer and delivery of sms messages between the communication parties [15]. The RF is the subsection of the electronic engineering that link the application of waveguide, transmission line, antenna and electromagnetic field philosophies to the design and application of devices that generate or exploit signals within the radio communication bands and the frequency ranges at about 20 kHz to 300 GHz [27]. This usually encompassed everything that transmits or receives radio wave signals such as mobile phones, wireless fidelity (Wi-Fi) and two-way communication radios. The RF engineering is exceedingly dedicated field that generally supervise several other

computing field such as; (i.) antenna systems design to provide radiative coverage of a specified geographical area by an electromagnetic field or to deliver an identified sensitivity of electromagnetic field imposition on the antenna. (ii.) The coupling design and transmission line structures to transport RF energy exclusive of harmful radiation. (iii.) Transmission line structures and circuit elements application required for the design of signal amplifiers, detectors, oscillators, combiners, mixers, filters, impedance transforming networks and other devices. (iv.) Authentication and measurement of performance of radio frequency devices and network systems [18].

The RF Base stations usually emit high frequency (HF) electromagnetic radiative signals in the range of several hundred MHz to several GHz in which mobile telephony industries exploits only smaller chunk of the frequencies between 935 to 960MHz and 18005 to 1880MHz [3]. However, the precisions of frequency bands utilization varies considerably between technologies (GSM, UMTS, CDMA2000, 3G, 4G, 5G, 6G) and across countries of the world [8]. The geographic spaces of Nigeria is currently undergoing broadband regime intensification which was orchestrated by the telecommunication industry involvement through establishment of 21 mobile wireless communication service providers and 20,000 base transceiver stations (BTS) spreads across the country [1], Kano, Jigawa and Katsina states from the North West Nigeria inclusive. The Nigeria telecommunication industry recently recorded extraordinary escalation in the development of supplies and value chains with remarkable advancement in the qualities and quantities of services made available to the telecommunication consumers. The telecommunication deregulation policy of the Federal Government of Nigeria (FGN) led to the intensification in the numerical composition of providers of the telecommunication services and equally the amount of subscribers or customers. Corresponding to the information from the National Bureau of Statistics (NBS), the Nigeria telecommunications data in the first quarter (Q1) 2020 suggested that a total of 189,282,796 subscribers were active on voice communication when juxtaposed with the 184,699,409 in third quarter (Q3) 2019 and 173,713,842 in (Q1) 2019. Empirically, this signified 2.48% expansion in voice subscriptions when analyzed based on (Quarter – by-Quarter) basis and 8.96% (Year -on- Year) basis. In the same way, a total of 136,203,231 subscribers were active on internet as against 126,078,999 in (Q3) in 2019 and 116,310,154 in (Q1) 2019. The telecommunications market establishment became the essential aspect of information communication technologies (ICTs) occupational productiveness in mobilizing support for the twenty first century business operations [7]. The ICTs innovation propelled economic effectiveness and kept in good condition the long-term commercial evolution of the telecommunication business ecosystems. With the rigorous adoption of ICTs, which activated the establishment of the digital economy over the past two decades had comprehensively influenced the opportunities and effectiveness of how businesses manufacture, fabricate and offer goods and services to the customers [10].

The empirical literature on ICT and efficiency emphasizes the principal significances and organizational transformations in the digital new world. Preponderances of considerations designates that the efficiencies of ICTs are undeniably encouraging and expressive. On the other hand, the organizational approaches of how to perfectly establish and consolidate all business processes on ICTs must also be considered. The telecommunication establishment principally participates in operating and delivering access to the amenities in transmission of voice communication, data services, multimedia text and video components [17]. The International Telecommunications Union (ITU) had established that 97% of the entire digital global world populace are now surrounded by the mobile cellular signal and 93% are bounded by at least 3G network technology penetration. The telecommunication utilization have broadly diffused into the global world establishing dominance in Europe, the Asia-Pacific region and America, in which more than 95% of the populace were connected by a 4G network technology or higher mobile broadband linkage [24]. Within the Arab nations the numerical strength of telecommunication connected populace are 91% while in the Commonwealth Independent Nations, 88% are connected and in Africa, 79% ratio of the populations are connected to telecommunication infrastructure. Demographically, 85 countries that make available data on mobile phone proprietorship, 61 have a greater percentage of men with mobile phones than women [23].

The Nigeria telecommunications sector witnessed some digital transformation in 2000 immediately after the deregulation of the telecommunication commercial business investment during the first tenure of general Olusegun Obasanjo administration [4]. Before the emergence of the global system for mobile telecommunication-GSM, the Nigeria telecommunication service sector were governmentally handled when it was called the “Nigeria Telecommunications Limited (NITEL)” [2]. However, the telecommunication services was characterized with several shortages, owning to lack of administrative competencies, ineffectiveness stretching from poor management capacity, policy shortages, exploitation and diminutive telephony performances in relation to its availability. Meanwhile, it was only some designated personnel offices, multinational corporations, government offices and official residences could afford the luxury of the telephony services. The establishment of global system for mobile telecommunication in Nigeria had brought meaningful development as the total active subscriptions have maintained consistent improvement. The Nigeria Communication Commission (NCC) had informed that telecommunication data for (Q4) 2019 suggested that a total of 184,699,409 subscribers were active on the voice communication subscription when juxtaposed with the 179,176,930 in Q3 2019 and 172,824,239 in (Q4) 2018. The figure signified 3.08% intensification on voice communication subscriptions quarter

by quarter and 6.87% increase year by year report. Comparably, a total of 126,078,999 telecommunication subscribers were active on internet as against 123,163,027 in (Q3) 2019 and 112,065,740 in (Q4) 2018. This signified 2.37% outgrowth in internet user's subscription Quarter by Quarter and 12.50% Year by Year.

In response to the increased deployment of mobile telephony transceiver base stations the aforementioned states, concern about the resultant exposure to electromagnetic fields and possibility of adverse health consequences have arisen. Moreover, a large number of different application services have been given license to use the radio frequency in the state which is part of the electromagnetic spectrum. According to Mobile Manufactures Forum 2013, assessment of exposure levels is most accurately achieved through onsite field measurements [9]. However, theoretical calculations are also common but are complicated by the many factors that influence the actual exposure such as the height, tilt and direction of antenna, absorption from trees and plants or reflections from buildings, as well as distance. Therefore, this paper employed field measurement of electromagnetic radiation emission from selected BTS in the capital city of Kano, Jigawa and Katsina states. The paper compiled the exposure data in the states and investigated the levels of compliance with health based exposure recommendations by ICNIRP international standard. This current research classified the electromagnetic influences of non-ionizing, non-visible radiation from the wireless transmission of the existing 3G, 4G and 5G network technology already reported in several biomedical literature and pointed when and how the effects are produced, the condition upon which the adverse effects are felt and procedure to curtail it. The research discovered that most of the clinical experimentations handled to the present time are not essentially conceived to classify the scenarios for the undesirable health effects of the wireless radiation from the existing network technology on the real-life operating scenario. Several researches and laboratory experimentations do not take into account of pulsing and modulation of the network carrier signal while reporting the health hazard of the wireless radio frequency radiation. While the immeasurable majorities do not interpret the synergistic harmful consequences of other toxic inducements such as dipolar chemical urtication and biological immunotoxicity caused by the ultra-high emission of wireless radiation produced by the existing network technology at certain radio frequencies. This research presented an evidence prove that the existing mobile network technology installations in Kano, Jigawa and Katsina state had modulated frequencies distribution therefore will not produce wireless radiation that will produce dangerous health condition such as discomforting symptoms, cancer, sensory disorder, sleeping disorder, congenital abnormality, infertility, immunotoxicity etc.

2. Safety Standard for Non-ionizing Radio Frequency Radiation

The two universally and generally acceptable standards for exposure guidelines with respect to RF electromagnetic radiation has been provided in Europe [11]. To that effect, the national radiological protection board (NRPB) guidelines were made public in 1993 while the international commission on non-ionization radiation protection (ICNIRP) were published and circulated publicly in 1998. The guidelines published by the (NRPB) clearly established the possibility of RF electromagnetic radiation to produce illness or injury through warming up of the human body tissues while the ICNIRP guidelines provided the conventional endorsements concerning high frequency (HF) electromagnetic exposure [13]. The ICNIRP provided shortcomings expressed in terms of the specific absorption rate (SAR) for the absorption of energy from HF fields [5]. The publication of the ICNIRP guidelines for limiting exposure to time-varying electromagnetic fields radiation propelled several many scientific studies on the effects of such fields have been published.

The study on the radio frequency range of 100 kHz has been conducted to assess the global environment health impact of the non-ionizing electromagnetic radio frequency radiation. The health hazard assessments had been undertaken by organizations such as the World Health Organization in 2006, 2007 [22], national radiation protection institutions HPA 2006 and by ICNIRP 2003 [21]. On the static and enormously low frequency (ELF) fields, ICNIRP's process of reviewing its guidelines is respectively finalized (ICNIRP 2009) or in progress (Protection, 2009). However, the RF beyond 100 kHz together with the frequencies utilization for the modern wireless communication technologies in addition to the most contemporary developments in 5G and 6G network technologies have been completed in the recent time while several others are still ongoing [16]. Although, there are expectations for new data need to be reviewed and assessed upward with respect to possible health hazards prior to the revisions of the updated ICNIRP's guidelines in the radio frequency bands as development in 5G and 6G is potentially taking some different dimensions in military intelligence, defense weaponry, industrial internet of things (IIoTs) and robotics technologies. The main objective of the current research is to make available the information regarding the safety of telecommunications (telecoms) infrastructure on the human health within the study area. This was necessitated by the citizen's health concerns and misconceptions on the electromagnetic radiation from telecoms masts in the geographical surrounding. The paper is structured into introduction, safety standard, literature, materials and method, result and discussion, future research focus, conclusion and recommendation.

3. Literature Review

The electromagnetic radiation (EMR) emitted from the electromagnetic radio frequency based station of the global system of mobile telecommunication (GSM) installations are grouped into two distinct categories (i.) ionizing and (ii.)

non-ionizing radiation [14]. The ionizing electromagnetic radiations are among the high-frequency classification such as Gamma rays and X-rays while the non-ionizing radiation (NIR) is the electromagnetic spectrum which has photon energies too weak to break atomic bonds [20]. The electromagnetic NIR comprised of microwave fields, infrared radiation, ultraviolet radiation and radiofrequency [20]. The electromagnetic spectrum (EMS) is the collection of frequencies of electromagnetic radiation (EMR) dispersed through the electromagnetic base station such as telecom mask. The ionizing radiation possesses an imposing quantum of electromagnetic energy to hit off electrons and ionize the electrically charged particles, while the NIR does not acquire a sufficient amount of electromagnetic energy to ionize atoms or molecules. The ionizing radiation are fundamentally classified into five groups, which include, neutron particles, X‐rays, gamma‐ray, beta‐particles and alpha‐particles [12]. The NIRs are the segment of EMS incorporating wavelength less than 100 nm low photon energy less than 12.4 eV portion of the electromagnetic spectrum from 1 Hz to 3 × 1015 Hz. However, the NIR is distributed into four sections according to the following order, optical radiation, microwave radiation, static electric-magnetic field and extremely low‐frequency field radiofrequency radiation [20]. The NIR constituents could be naturally produced from the, sunlight or technologically synthesized by humans through wireless communications devices installations. The EMR influences are categorized into three performance energy level which include; Low energy level influence, Medium energy level influence and finally High energy level. The High energy level radiation when potentially exposure to the human can cause damages to the body and the affected cells cannot be repaired rapidly enough with the proportion that may immediately exterminate the exposed personality. The high energy EMR is potentially dangerous to all tissues of a living organisms on the account that its influences are naturally discomforting.

The current paper provided a review of the health consequence of the electromagnetic radiation (EMR) on the physical and mental health of the community of people when potentially exposed. WHO (World Health Organization) had already categorized the Radio frequency (RF) emissions as a carcinogen of the group 2B category which reasonably promotes cancerous tissue formation which is caused by genome or disruption of cellular metabolic processes [19]. Such fine grain study suggested that cellphone usage will led to the development of malignant tumors, particularly of the brain. According to Tettamanti et al., the effects of radiofrequency electromagnetic field exposure (RF-EMF) from mobile phone utilization on the societal health performances had been researched in the cross sectional findings [26]. However, the absence of clinical confirmation of the sensitive health influences of RF-EMF on the society wellbeing and comprehensive health status does not rule out the long-term electromagnetic radioactive effects when potentially exposure to RF-EMF from mobile phones base stations. As a result, the purpose of the contemporary investigation was to establish the long-term effects of RF-EMF exposure from mobile phone use.

The ionizing and non-ionizing electromagnetic rays emitted by the RF-EMF possessed several distinct energy level. As much as necessary concerns have been raised about 5G that some cities have canceled or delayed the installation of the base stations on the premise of the electromagnetic energy emission [3]. To that effect, the members of the IEEE Future Networks Initiative that is assisting to consolidate 5G development and deployment, appropriated the reports and further issued a short paper titled “5G Communications Systems and Radiofrequency Exposure Limits”. Above all, the report reviewed the current recommendations for RF-EMF exposure on the society wide space. Several concerns regarding 5G network considered negative influences on human health stem from its cell towers being uncommon architecture with respect to existing 4G and 3G cellular networks [25]. In the physical implementation, the 5G radio replacing a 4G radio at 750 MHz will have the same coverage as the 4G radio, assuming no modification to the implementable antenna. Although, several opponents insisted that 5G network must be proven safe before regulators should allow its deployments but logically, it is very impossible to prove anything with 100% certainty.

Regardless of the network implementation already in existence, 3G, 4G, 5G or 6G, the contention over the electromagnetic radiation safety (EMR) is whether the risks are manageable within an acceptable requirement to drive infrastructures and investments without causing potential health damages. Several initial medical research submissions on the conceivable health effects of EMR commenced approximately 60 years ago and factually thousands of findings since then had been documented as either no health risk or inconclusive results. Comparatively, small number of scholarly submissions have been maintained that proved substantial RF-EMF risk abundance but those studies have not been replicated whereas reproducibility is the fundamental aspect of scientific discoveries [6].

4. Materials and Method

The materials used are handheld spectrum analyzer (Aaronia HF 4040V3), the wheel meter and a digital computer. The study was carried out at North Western region of Nigeria. The state lies between latitudes 11°N and 13°N and longitudes 8°E and 10°35E with average rainfall of between 600mm to 1000mm, while ambient temperature fluctuates between 15°C and 35°C. Assessments of exposure levels were achieved through onsite field measurements. Data on electromagnetic emissions from selected Airtel, Glo, MTN and Etisalat base stations at Kano, Katsina, and Dutse were measured and analyzed using Microsoft Excel. The received power (dBm) and exposure limits (mW/m^2) measured at distances from 20 to 460 meters away from the selected Base Stations with frequency range of 100MHz to 4GHz. The net effect of RF emissions were evaluated and compared with ICNIRP standard.

5. Result and Discussion

Results for the field measurement were presented in tabular and graphical forms. The Table 1 to Table 5 below presented the measured radiation levels, while figure 1 to figure 5 presents the graphs of distance against the exposure limit radiated from base transceiver stations (BTS) for Kano Municipal, Nasarawa, Dala, Katsina and Dutse respectively.

Table 1. *Kano Municipal Radiation Levels.*

Distance (Meter)	MTN 950-955MHz	Glo 945-950MHz	Etisalat 890-895MHz	Airtel 955-960 MHz
	Power (mW/m^2)	Power (mW/m^2)	Power (mW/m^2)	Power (mW/m^2)
20	1.24	1.06	2.47	2.06
40	1.45	1.18	4.83	2.25
60	2.37	5.11	5.15	2.35
80	4.14	6.32	6.00	2.38
100	6.26	11.67	6.75	7.16
120	6.34	13.68	7.16	16.34
140	16.86	16.47	7.60	35.30
160	20.51	21.65	7.88	35.45
180	20.23	21.88	8.99	46.44
200	43.13	29.54	13.35	80.40
220	55.63	32.23	16.39	89.61
240	41.14	39.17	18.26	95.85
260	17.11	49.85	18.38	89.75
280	22.69	78.15	20.96	115.90
300	25.54	95.61	24.95	214.64
320	80.97	98.62	25.59	275.08
340	77.47	104.33	30.80	245.80
360	90.17	145.60	36.93	342.08
380	71.20	159.48	57.15	355.18
400	74.21	161.30	60.20	300.40
420	50.11	164.37	75.45	450.30
440	70.18	173.50	80.35	403.45
460	53.16	134.45	95.55	415.56

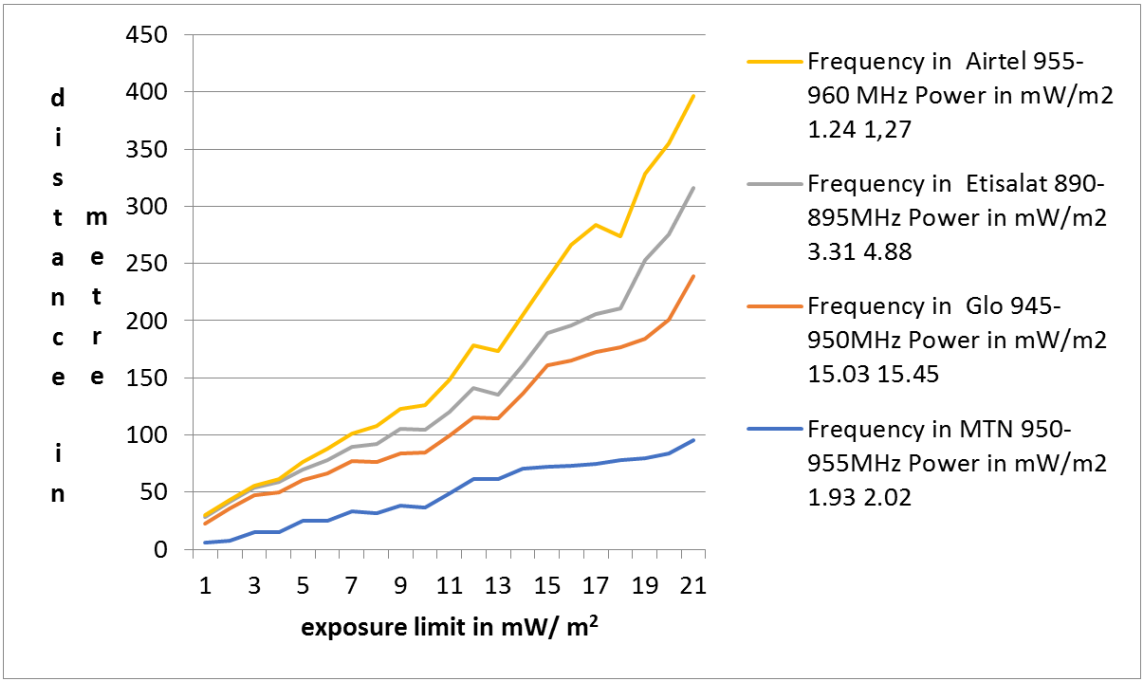

Figure 1. *Graph for Kano Municipal Exposure Limits.*

Table 2. *Nasarawa Radiation Levels.*

Distance (Meters)	MTN 950-955MHz	Glo 945-950MHz	Etisalat 890-895MHz	Airtel 955-960 MHz
	Power (mW/m^2)	Power (mW/m^2)	Power (mW/m^2)	Power (mW/m^2)
20	1.16	1.17	11.31	1.43
40	1.53	1.28	12.78	1.52
60	1.62	1.71	15.51	7.94
80	2.05	2.89	16.66	11.05
100	2.30	7.42	16.51	11.36
120	3.06	15.91	26.78	11.48
140	6.51	16.92	23.94	12.26
160	6.72	18.53	28.58	15.47
180	11.46	43.53	34.83	16.97
200	12.06	46.23	39.84	18.59
220	12.62	46.65	32.78	19.39
240	13,.36	58.23	43.93	22.95
260	14.12	59.31	47.98	23.31
280	17.60	62.50	49.80	25.18
300	20.32	63.49	60.53	30.16
320	21.38	74.93	62.30	31.13
340	22.27	90.35	64.84	31.29
360	24.41	92.08	65.03	38.59
380	26.50	108.89	68.78	39.67
400	30.33	120.96	67.55	56.47
420	31.16	135.45	70.62	71.03
440	48.11	150.34	75.66	76.43
460	50.56	162.85	78.56	84.27

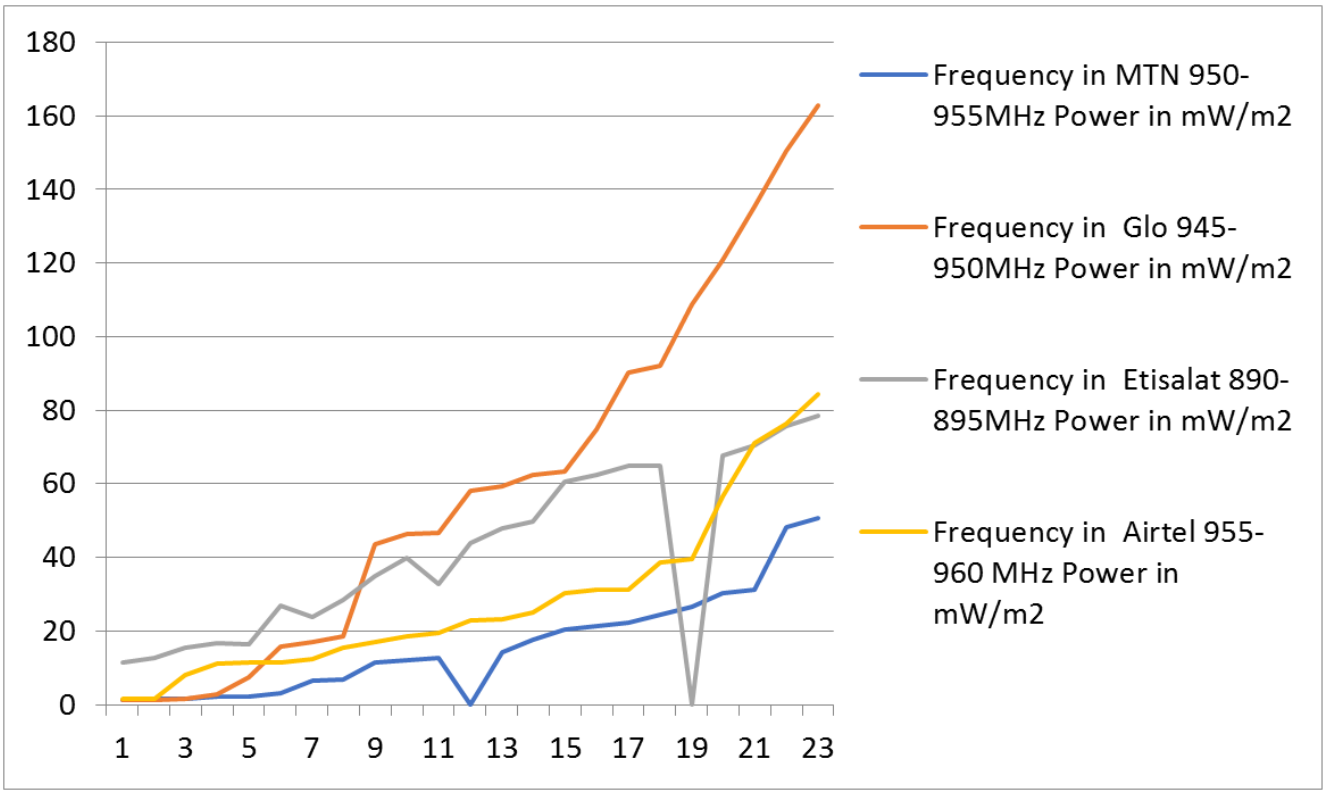

Figure 2. *Graph for Nasarawa Exposure Limits.*

Table 3. *Dutse Radiation Levels.*

Distance (Meters)	MTN 950-955MHz	Glo 945-950MHz	Etisalat 890-895MHz	Airtel 955-960 MHz
	Power (mW/m^2)	Power (mW/m^2)	Power (mW/m^2)	Power (mW/m^2)
20	1.93	15.03	3.31	1.24
40	2.02	15.45	4.88	1.27
60	6.00	16.65	5.35	1.67
80	7.25	28.44	6.02	1.70
100	15.09	32.40	6.17	1.96
120	15.30	34.77	8.72	2.25
140	24.79	35.68	8.90	7.04
160	25.23	41.02	11.45	10.48
180	33.64	43.82	12.27	11.69
200	31.76	44.50	15.90	15.33
220	37.89	45.53	22.05	17.70
240	36.34	48.47	19.63	21.64
260	48.59	50.67	21.41	27.89
280	61.11	54.53	25.10	37.28
300	61.22	53.41	20.26	38.10
320	70.41	65.71	24.49	44.46
340	71.86	88.87	28.15	47.78
360	72.78	92.48	30.35	70.30
380	75.08	97.49	32.96	77.75
400	77.78	98.61	34.24	62.80
420	79.89	104.39	68.61	75.89
440	84.05	116.62	74.92	79.42
460	95.25	143.80	76.72	80.45

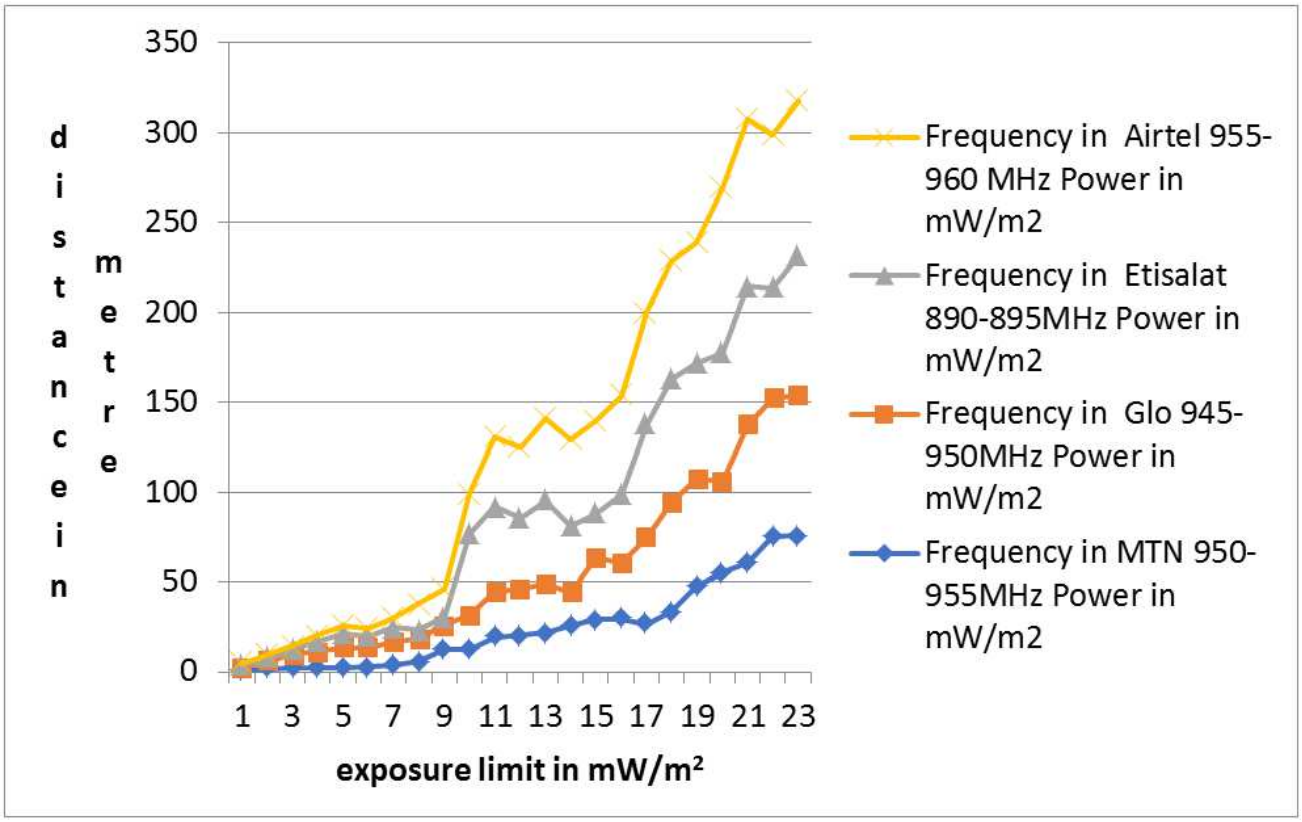

Figure 3. *Graph for Dutse Exposure Limits.*

Table 4. *Dala Radiation Levels.*

Distance (Meters)	MTN 950-955MHz	Glo 945-950MHz	Etisalat 890-895MHz	Airtel 955-960 MHz
	Power (mW/m^2)	Power (mW/m^2)	Power (mW/m^2)	Power (mW/m^2)
20	1.21	1.56	1.04	2.79
40	1.94	1.63	1.28	2.68
60	2.20	1.67	1.72	2.88
80	5.68	1.68	2.67	3.35
100	8.89	3.68	3.43	3.24
120	8.57	4.64	3.87	3.65
140	9.15	3.78	4.40	4.46
160	9.55	7.93	4.87	5.78
180	10.19	9.28	4.07	5.91
200	10.54	12.61	4.68	5.87
220	10.59	19.60	6.91	5.92
240	11.43	19.82	13.17	6.64
260	12.72	20.80	14.91	14.97
280	13.79	19.23	17.88	13.08
300	13.41	20.11	22.33	22.67
320	14.02	23.68	23.80	23.29
340	14.19	21.73	37.40	34.64
360	15.56	28.47	39.29	45.79
380	18.53	39.78	46.57	36.66
400	43.20	66.13	49.40	51.49
420	48.45	68.45	51.45	54.70
440	53.43	70.85	53.80	57.10
460	56.43	74.05	55.87	61.20

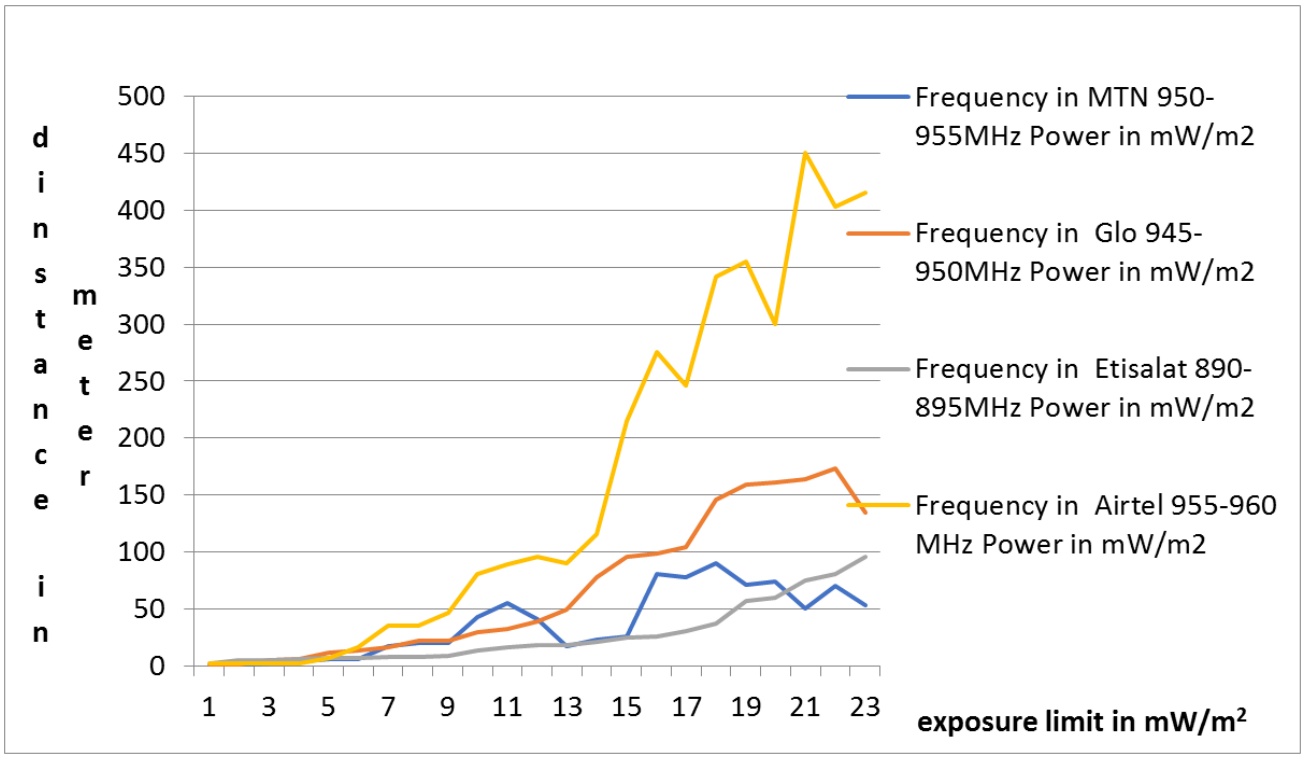

Figure 4. *Graph for Dala Exposure Limits.*

Table 5. *Katsina Radiation Levels.*

Distance (Meters)	MTN 950-955MHz	Glo 945-950MHz	Etisalat 890-895MHz	Airtel 955-960 MHz
	Power (mW/m^2)	Power (mW/m^2)	Power (mW/m^2)	Power (mW/m^2)
20	1.04	1.23	1.02	1.31
40	1.92	4.38	1.46	1.71
60	2.30	7.32	3.14	1.89
80	2.33	9.50	4.75	3.68
100	2.49	10.91	7.64	4.66
120	2.71	10.69	6.38	4.50
140	4.03	12.62	7.99	5.62
160	5.90	12.83	4.62	14.55
180	12.55	13.62	4.62	15.42
200	12.62	19.17	44.82	22.68
220	19.15	25.68	46.95	38.82
240	20.31	25.48	39.82	39.13
260	22.02	27.19	46.02	45.59
280	25.65	18.64	36.74	48.06
300	29.27	34.64	23.93	51.49
320	29.48	30.90	38.58	54.76
340	26.67	48.21	62.87	62.51
360	33.63	60.84	68.27	65.82
380	47.38	60.09	64.50	67.34
400	55.58	50.14	72.20	91.36
420	60.45	77.09	77.28	92.73
440	75.43	76.76	61.27	85.55
460	76.09	78.43	76.78	86.56

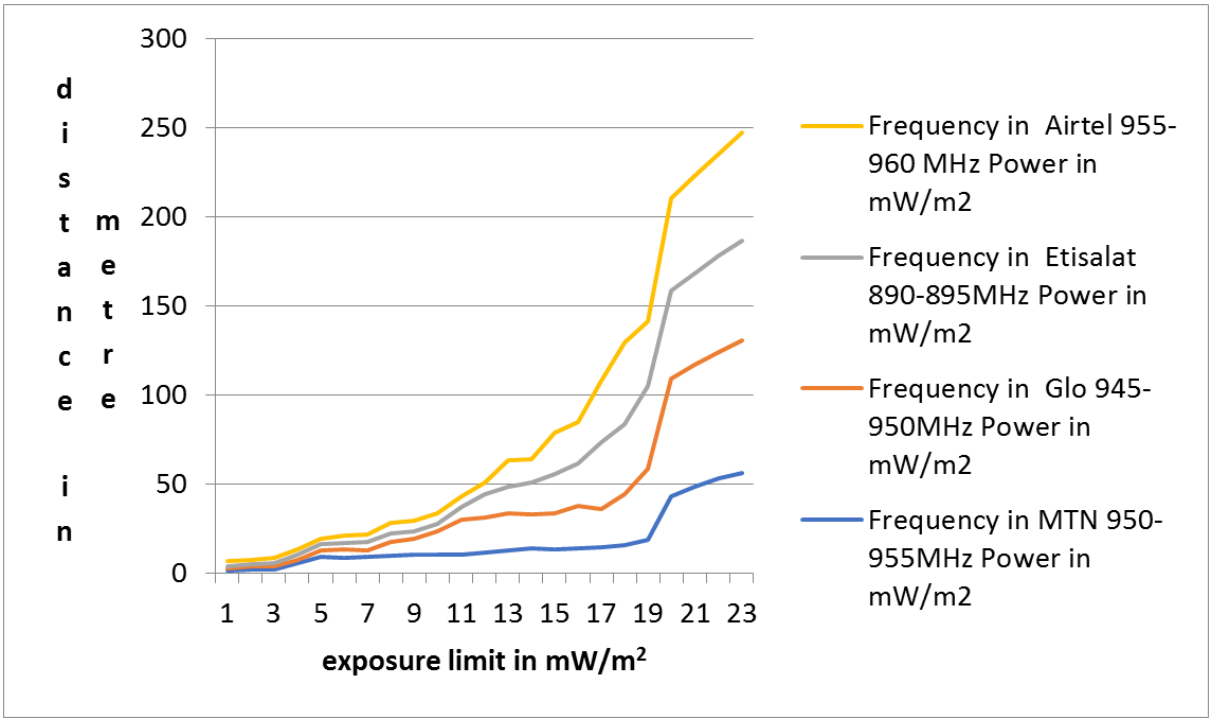

Figure 5. *Graph for Katsina Exposure Limits.*

From the graphs, result clearly shows that exposure limits for the GSM operators considered in this study decreases slightly at different rates over the measured distance. As the distances increases from the BTS there is significant decrease in the exposure limit. The results shows that the exposure limit from the base transceiver stations have an average of 17-70mW/m^2, which is far below the recommendation of International Commission on Non-Ionization Radiation

Protection (ICNIRP, 1998) of 4-9W/m^2 as the exposure limit for electromagnetic radiation from base transceiver stations for GSM 900MHz and 1800MHz.

6. Future Research Focus

The implementation of the 5G New Radio and 5G Core Network (5GC) is to assure certainty that they have flexibility to maintain the multiplicity of the new use cases at the same time making things easier for operations. Even though the strategic technology achievements are revealed as the sequence of investment opportunities, there exist no suggestion for product strategic plans that operators will adopt distinctive preliminary deployment measures. The novel 5G network technology strategy should be a flexible preparation procedure to sustain the premeditated and long investment planning, through corresponding short-term and long-term investment objectives alongside unambiguous technology resolutions across countries and regions. The fundamental philosophy is to guarantee that the forceful 5G network technology platform currently in place will be utilized to tackle and economically boost the subsisting use cases, and the foundation for reinvestment in addressing the subsequent technology waves. From the knowledge and principle of electromagnetism, human beings are constituted of substantial amount of oriented cells with diverse electromagnetic field attributes. The biological attributes of the human tissue under diverse electromagnetic radiative emission are studied and that had provided the basis upon which the current research on the effects of electromagnetic fields on the human body. The health and healthcare consequences of the frequency radio electromagnetic waves from 3G, 4G and 5G network technology base station deployment had formed the fundamental basis for current research.

On the several findings of the research, deploying 3G, 4G or 5G network technology under the ultra-frequency baseband above 20 GHz will produce effects such as heating up of the body tissues due to electromagnetic field inducement on the account that human body is dipolar in nature. The effects will extend to produce dielectric polarization, ionic polarization, interfacial polarization and orientational polarization. This is generally on the account that variations on dielectric properties of biological tissues with the frequency of the electromagnetic field inducement are very dissimilar. While it is very imperative to determine the frequency distribution in deploying the novel 5G network to avoid adverse dielectric dispersion that may flow into the human body. The future research will fundamentally consolidate on the current findings to ensure that subsequent telecommunication base station infrastructures installation does not constitute health hazard to the society.

7. Conclusion and Recommendation

Electromagnetic field emission from GSM base stations in north-western Nigeria was measured, analyzed and assessed. The assessment results confirmed that the GSM service providers in the selected states comply with health based exposure recommendations by ICNIRP standard. It can be concluded that, people living in those communities are safe and secure to use the services provided by *Airtel, Glo, MTN and Etisalat* telecommunication companies. It is recommended that similar study should be carried out at major cities in Nigeria, where there is complex, sophisticated and highly congested traffic base stations. Similarly, medical survey study should be carried out on the people living within the vicinity of these telecommunication tools in order to ascertain the adverse health effect or otherwise.

Acknowledgements

The authors wish to acknowledge the Tertiary Education Trust Fund (TETFUND Nigeria) for sponsoring this research through the Institution Based Research (IBR) intervention.

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