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COMPARATIVE ANALYSIS OF RADIOFREQUENCY RADIATION EMISSIONS AMONG MAJOR SMARTPHONE BRANDS

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ABSTRACT

This study presents a comprehensive comparative analysis of radiofrequency (RF) radiation emissions from major smartphone brands, focusing on measured RF power and power density. A dataset was formulated by measuring RF power emissions from randomly selected eleven (11) smartphones from different brand at distance of 5 mm using a handheld spectrum analyzer. Tecno Camon has the highest power density of 2.0753 nW/cm2 and Gionee F103 has the lowest power density of 0.4991 nW/cm2. All tested smartphones meet the safety standards set by regulatory bodies Federal Communications Commission (FCC) of 1.0 mW/cm2 and the International Commission on Non-Ionizing Radiation Protection (ICNIRP). The outcomes of this research will guide public in making informed decisions regarding smartphone usage and radiation safety.

Keywords: Radiation, Radio-frequency, Smartphones, Spectrum Analyzer, Human health

INTRODUCTION

The exponential growth of mobile telecommunication technologies has led to a significant surge in smartphone usage across the globe, particularly in developing nations such as Nigeria (Ajao et al., 2021). With the proliferation of smartphones, there is a concomitant rise in concerns over the emission of radiofrequency (RF) radiation, which poses potential health and environmental hazards (Sivani & Sudarsanam, 2012). RF radiation is a non-ionizing electromagnetic wave typically emitted from smartphones during operations such as voice calls, data transfer, and wireless connections (Sultan et al., 2015). Unlike ionizing radiation, Chemical bonds are not broken by RF radiation; however, prolonged or intense exposure may lead to thermal and non-thermal biological effects (Hardell & Carlberg, 2015). Radiofrequency radiation is a form of electromagnetic radiation, typically generated by electronic devices such as mobile phones, Wi-Fi routers, and Bluetooth devices. Mobile phones function within the range of 100 MHz to 100 GHz, with most consumer smartphones using frequencies around 900 MHz, 1800 MHz, and more recently, 5 GHz for 4G and 5G networks. Radiofrequency Radiation (RF) interacts with biological tissues, primarily by inducing heating effects (Bello *et al.,* 2021). The radiofrequency power density is a measure of the power of an RF signal spread over a given area, typically expressed as power per unit area (W/m^2).

In Nigeria, the increasing affordability of smartphones has opened up the telecommunications market, with several major brands dominating consumer preferences (Olisah et al., 2022). These devices, though similar in function, vary significantly in design parameters such as antenna placement, transmission strength, frequency bands, and specific absorption rates (SAR), which influence the magnitude of RF radiation power and power density they emit (Kumar et al., 2014). Consequently, understanding the comparative emissions from these brands is essential for ensuring public safety and guiding regulatory frameworks (Adejoh et al., 2020). Power and power density are two key parameters in evaluating RF exposure. Power refers to the total energy transmitted per unit time, while power density measures the energy distributed over a unit area (ICNIRP, 2020). Higher values of either parameter can elevate the risk of tissue heating and possible health complications, particularly during prolonged usage or close body contact (Redmayne & Johansson, 2014). Although global agencies such as the International Commission on Non-Ionizing Radiation Protection (ICNIRP) and the Federal Communications Commission (FCC) have set exposure limits, there is still ambiguity surrounding the cumulative and long-term impacts of radiofrequency emissions from mobile devices (Zothansiama et al., 2017).

Recent studies in Nigeria have begun exploring the levels of RF radiation in urban environments (Usikalu et al., 2018), but there remains a paucity of comparative assessments among different smartphone brands available in Nigeria. This disparity is crucial given Nigeria's distinct climate, infrastructure, and socioeconomic circumstances, which could affect RF exposure and propagation patterns (Ezenwaji et al., 2021). Moreover, most available smartphones in Nigeria are either imported or locally assembled, yet there is little independent validation of their compliance with recommended RF emission standards (Ayeni et al., 2019). The need for such comparative analysis becomes even more urgent with the increased usage of smartphones among youths, students, and professionals, many of whom are unaware of potential radiation risks (Olowookere et al., 2020). Studies have linked excessive mobile phone use to symptoms such as headaches, fatigue, sleep disturbances, and possible neurophysiological disorders (Meo et al., 2019). Although causality remains debated, preventive and precautionary principles necessitate ongoing scientific evaluations, especially in countries with limited regulatory enforcement (Onyeonoru & Aina, 2022). Additionally, differences in power density levels across smartphone models may be influenced by operating frequency, network connectivity quality, background applications, and even the use of accessories such as earphones and cases (Dasdag & Akdag, 2016). Therefore, a systematic and controlled measurement of RF emissions under standardized conditions is necessary to generate reliable data that can inform both consumers and policymakers (Fernández et al., 2019).

The present study seeks to conduct a comparative analysis of RF radiation power and power density emissions from major smartphone brands in Nigeria using calibrated broadband RF meters and standardized protocols. In Nigeria, where regulatory monitoring is still uneven and public understanding of electromagnetic field (EMF) safety is low, this research is crucial (Bamgbose et al., 2023). By highlighting the variability in emissions across brands, this study aims to contribute toward evidence-based decision-making in smartphone use and regulation. The study aligns with international calls for increased transparency in mobile device emissions and their health implications (Russell, 2018). As the Nigerian government continues to promote digital inclusion and mobile technology as part of its development agenda, safeguarding users from potential RF hazards must be integrated into national telecommunication and health policies (NCC, 2021).

This investigation responds to a pressing need for localized scientific data on RF emissions in Nigeria. It offers a robust comparative framework for evaluating the safety of commonly used smartphones, thereby reinforcing public health advocacy, regulatory compliance, and consumer protection.

MATERIALS AND METHODS

Experimental Design

This research adopted an experimental and comparative approach to analyze the radiofrequency (RF) radiation power and power density emissions from randomly selected smartphone brands within the Main Campus of Ahmadu Bello University Nigeria. The study focused on measuring real-time emissions under controlled conditions to ensure accuracy, reliability, and reproducibility of data. RF radiation measurements were conducted using a calibrated handheld spectrum analyzer (Fig. 1). The spectrum analyzer calibration was verified using a reference signal generator certified by the Nigerian Communications Commission (NCC) standards unit prior to measurements. The experimental design adopted Bello *et al.* (2021) procedure.

Data Collection

Eleven major smartphone brands were randomly selected for analysis. All measurements were performed in a controlled indoor lab environment free from external RF interference. Smartphones were placed at a 5 mm fixed distance from the spectrum analyzer, this was done to simulate the distance at which the phone is held to the ear during a phone call ((Bello *et al.,* 2021). Fixed distance 5 mm was accurately maintained throughout the measurement. The measurement was done between 0 and 15 min. and time frame of 5 min. All measurements were taken at call mode. Each measurement was taken immediately after a call is initiated and lasted for 15 min. at a span of 5 min. The spectrum analyzer is capable of measuring received radiated power in decibels relative to mill watt (dBm). These powers (dBm) were converted to power (mW) using the relation below. (Bello *et al.,* 2021).

$$Power\ (mW) = 1m \times 10^{\frac{p(dBm)}{10}} \quad (1)$$

Then the values were then converted to power density using the relation

$$Power\ density\ (nW/cm^2) = \frac{power(mW)}{\pi r^2} \quad (2)$$

where r is distance between the smartphone and the analyzer; *r = 5mm*

Figure 1: A Hand-held Spectrum Analyzer

RESULTS AND DISCUSSION

The study examined and compared the radiofrequency (RF) radiation power and power density emissions from selected major smartphone brands commonly used in Nigeria. Results of radiofrequency power obtained were shown in table 1. This displays the radiation emitted by the smartphones at a fixed distance of 5 mm and interval of 5 minute each, from the spectrum analyzer's antenna, measured power in decibels (dBm).

Table 1: The Power(dBm) from Different Models of Smartphones at a Distance of 5 mm

Brand	Model	0 min	5 min	10 min	15 min
TECNO	Camon 11	-57.02	-58.08	-58.94	-57.69
	Spark 2	-60.81	-61.03	-58.41	-58.41
	Pouvoir 3	-59.71	-62.60	-63.38	-62.93
INFINIX	S4	-62.01	-60.88	-63.97	-61.91
	Hot 6	-60.11	-64.22	-63.15	-63.02
SAMSUNG	C9 pro	-57.19	-58.66	-57.70	-58.22
IPHONE	iPhone 6	-60.92	-64.32	-61.09	-61.32
	iPhone 6s	-60.46	-61.87	-64.40	-63.58
HTC	Desire 10 pro	-61.05	-65.55	-64.02	-60.81
LG	G5	-61.87	-60.04	-60.69	-60.13
GIONEE	F103	-62.14	-64.21	-65.60	-65.19

The results obtained in this work have confirmed the presence of radiation from the 11 smartphones investigated. Table 2 shows the radiation power density level from these smartphones ranges from 2.0753 $(nW/cm^2)$to 0.4991 (nW/cm^2). Measurements were taken each at a distance of 5 mm from the smartphone to the spectrum analyzer's antenna. Measurements were also taken immediately after a call is initiated and lasted for 15 min. at every 5 min. each. There is a slight variation from the measured radiation for the different smartphone models investigated. This may be due to the various materials that were used in the manufacturing of these smartphone's antennae and also to the model type.

Table 2: Shows the Calculated Values of Power Densities(nW/cm^2) and the Average Power Density

Brand	Model	0 min.	5 min.	10 min.	15 min.	Average power(nW/cm^2)
TECNO	Camon 11	2.5285	1.9808	1.6249	2.1670	2.0753
	Spark 2	1.0565	1.0043	1.8359	1.8024	1.4248
	Pouvior 3	1.3610	0.6996	0.5846	0.6484	0.8234
INFINIX	S4	0.8014	1.0396	0.5103	0.8837	0.8088
	Hot 6	1.2412	0.4818	0.6164	0.6351	0.7436
SAMSUNG	C9 pro	2.4314	1.7332	2.1619	1.9180	2.0611
IPHONE	iPhone 6	1.0300	0.4708	0.9905	0.9394	0.8577
	iPhone 6s	1.1451	0.8277	0.4622	0.5583	0.7483
HTC	Desire 10 pro	0.9997	0.3547	0.5045	1.0565	0.7289
LG	G5	0.8277	1.2614	1.0861	1.2355	1.1027
GIONEE	F103	0.7778	0.4829	0.3506	0.3853	0.4991

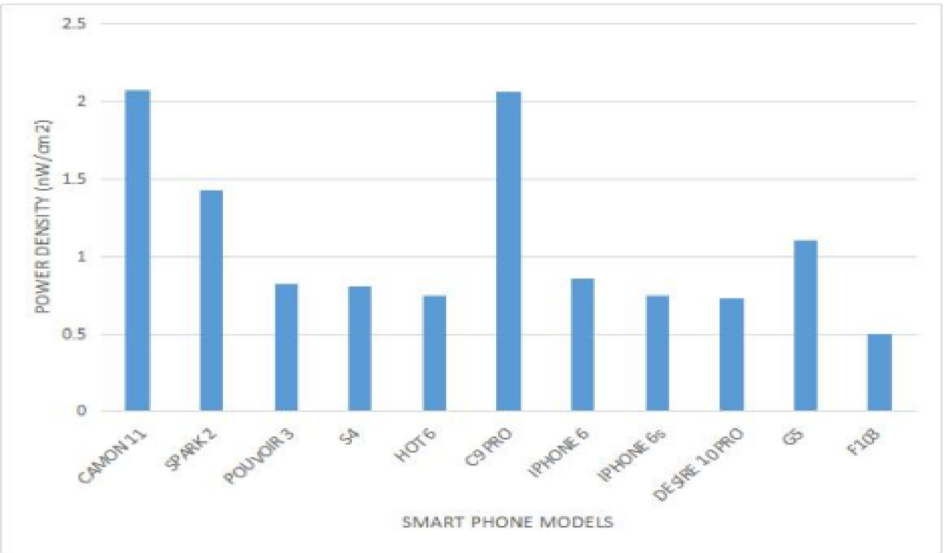

Figure 2: Variation of Power Density among Different Smartphone Models

From figure 2 the highest radiation measured was from the Tecno Camon 11 model to be 2.0753 (nW/cm^2), the Samsung C9 PRO model was 2.0611 (nW/cm^2) and the lowest radiation measured was from the Gionee F103 model and was 0.4991 (nW/cm^2). Tecno, Samsung, and the LG brand measured the highest radiation. iPhone, Infinix, and HTC brands measured intermediate and the least radiation level from the Gionee brand.

Table 3: The Smartphones Power Densities(nW/cm^2) and International Standard Limit

Brand	Model	Ave. Power density(nW/cm^2)	FCC Limit(mW/cm^2) (FCC 2020)	ICNIRP Limit(W/m^2) (ICNIRP 2020)	Status
TECNO	Camon 11	2.0753	1	10	Safe
	Spark 2	1.4248	1	10	Safe
	Pouvior 3	0.8234	1	10	Safe
INFINIX	S4	0.8088	1	10	Safe
	Hot 6	0.7436	1	10	Safe
SAMSUNG	C9 pro	2.0611	1	10	Safe
IPHONE	iPhone 6	0.8577	1	10	Safe
	iPhone 6s	0.7483	1	10	Safe
HTC	Desire 10 pro	0.7289	1	10	Safe
LG	G5	1.1027	1	10	Safe
GIONEE	F103	0.4991	1	10	Safe

The obtained values of the calculated power densities from this work showed that the RF radiation levels from these smartphones' models are still within the (F.C.C.) recommended power density limit of $1.0(m\,W/cm^2)$ and ICNIRP limit as shown in table 3. The power density radiation level is extremely small and so low compared to the international standard exposure limit of $1.0(m\,W/cm^2)$. The concept of no safe dose of radiation remains unclear. This is supposed to be considered as this is not the only non-ionizing RF radiation that we are exposed to. A power density of 2.0753 (nW/cm^2) may seem very minimal and inconsequential, but it is not when considering the amount of time, we spend daily on our smartphones. The distance from the exposed tissue to the phone's antenna is another point to consider, as heat shocks and vibrations due to destructive interference may have an impact on the body's exposed area. Continuous accumulation of these radiations on that exposed tissue or body part is what causes the effects; distance from base stations also plays a major role. The smartphones which recorded a higher level of radiation were found to be of newer or latest models, latest models are known to have stronger antenna strength to support the faster network bands like the 3G and 4G and the upcoming 5G network. This may mean that the newer smartphones might emit more radiation compared to the older models of smartphones. The analysis power densities from this work showed that the RF radiation levels from these smartphones' models are still within safe limit of international (FCC) standard. There is need for enhanced public enlightenment and potentially regulatory reforms that mandate transparency in RF emission ratings and power density labeling on smartphone to the public.

CONCLUSION

The comparative analysis of radiofrequency (RF) radiation power and power density emissions among major smartphone brands in Nigeria has revealed insignificant variations in emission levels that reflect the design philosophies and radiation management strategies of different manufacturers. Eleven (11) widely used brands were tested across call operational modes and lasted for 15 min. at time frame of 5 min and distances 5 mm from the source. Results consistently showed that Tecno Camon 11 model showed a high level of radiation of 2.0753 $n\,W/cm^2$, the least was obtained from the Gionee F103 model of value 0.4991 $n\,W/cm^2$. The findings shows that all smartphones tested operate within the internationally accepted safety thresholds set by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) and Federal Communications Commission (FCC).

This study also extends into the realm of public health policy, technology regulation, and consumer advocacy. In a country like Nigeria, where the usage of mobile phones is exceedingly high and usage is not often accompanied by radiation safety education, there is a significant knowledge gap. Users rarely consider RF emission levels when purchasing smartphones, focusing instead on cost, battery life, and camera quality. More public education is required, as are possible legislative changes that would require the public to be informed about RF emission ratings and power density labels on smartphones.

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