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Evaluation of Electromagnetic Field Exposure Level from Mobile Phones and Its Health Risks

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ABSTRACT

This study investigated the electromagnetic field (EMF) exposure and Specific Absorption Rate (SAR) levels associated with different mobile phone models operating at frequencies of 900 MHz and 2100 MHz. The objective was to assess the electric field strength, magnetic field strength, and power density emitted by these devices, and to determine the potential impact of mobile phone radiation on human health. Using an EMF Multi-Function Meter (GQ EMF-390V2 Electronics), measurements of the electric field (E), magnetic field (H), and power density (S) were obtained. The specific absorption rate (SAR) and health risk index (HRI) were computationally analyzed from dielectric and density data for seven (7) head tissues and the measured electric field over a range of popular mobile phone models and compared their EMF exposure levels against the safety limits set by the International Commission on Non-Ionizing Radiation Protection (ICNIRP). The study found that while most mobile phones complied with ICNIRP safety standards, significant differences in radiation emission were observed between models, with certain devices exceeding recommended SAR thresholds. The findings suggested that radiation exposure varies across phone designs and operating frequencies, with potential implications for long-term health, especially in sensitive tissue areas like the brain and cerebrospinal fluid. This study indicated the importance of adhering to EMF safety guidelines and encourages consumers to be aware of SAR values when selecting mobile devices, particularly those frequently used close to the head.

Keyword: Electromagnetic field exposure, Specific Absorption Rate, Health Risk Index, Head tissues, Mobile phones

INTRODUCTION

The rapid increase in smartphone ownership and use has solidified the significance of mobile phones in modern culture. Recent figures indicate that 6.6 billion persons, or 83.72% of the global population, own smartphones, a notable rise from 3.7 billion users (49.40%) in 2016 (Ahmad & Shaharun, 2023). In addition to conventional communication, mobilephones have features like internet access, Bluetooth, and digital information exchange, making them important (Akpolile & Ugbede, 2019). Nonetheless, their functionality is intrinsically dependent on electromagnetic field (EMF) radiofrequency (RF) radiation, which is the foundation of all wireless technologies (Ayinmode & Farai, 2013; Akpolile & Ugbede, 2019).

Mobile communication depends on the exchange of data via radio waves, with networks reaching almost the whole world (Akbal et al., 2012). Although electromagnetic waves are pervasive, their potential health effects often escape public awareness (Damian, 2011; Buckus et al., 2014). Studies indicates that electromagnetic radiation (EMR) emitted by mobile phones and base station antennas may impact human health at the cellular level (Januševičienė & Venckus, 2011; Paulauskas & Klimas, 2011; Akeju et al., 2016). At radio frequencies, EMF enters the human body, with exposure quantified using the Specific Absorption Rate (SAR), a metric signifying energy absorbed per kilogram of tissue (Hillert et al., 2006; Zhang & Alden, 2011).

Proximity to mobile phones during operation exposes users to substantial electromagnetic fields (Buckus et al., 2014). The highest radiation intensity is seen within 1–10 cm from the antenna, with peak absorption occurring in epidermal layers at a depth of 1 cm (Baltrenas et al., 2011). Although radiation levels decrease dramatically during standby mode, proximity to base stations also modifies exposure, with shorter distances related to lower radiation levels (Buckus et al., 2014). The electromagnetic fields created by mobile phones, whether steady analog transmissions or digital-pulsed fields, interact with biological tissues. This interaction may generate molecular alterations and thermal impacts, depending on parameters such as radiation intensity, exposure time, and individual biological features (Grigoriev, 2010; Lin, 2002; Buckus et al., 2014).

The increase in mobile phone usage has led to elevated levels of ambient electromagnetic pollution, prompting assessments of their safety (Mousa, 2011; Buckus et al., 2014; Ahmad & Shaharun, 2023). Dosimetric metrics, including power density (W/m^2), electric field strength (V/m), magnetic field strength (A/m), and SAR, are important for measuring RF radiation exposure (Ayinmode & Farai, 2013; Osaigbovo & Isabona, 2018; Akpolile & Ugbede, 2019). Regulatory bodies such as the International Commission on Non-Ionizing Radiation Protection (ICNIRP), the Federal Communications Commission (FCC), and the Institute of Electrical and Electronics Engineers (IEEE) have established SAR limits to mitigate risks associated with tissue heating, particularly for frequencies between 3 kHz and 300 GHz (Zhang & Alden, 2011; Akpolile & Ugbede, 2019; Ahmad & Shaharun, 2023).

Given the extensive usage of mobile phones and improvements in wireless technology, the public is increasingly exposed to RF radiation. This underscores the need of examining the RF properties of different phone manufacturers and determining SAR values in human tissues. Such studies are vital for understanding the possible health repercussions of cell phone use. Accordingly, this work intends to measure the electric field (E-field), magnetic field (H-field), and power density of regularly used mobile phones, as well as computationally analyse SAR values and health risk index in various tissues of the head.

MATERIALS AND METHOD

Accurate dosimetric assessment of electromagnetic RF fields is essential for protecting humans from potential health hazards. Field measurements, which utilize electromagnetic RF survey meters or detectors, are typically preferred for on-the-spot and precise evaluations of field quantities at various points of interest. In this study, measurements of the electric field (E), magnetic field (H), and power density (S) were conducted on 34 mobile phones of various models and brands owned by individuals in Delta State, Nigeria. The measurements were performed using an EMF Multi-Function Meter (GQ EMF-390V2 Electronics) in an isolated unit to minimize interference from other RF sources. Background RF field levels were recorded for each measurement and subsequently subtracted to ensure accuracy. The recorded values were compared against internationally established standards for electromagnetic field exposure limits. To quantify the rate of RF radiation absorption in different head tissues, the Specific Absorption Rates (SAR) were calculated. The SAR values were derived using the measured E-field strength, along with the dielectric properties of the head tissues—relative permittivity (ε), electrical conductivity (σ), and density (ρ)—based on the formula:

$$\mathrm{SAR} = \frac{\sigma E^2}{\rho} \tag{1}$$

where σ, E and ρ indicates the electrical conductivity of the biological tissue in (S/m), Electric field intensity emitted by the mobile phone in (V/m) and the density of the biological tissue in (kg/m^3). Calculations were performed at two standard frequencies, 900 MHz and 2100 MHz, reflecting common operating frequencies for mobile phones. The study focused on analyzing the Specific Absorption Rate (SAR) in several head tissues, including the skin, fat, skull, dura mater, brain, cerebrospinal fluid (CSF), and muscle. The dielectric characteristics and densities of various tissues were acquired from Osaigbovo and Isabona (2018) and reported in Table 1. The health risk index (HRI), an important risk indicator, was computed in conformity with the criteria stated by Khurana et al. (2009), where the maximum permissible SAR value as per the International Commission on Non-Ionizing Radiation Protection (ICNIRP) is 2 W/kg over 10 g of tissue. To examine the correlations among electromagnetic frequency factors and their effect on SAR, a correlation matrix was developed. Computational analysis and data visualization were accomplished utilizing the Python programming language in the ANACONDA environment, notably using the Spyder development tool (Sivapriya et al., 2019). Python tools, such as Matplotlib and Seaborn, played a vital role in displaying massive datasets via maps, plots, and trend graphs, allowing effective understanding and transmission of findings. These technologies are essential for comprehending complicated data patterns and making educated choices in data science. The choice of the programming language was because it is at the core of the growing economy of today, owing to its speed, accuracy, and reliability, and because it is open-source and user-friendly, making it accessible at all times (Akpojotor and Ehwerhemuepha, 2012; Omoriwhovo et al., 2022; Oghenekome and Asare, 2025).

Table1. Dielectric Properties of the Tissues at 900 MHz and 2100 MHz (Osaigbovo and Isabona, 2018)

	900 MHz		2100 MHz		Density
	ε_r	σ (S/m)	ε_r	σ (S/m)	ρ (kg/m^3)
CSF	68.6	2.41	66.76	3.15	1030
DURA	44.4	0.96	42.49	1.47	1030
Brain	45.80	0.77	43.05	1.31	1030
Muscle	55.90	0.97	54.04	1.57	1480
Skin	43.88	0.86	38.43	1.31	1010
Skull	20.80	0.34	15.28	0.51	1850
Fat	11.30	0.11	5.32	0.09	920

RESULTS

The study presents the measured values of electric field strength (E-field), magnetic field strength (H-field), and power density for various mobile phone models at different frequencies, along with the Specific Absorption Rate (SAR) for human head tissues as presented in Table 2 and 3 respectively. The results are categorized based on their operating radio frequencies (900 MHz, 1800 MHz, and 2100 MHz). Tables 4 outlines the ICNIRP recommended safety limits for E-field and H-field strengths, power density, and SAR values at the specified frequencies.

Table 2: E-field, H-field, Power density values of other phone models and SAR to different tissues of the head at 900 MHz

Phone Model	E (V/m)	H (A/m)	S (mW/m^2)	SAR values of tissues in the head region (W/kg)						
				CSF	DURA	Brain	Muscle	Skin	Skull	Fat
Infinix Hot	1.0	12.75	20.4553	0.002340	0.000932	0.000748	0.000655	0.000851	0.000184	0.000120
Infinix Smart	1.0	0.65	20.0925	0.002340	0.000932	0.000748	0.000655	0.000851	0.000184	0.000120
Infinix Note	1.0	0.60	5.1200	0.002340	0.000932	0.001427	0.000655	0.000851	0.000184	0.000120
Vivo Y20	3.0	0.50	9.4710	0.021058	0.008388	0.006728	0.005899	0.007663	0.001654	0.001076
Tecno Pouvoir	1.3	0.60	18.0530	0.003954	0.001575	0.001263	0.001108	0.001439	0.000311	0.000202
Tecno Spark	1.0	0.60	12.1940	0.002340	0.000932	0.000748	0.000655	0.000851	0.000184	0.000120
Tecno Camon	1.0	0.60	12.9900	0.002340	0.000932	0.000748	0.000655	0.000851	0.000184	0.000120

Tecno F1	3.0	0.60	201.6000	0.021058	0.008388	0.006728	0.005899	0.007663	0.001654	0.001076
Tecno POP	2.0	0.85	4.7040	0.009359	0.003728	0.002990	0.002622	0.003406	0.000735	0.000478
OPPO	2.5	0.60	87.7650	0.014624	0.005825	0.004672	0.004096	0.005322	0.001149	0.000747
Redmi	1.0	0.50	92.6000	0.002340	0.000932	0.000748	0.000655	0.000851	0.000184	0.000120
Redmi Note	1.5	0.60	7.2110	0.005265	0.002097	0.001682	0.001475	0.001916	0.000414	0.000269
Nokia 61T	1.0	0.50	2.9320	0.002340	0.000932	0.000748	0.000655	0.000851	0.000184	0.000120
Itel X16 Pro	0.7	0.60	1.6320	0.001147	0.000457	0.000366	0.000321	0.000417	0.000090	0.000059
Blade V8 Vita	4.5	0.60	470.2000	0.047381	0.018874	0.015138	0.013272	0.017243	0.003722	0.002421
Galaxy	1.3	0.55	46.5450	0.003954	0.001575	0.001263	0.001108	0.001439	0.000311	0.000202
Samsung Galaxy	1.0	0.53	32.5380	0.002340	0.000932	0.000748	0.000655	0.000851	0.000184	0.000120
Samsung	1.0	0.50	11.2200	0.002340	0.000932	0.000748	0.000655	0.000851	0.000184	0.000120
Huawei P20 Lite	1.0	0.60	14.1400	0.002340	0.000932	0.000748	0.000655	0.000851	0.000184	0.000120
iPhone 6	2.0	0.50	2.9840	0.009359	0.003728	0.002990	0.002622	0.003406	0.000735	0.000478
iPhone 6 Plus	2.0	0.60	11.3900	0.009359	0.003728	0.002990	0.002622	0.003406	0.000735	0.000478
iPhone 6s	1.0	0.16	7.1830	0.002340	0.000932	0.000748	0.000655	0.000851	0.000184	0.000120
iPhone 7	1.0	0.53	29.4680	0.002340	0.000932	0.000748	0.000655	0.000851	0.000184	0.000120
iPhone 7 Plus	1.0	0.60	6.1900	0.002340	0.000932	0.000748	0.001061	0.000851	0.000184	0.000120
iPhone 8 Plus	1.7	0.53	19.5030	0.006762	0.002694	0.002160	0.001894	0.002461	0.000531	0.000346
iPhone X	1.2	0.53	18.8760	0.003369	0.001342	0.001077	0.000944	0.001226	0.000265	0.000172
iPhone XS Max	1.7	0.60	67.0680	0.006762	0.002694	0.002160	0.001894	0.002461	0.000531	0.000346
iPhone 11 Pro	1.0	0.50	19.1505	0.002340	0.000932	0.000748	0.000655	0.000851	0.000184	0.000120
iPhone 11 Pro Max	1.0	0.57	57.8600	0.002340	0.000932	0.000748	0.000655	0.000851	0.000184	0.000120
iPhone 12	1.0	0.60	21.2700	0.002340	0.000932	0.000748	0.000655	0.000851	0.000184	0.000120
iPhone 12 Pro	1.0	0.60	81.7700	0.002340	0.000932	0.000748	0.000655	0.000851	0.000184	0.000120
iPhone 12 Pro Max	1.0	0.56	116.6500	0.002340	0.000932	0.000748	0.000655	0.000851	0.000184	0.000120
iPhone 13	2.0	0.50	18.5300	0.009359	0.003728	0.002990	0.002622	0.003406	0.000735	0.000478

Table 3: E-field, H-field, Power density values of other phone models and SAR to different tissues of the head at 2100 MHz

Phone Model	E (V/m)	H (A/m)	S (mW/m^2)	SAR values to tissues in the head region (W/kg)						
				CSF	DURA	Brain	Muscle	Skin	Skull	Fat
Infinix Hot	1.0	12.75	20.4553	0.003058	0.001427	0.001272	0.001061	0.001297	0.000276	0.000098
Infinix Smart	1.0	0.65	20.0925	0.003058	0.001427	0.001272	0.001061	0.001297	0.000276	0.000098

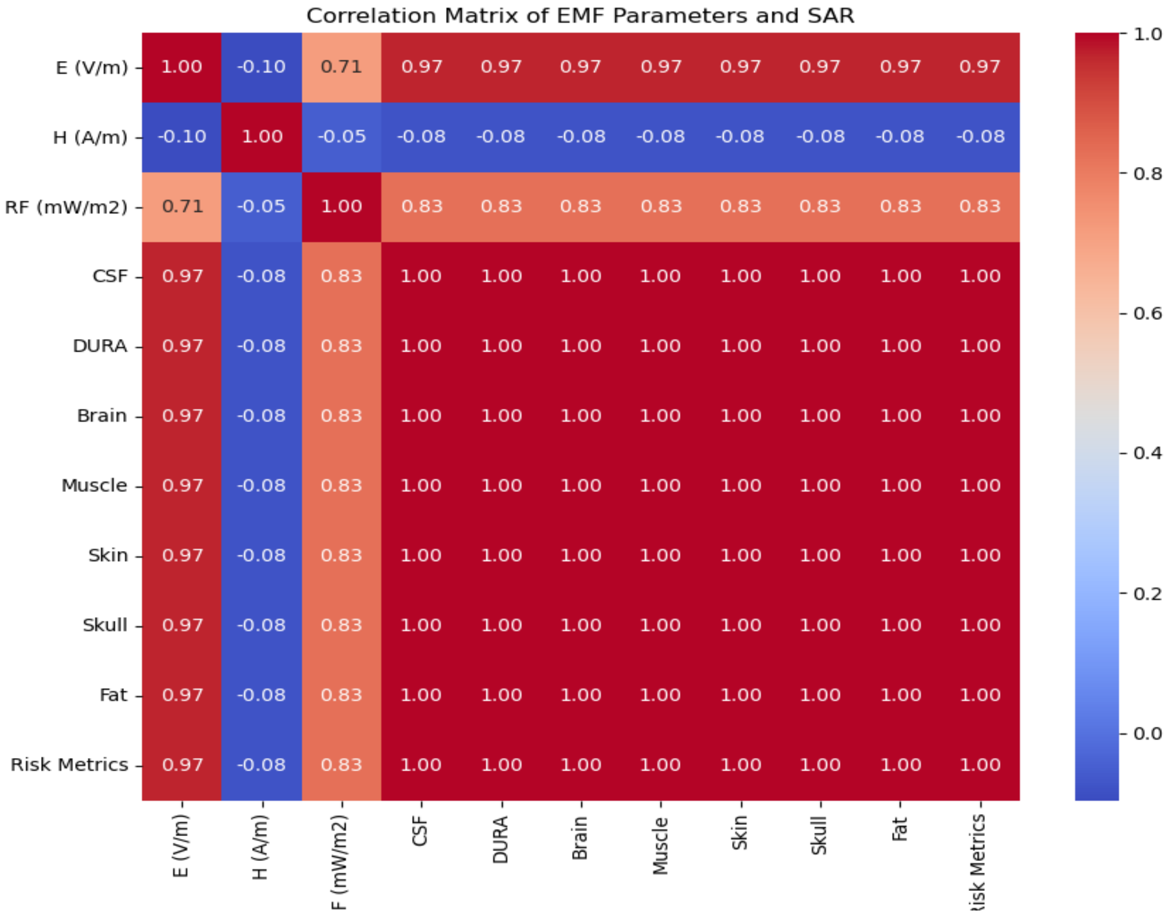
Infinix Note	1.0	0.60	5.1200	0.003058	0.001427	0.001272	0.001061	0.001297	0.000276	0.000098
Vivo Y20	3.0	0.50	9.4710	0.027524	0.012845	0.011447	0.009547	0.011673	0.002481	0.000880
Tecno Pouvoir	1.3	0.60	18.0530	0.005168	0.002412	0.002149	0.001793	0.002192	0.000466	0.000165
Tecno Spark	1.0	0.60	12.1940	0.003058	0.001427	0.001272	0.001061	0.001297	0.000276	0.000098
Tecno Camon	1.0	0.60	12.9900	0.003058	0.001427	0.001272	0.001061	0.001297	0.000276	0.000098
Tecno F1	3.0	0.60	201.6000	0.027524	0.012845	0.011447	0.009547	0.011673	0.002481	0.000880
Tecno POP	2.0	0.85	4.7040	0.012233	0.005709	0.005087	0.004243	0.005188	0.001103	0.000391
OPPO	2.5	0.60	87.7650	0.019114	0.008920	0.007949	0.006630	0.008106	0.001723	0.000611
Redmi	1.0	0.50	92.6000	0.003058	0.001427	0.001272	0.001061	0.001297	0.000276	0.000098
Redmi Note	1.5	0.60	7.2110	0.006881	0.003211	0.002862	0.002387	0.002918	0.000620	0.000220
Nokia 61T	1.0	0.50	2.9320	0.003058	0.001427	0.001272	0.001061	0.001297	0.000276	0.000098
Itel X16 Pro	0.7	0.60	1.6320	0.001499	0.000699	0.000623	0.000520	0.000636	0.000135	0.000048
Blade V8 Vita	4.5	0.60	470.2000	0.061930	0.028900	0.025755	0.021481	0.026265	0.005582	0.001981
Galaxy	1.3	0.55	46.5450	0.005168	0.002412	0.002149	0.001793	0.002192	0.000466	0.000165
Samsung Galaxy	1.0	0.53	32.5380	0.003058	0.001427	0.001272	0.001061	0.001297	0.000276	0.000098
Samsung	1.0	0.50	11.2200	0.003058	0.001427	0.001272	0.001061	0.001297	0.000276	0.000098
Huawei P20 Lite	1.0	0.60	14.1400	0.003058	0.001427	0.001272	0.001061	0.001297	0.000276	0.000098
iPhone 6	2.0	0.50	2.9840	0.012233	0.005709	0.005087	0.004243	0.005188	0.001103	0.000391
iPhone 6 Plus	2.0	0.60	11.3900	0.012233	0.005709	0.005087	0.004243	0.005188	0.001103	0.000391
iPhone 6s	1.0	0.16	7.1830	0.003058	0.001427	0.001272	0.001061	0.001297	0.000276	0.000098
iPhone 7	1.0	0.53	29.4680	0.003058	0.001427	0.001272	0.001061	0.001297	0.000276	0.000098
iPhone 7 Plus	1.0	0.60	6.1900	0.003058	0.001427	0.001272	0.001061	0.001297	0.000276	0.000098
iPhone 8 Plus	1.7	0.53	19.5030	0.008838	0.004125	0.003676	0.003066	0.003748	0.000797	0.000283
iPhone X	1.2	0.53	18.8760	0.004404	0.002055	0.001831	0.001528	0.001868	0.000397	0.000141
iPhone XS Max	1.7	0.60	67.0680	0.008838	0.004125	0.003676	0.003066	0.003748	0.000797	0.000283
iPhone 11 Pro	1.0	0.50	19.1505	0.003058	0.001427	0.001272	0.001061	0.001297	0.000276	0.000098
iPhone 11 Pro Max	1.0	0.57	57.8600	0.003058	0.001427	0.001272	0.001061	0.001297	0.000276	0.000098
iPhone 12	1.0	0.60	21.2700	0.003058	0.001427	0.001272	0.001061	0.001297	0.000276	0.000098
iPhone 12 Pro	1.0	0.60	81.7700	0.003058	0.001427	0.001272	0.001061	0.001297	0.000276	0.000098

iPhone 12 Pro Max	1.0	0.56	116.6500	0.003058	0.001427	0.001272	0.001061	0.001297	0.000276	0.000098
iPhone 13	2.0	0.50	18.5300	0.012233	0.005709	0.005087	0.004243	0.005188	0.001103	0.000391

Table 4: ICNIRP reference levels and recommended limits for general public exposure to time-varying E, H fields, Power density and SAR at different frequency (Akpolile and Ugbede, 2019)

Frequency (MHz)	E (V/m)	H (A/m)	S (W/m2)	Whole-body average SAR (W/kg)	Localized SAR (head and trunk) (W/kg)	Localized SAR (limbs)(W/kg)
900	41.25	0.111	4.5	0.08	2.00	4.00
1800	58.34	0.157	9.0	0.08	2.00	4.00
2100	61.00	0.160	10.0	0.08	2.00	4.00

Figure 1 presents the correlation matrix analyzing the relationships between electromagnetic field (EMF) parameters, including electric field strength (E), magnetic field strength (H), radiofrequency (RF) power density, and specific absorption rate (SAR) in various head tissues, alongside associated health risk metrics at frequencies of 900 MHz and 2100 MHz. Figure 2 illustrates the RF power density across different phone models at 900 MHz and 2100 MHz. Figure 3 highlights the SAR values for various tissues by phone model at the same frequencies, while Figure 4 shows the corresponding risk metrics for phone models at 900 MHz and 2100 MHz.



	E (V/m)	H (A/m)	F (mW/m2)	CSF	DURA	Brain	Muscle	Skin	Skull	Fat	isk Metrics
E (V/m)	1.00	-0.10	0.71	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97
H (A/m)	-0.10	1.00	-0.05	-0.08	-0.08	-0.08	-0.08	-0.08	-0.08	-0.08	-0.08
RF (mW/m2)	0.71	-0.05	1.00	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83
CSF	0.97	-0.08	0.83	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
DURA	0.97	-0.08	0.83	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Brain	0.97	-0.08	0.83	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Muscle	0.97	-0.08	0.83	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Skin	0.97	-0.08	0.83	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Skull	0.97	-0.08	0.83	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Fat	0.97	-0.08	0.83	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Risk Metrics	0.97	-0.08	0.83	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Figure 1: Correlation Matrix of EMF Parameters and SAR values at 900 and 2100 MHz

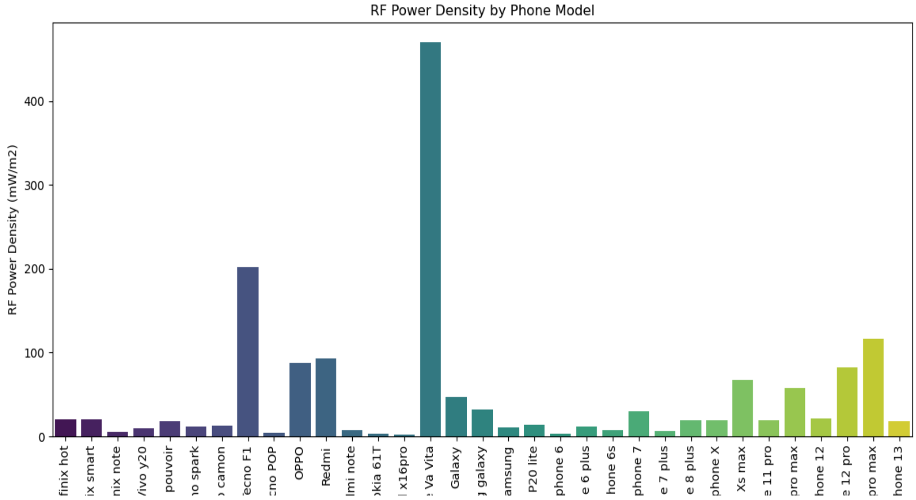


Figure 2: Radio Frequency (RF) Power Density by Phone Model at 900 and 2100 MHz

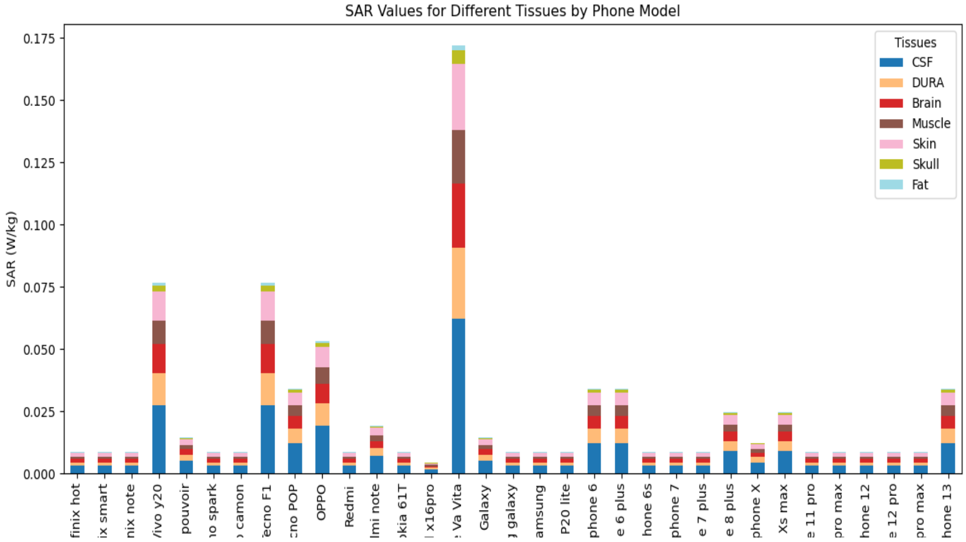


Figure 3: SAR values for different Tissues by Phone models at RF of 900 and 2100 MHz

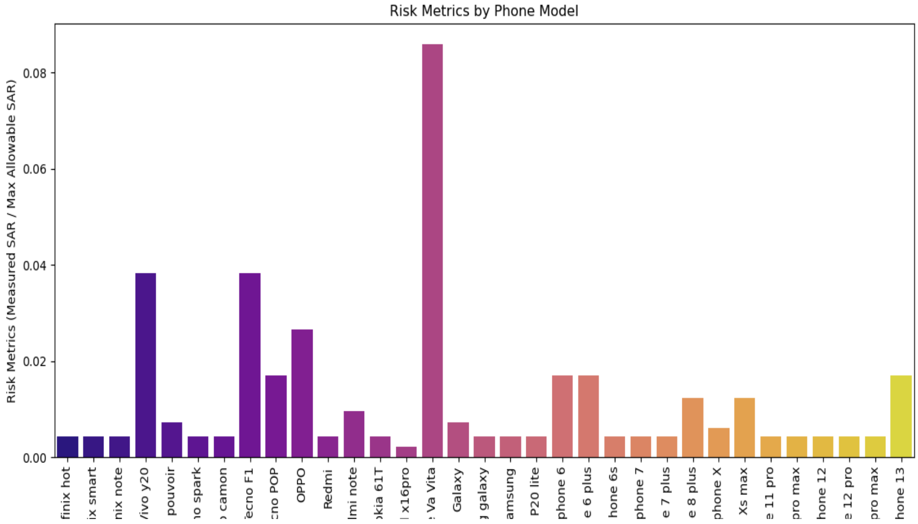


Figure 4: Health risk Index by Phone Model at RF of 900 and 2100 MHz

DISCUSSION

The study identifies the Blade Va Vita model as exhibiting the highest RF power density (470.2 mW/m^2) and SAR values, particularly in cerebrospinal fluid (CSF) and brain tissues, as presented in Tables 2 and 3 and Figure 2. These findings suggest elevated electromagnetic exposure in this model, confirming the work of Gandhi et al. (2012), who reported that phones with higher power densities lead to greater energy absorption in tissues. Similarly, Yi et al. (2023) observed high SAR values in certain phone models can be due to the construction materials and design choices. In contrast, models like the iPhone 12 and Samsung Galaxy consistently demonstrated low RF power density and SAR values, indicative of effective design strategies to minimize electromagnetic exposure. These observations align with safety recommendations by the IEEE and ICNIRP (Yi et al., 2023). The study further highlighted that soft tissues with high water content, such as CSF and brain tissues, exhibit higher SAR values, while tissues like fat and skin show lower absorption rates as indicated in Figure 3. This pattern is consistent with the dielectric properties of tissues described by Gabriel et al. (1996), which indicate that tissues with higher conductivity and permittivity absorb more RF energy. The results emphasize the importance of tissue-specific exposure guidelines, particularly for vulnerable regions like the brain. Strong correlations were observed between electric field strength (E), RF power density, SAR, and health risk metrics, as depicted by the correlation matrix in Figure 1. These correlations reinforce findings from previous studies that electric fields and RF power densities significantly influence energy absorption and health risks. For instance, Iakovidis et al. (2022) emphasized the necessity of continuous RF-EMF monitoring to mitigate potential health risks. However, the weak correlation between magnetic field strength (H) and other parameters suggests that mitigation strategies should prioritize electric fields and RF power density. These findings align with Bonato et al. (2022), who highlighted similar observations in their evaluation of 5G networks.

The presence of outliers, such as the Blade Va Vita model, and variability in SAR-to-threshold ratios across devices as shown in Figure 4 indicate inconsistencies in compliance with safety standards. Devices with higher SAR values, including the Blade Va Vita and Tecno F1, may pose increased health risks depending on usage duration and proximity to the user. These concerns are consistent with the studies by Hardell and Carlberg (2015) and Akpolile and Ugbede (2019), which linked high RF exposure to potential thermal effects and carcinogenic risks. More recent epidemiological evidence strengthens these concerns. A large-scale case-control study by Coureau et al. (2014) reported a significant association between long-term, high-level mobile phone use and an increased risk of glioma and meningioma, particularly in the temporal lobe, the region most exposed during typical phone use. Furthermore, a comprehensive review by Belpomme et al. (2018) highlighted that chronic RF-EMF exposure, even at levels below current ICNIRP thermal guidelines, can induce non-thermal biological effects, including oxidative stress and DNA damage, which are mechanisms potentially linked to carcinogenesis. These findings underscore the need for a precautionary approach, especially for vulnerable populations like children, whose developing nervous systems may be more susceptible (Kostoff et al., 2020).

These risks could be mitigated through the use of hands-free devices, appropriate phone casing accessories to absorb radiation energy, and adherence to ICNIRP guidelines, as emphasized by Bonato et al. (2022). Conversely, models with consistently low SAR values, such as the iPhone 12 and Samsung Galaxy, highlight compliance with rigorous SAR regulations, underscoring adherence to the safety standards set by ICNIRP.

While this study provides a comprehensive assessment of EMF exposure from mobile phones, it is not without limitations. The use of a single EMF meter (GQ EMF-390V2) and a relatively small sample size of 34 phones, predominantly from one geographic region, may limit the generalizability of the findings. Furthermore, the controlled “isolated unit” environment, while effective for minimizing external interference, does not fully replicate real-world usage scenarios where users are exposed to multiple, overlapping RF sources. Future studies should aim to include a wider variety of devices, including those operating on newer 5G frequency bands, and employ a larger, more diverse sample of users across different environments to validate and extend these findings.

In the context of rapidly evolving mobile technology, the emergence of 5G networks introduces new frequency bands (e.g., 3.5 GHz, 28 GHz) and beamforming technologies that may alter EMF exposure patterns (Simkó and Mattsson, 2019). Preliminary studies on 5G exposure, such as those by Bonato et al. (2022), suggest that while localized SAR levels for 5G handsets may remain within ICNIRP limits, the use of multiple antennas and higher frequencies could lead to more superficial energy absorption in skin and corneal tissues. This shift necessitates updated dosimetric models and safety guidelines that consider these novel exposure scenarios, a topic that warrants further investigation.

CONCLUSION

This study has been able to assess the variability in electromagnetic field (EMF) exposure levels and Specific Absorption Rates (SAR) for different mobile phone models at operational frequencies of 900 MHz and 2100 MHz. The measured electric field strength (E-field), magnetic field strength (H-field), and power density reveal significant differences across phone models, with some exceeding the ICNIRP recommended safety limits. Additionally, SAR values for various tissues (cerebrospinal fluid, dura, brain, muscle, skin, skull, and fat) indicate varying levels of radiation absorption, depending on the phone model and operational frequency. The results of this study indicated the need for strict regulatory measures to ensure mobile phones comply with international safety standards to minimize health risks. Consumers should be aware of SAR values when selecting mobile devices, particularly those frequently used close to the head. They are also advised to use hand-free devices and also employ proper phone casing accessories which have the potential of absorbing part of the radiation energy thereby reducing the exposure to radiation.

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