



Electromagnetic Field Levels of Selected Mobile Phones and their Harm-causing Potential on the Users

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Abstract

The aim of this study was to investigate some commonly-used mobile phones for the electromagnetic field radiations emitted by them so as to determine their harm-causing potential on the user's health. The mobile phones under consideration were Itel Model 1701, Tecno Model S1, and Infinix Model 6. An Electromogmeter was employed for measurement of phones' electromagnetic parameters (electrical field strength, magnetic field strength, and power density) at various distances (0.05, 0.15, 0.25, 0.35, and 0.45 m). The Specific absorption rate (SAR) was computed from the relevant mean data obtained at 0.05 m and compared with some standard stipulations. It was found that each of the measured parameters varied significantly with the distance from the radiation source (mobile phone). The computed head SAR values $(6.23 - 74.12) \times 10^{-8}$ W/kg were below the limits set by the International Conference on Non-Ionising Radiation Protection and Federal Communications Commission. Findings generally revealed that though Tecno Model S1 could be the safest for use, prolonged exposure to the emissions from the phones might be harmful to health.

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1.0 Introduction

Electromagnetic field (EMF) consists of electric and magnetic fields and is a part of the physical electromagnetic spectrum ranging from the extreme low of static magnetic fields to the extreme high of gamma rays. A wide spectrum of electromagnetic waves are emitted by radar, communication equipment, mobile phone base stations, high voltage lines, radio and television transmitters, substations, and electrical equipment at home and work, in addition to many electrical systems in the environment (Kivrak *et al.*, 2017). Rusu *et al.* (2019) noted that the variety of electric/electronic products and devices used in transport sector, trade market, industry, telecommunications, medicine, agriculture, education, domestic activities alongside with all electric networks generate around us a bundle of EMFs. EMF is present in various forms ranging from extremely low frequency (ELF) fields produced by power lines to radiofrequency (RF) fields emitted by wireless communication devices and it plays ubiquitous roles in today's modern society (Bosch-Capblanch *et al.*, 2024). Every mobile communication involves signal transfer by electromagnetic wave (EMW) through radiofrequency and microwave signals (Bhargavi *et al.*, 2013). It has been estimated that more than 3 billion people across the world are exposed to EMF every day (Fragopoulou *et al.*, 2010). Though EMFs are essential for technologies like electricity generation, telecommunications, and medical imaging, concerns have been raised regarding their potential impacts on health. Consequently, lifetime exposure to EMF has become a subject of scientific investigation keeping in mind that, in regards to possible hazards caused by EMFs, one of the legitimate concerns of users of wireless devices is safety. For instance, Panait *et al.* (2019) researched on electromagnetic pollution of the environment due to leakage radiation from microwave ovens. They compared the values of the EMFs generated by

three types of microwave ovens with the values available in scientific literature, guides and protocols, considering their impact on human health. Taheri *et al.* (2017) investigated the possible effects of exposure to EMFs from Wi-Fi router and mobile phone simulator on antibacterial susceptibility of pathogenic bacteria *Listeria monocytogenes* and *Escherichia coli* and Belpomme *et al.* (2018) studied on the international perspective of thermal and non-thermal health effects of low intensity non-ionising radiation. Both groups of researchers reported that RF fields emitted from base stations can affect cells and tissues of organisms. Ilori and Adeleye (2019) conducted a study on the radiation absorbed dose rate from selected mobile phone Base Stations in Ibadan, Oyo State, Nigeria. They found evidence of subjective symptoms and hypersensitivity to various EMF sources of numerous mobile phones and base stations. A similar observation was reported recently by Nwachukwu *et al.* (2021) from their study on background radiation of Telecommunication Masts in Ebonyi State, Nigeria. Sajedifar *et al.* (2019) examined the effect of battery charge levels of Mobile phone on the amount of electromagnetic waves emission with particular emphasis on the potential risks associated with prolonged exposure to the electromagnetic waves. So far, there is no scientific information on the health risk(s) caused specifically by EMF emissions from mobile phones on their users, thereby leaving the scientific community with speculations in that regard.

Therefore, the aim of this study is to investigate some mobile phones for the EMF radiations emitted by them so as to determine their harm-causing potential on the user's health. Mobile phones have constituted an aspect of technological innovations that turns the world into a global village through their daily applications for certain purposes such as voice calls making, text messaging, execution of video calls, tasks scheduling, navigation of locations,

taking of snapshots, recording of audio and video signals, carrying out of internet and banking services as well as security and health matters (Owoh *et al.*, 2020). Recently, it has been observed that there is proliferation of the markets with cheap unbranded smartphones. It is common knowledge that, at various times, many fake and sub-standard mobile phones (with more features and functions when compared with some of the known quality brands) have found their way into the markets through the activities of smugglers and dubious businessmen, thus bypassing quality assessment regulatory authorities. With this practice, they even get into many hands and homes owing to their comparative affordability margin, without any known safety level associated with their usage. As of 2019, the Digital Global Report showed that about 5.11 billion people used mobile phones (Kemp, 2019). Nowadays, both young and old can now afford at least one phone for personal use thus underscoring the fact that mobile phones are no longer the preserve of few wealthy individuals in any society (Owoh *et al.*, 2020). It is hoped that findings from this study will help to address the concerns by private organisations, government institutions and the general public on other cases of related health challenges reported by smartphone users but are yet to be scientifically verified and documented.

2.0 Materials and Methods

2.1 Materials

Mobile phones (namely Infinix Model 6, Tecno Model S1, Itel Model 1701), retort stands, Electromogmeter (TES-92), and uniform metre rule were the main materials used in this study. The phones were collected at random, one each, from their users and used as the sources of EMF radiations. Table 1 shows the abbreviations adopted for the collected mobile phones in this study.

Table 1: Coding for the Mobile phones in the study

Mobile phone type	Code used
Itel Model 1701	ITEP
Tecno Model S1	TCS1
Infinix Model 6	IFH6

2.2 Measurement of the Mobile phones' EMF radiations

Electric field strength (in mV/m), magnetic field strength (in $\mu\text{A/m}$), and power density (in $\mu\text{W/cm}^2$) were the EMF parameters measured for each of the mobile phones. The measurements were performed using the Electromogmeter and in the Physics Laboratory of Akwa Ibom State University, Ikot Akpaden, Mkpat Enin, Akwa Ibom State, Nigeria described by Latitude of $04^\circ 37.59'N$ and Longitude of $07^\circ 44.88'E$ at Elevation of 201 ft. Figure 1 shows the experimental setup used for the measurements in this study. The phone under test was clamped to the retort stand, ensuring that a good line of sight was maintained between its transceiver and the sensor of the Electromogmeter. The distance of the radiation source (mobile phone) from the Electromogmeter was measured using the metre rule. At each distance of interest (from 0.05 m to 0.45 m), the instantaneous values of the EMF parameters of the phone were measured in tri-axis configuration and under calls engagement mode. In order to avoid interference effect, the caller always stood at a distance of about 12 m from the experimental setup. Also, any active sources of electromagnetic radiations were put off and kept away from the laboratory unit where the experimental setup was mounted. The measurement of each EMF parameter was carried out thrice for every phone under test. The mean and standard error values of each category of the measured EMF data were computed and analysed.

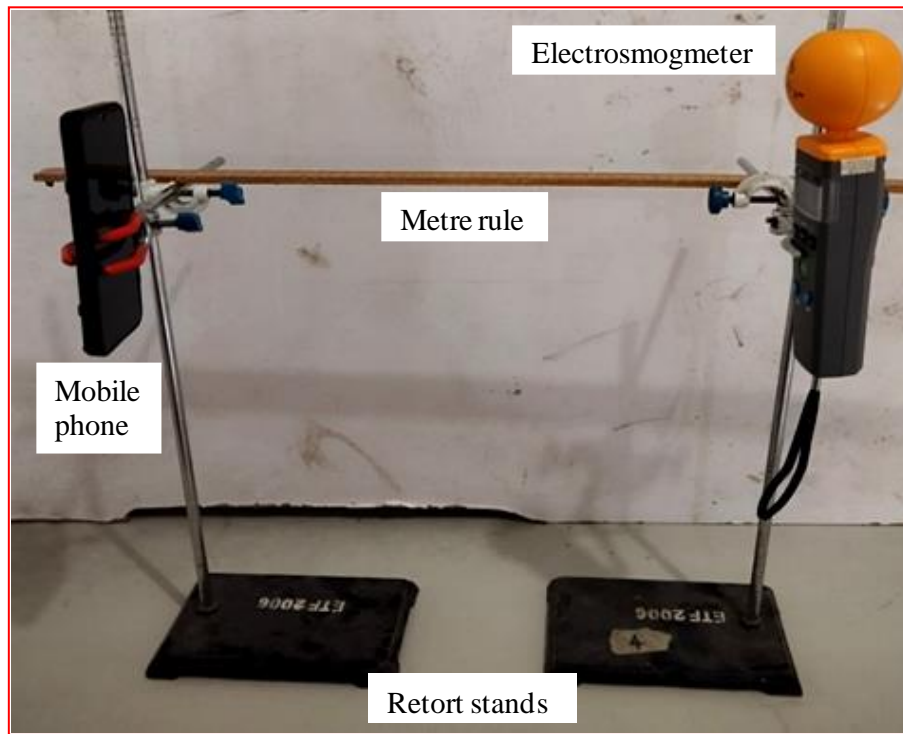


Fig. 1: Setup for measurement of the electromagnetic parameters of the phones

2.3 Determination of Specific Absorption Rate (SAR)

For the purpose of assessing the harm-causing potential(s) of the EMF radiations from the tested mobile phones, the localised SAR of human head was determined. In this case, the maximum values of the electric field strength obtained at 0.05 m were applied to calculate the localised SAR of human head using the relation (Joanna *et al.*, 2012)

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

where σ = tissue conductivity, ρ = tissue density, and E = electric field strength. The value of E was obtained using the relation expressed by Kumar and Pathak (2011) as:

$$E = E_0 \exp \left| -z/\delta \right| \quad (2)$$

where E_0 = incident electric field on the body surface, δ = skin depth, and z = depth of tissue with respect to incident field. For computation of the skin depth, the following equation was applied (Sallomi, 2012):

$$\delta = \sqrt{\frac{1}{\pi\mu\sigma}} \quad (3)$$

where μ = tissue permeability ($4\pi \times 10^{-7} \text{ Hm}^{-1}$) and f = frequency (900 MHz and 1800 MHz) of the electromagnetic radiations. The values of tissue density and conductivity applied in eq. 1 above were based on the data provided by Stankovic *et al.* (2017) as shown in Table 2.

Table 2: Characteristics of human head tissues

Tissue	$\sigma (\text{Sm}^{-1})$	$\rho (\text{kgm}^{-3})$
Skin	0.867 ^a	1109
	1.180 ^b	1109
Fat	0.109 ^a	911
	0.143 ^b	911
Bone	0.143 ^a	1908
	0.275 ^b	1908
Brain	0.7665 ^a	1046
	1.710 ^b	1046

a = value at 900 MHz and *b* = value at 1800 MHz

The computed SAR data obtained in this study were compared with the stipulations in the International Commission on Non-Ionizing Radiation Protection (ICNIRP, 1998) and Federal Communications Commission (FCC, 2007) so as to establish whether or not the EMF radiations emitted from the tested mobile phones pose any significant health effect.

2.4 Analysis of the data

The measured EMF data were analysed graphically using Origin Software (Version 2019b). Also, the data were examined statistically by subjecting them to one-way analysis of variance (ANOVA) at 0.05 level of significance using Statistical Package for the Social Sciences (SPSS) Software.

3.0 Results and Discussion

Table 3 shows the measured EMF radiations at various distances from the tested mobile phones. From the results, it is seen that the magnetic field strengths are greater compared to the electric field strengths obtained under the same conditions. This implies that the selected phones

have the ability to emit electromagnetic radiations with greater proportion of magnetic field effect than the electric field counterpart.

Irrespective of the distances of the user from the phones, it is clear from the results that TCS1 emits the least proportions of the radiations, followed by the ITEP and then the IFH6. The maximum mean power density ($52.10 \mu\text{W}/\text{cm}^2$) in this case is far less than the minimum value of $0.3 \mu\text{W}/\text{m}^2$ reported by Shalangwa *et al.* (2011) for testing selected mobile phones of different models held at a distance of 0.01 m from the head. The disparity noticed may be due to the twin factors of measurement distance, the type, and model of phones involved in the study.

Table 3: Electromagnetic radiation data obtained for the mobile phones

<i>D</i> (m)	Iitel Model 1701			Tecno Model S1			Infinix Model 6		
	mV/m	$\mu\text{A}/\text{m}$	$\mu\text{W}/\text{cm}^2$	mV/m	$\mu\text{A}/\text{m}$	$\mu\text{W}/\text{cm}^2$	mV/m	$\mu\text{A}/\text{m}$	$\mu\text{W}/\text{cm}^2$
0.05	22.23	44.28	51.11	8.54	21.00	25.00	26.84	46.77	52.10
	± 0.02	± 0.01	± 0.01	± 0.02	± 0.02	± 0.01	± 0.02	± 0.01	± 0.02
0.15	19.14	35.48	36.50	3.22	12.88	12.95	21.00	35.97	36.99
	± 0.01	± 0.02	± 0.01	± 0.01	± 0.02	± 0.01	± 0.02	± 0.01	± 0.02
0.25	12.54	22.91	20.31	2.11	8.54	4.62	12.58	23.91	22.23
	± 0.01	± 0.02	± 0.02	± 0.02	± 0.02	± 0.01	± 0.02	± 0.01	± 0.01
0.35	7.04 \pm	17.56	15.99	1.83	5.40	2.72	7.96	18.19	16.92
	0.02	± 0.01	± 0.01	± 0.02	± 0.01	± 0.02	± 0.02	± 0.02	± 0.01
0.45	4.53 \pm	13.97	11.24	1.28	4.39	1.34	4.91	14.63	11.49
	0.02	± 0.02	± 0.01	± 0.02	± 0.01	± 0.02	± 0.01	± 0.02	± 0.02

D=Distance of the mobile phone from the Electrosmogmeter sensor

Figure 2 graphically illustrates the variations in the measured EMF parameters with the distances from the mobile phones. It can be seen that each of the examined parameters decreases with increasing distances of the mobile phone (source of radiation), signifying that the effect of the radiations diminishes as the user's body is far away from the phone that emits the radiations. Specifically, the parameters decay exponentially with the distance. This observation means that, if there is a long-term exposure to the emitted radiation, less effect of it would be experienced

by a user whose body is usually at a distance that is reasonably far from the phone used.

Table 4 shows the results of the ANOVA. It can be seen that the ITEP and IFH6 do not differ significantly in the strengths of the electric and magnetic fields associated with their emitted radiations. However, the TCS1 shares with them in terms of power density only. This observation may be attributed to differences in the ages, types and/or qualities of the tested phones.

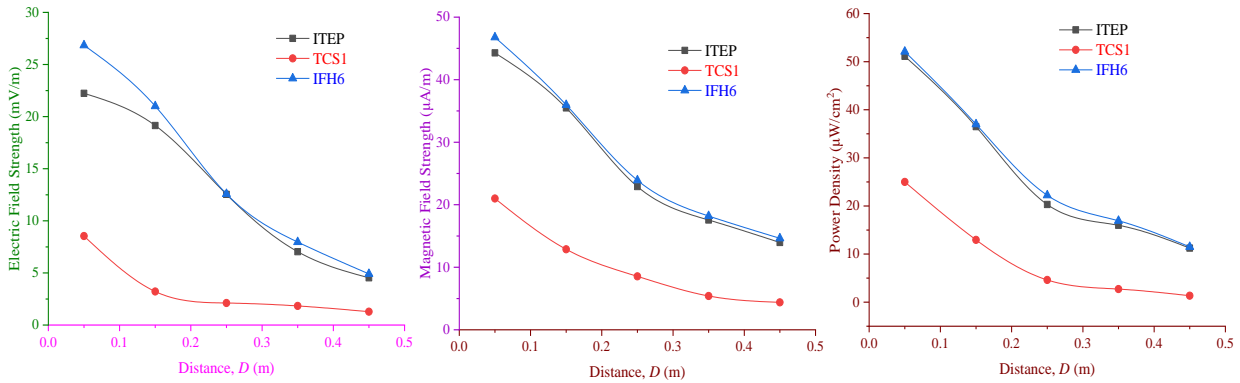


Fig. 2: Plots of the EMF parameters against distance

Table 4: Results of ANOVA test for the measured data

Parameters	Paired devices	Total SS	df	<i>p</i> -value	<i>F</i> -value	Remark
Electric field strength	ITEP vs TCS1	500.6208	9	0.02868	7.09054	SGN
	ITEP vs IFH6	569.2470	9	0.775973	0.08665	INS
	TCS1 vs IFH6	684.9838	9	0.30375	6.89491	SGN
Magnetic field strength	ITEP vs TCS1	1501.321	9	0.034342	6.48654	SGN
	ITEP vs IFH6	1356.279	9	0.901214	0.01642	INS
	TCS1 vs IFH6	1652.011	9	0.030874	6.83986	SGN
Power density	ITEP vs TCS1	2257.840	9	0.073127	4.25205	INS
	ITEP vs IFH6	2178.244	9	0.932182	0.00771	INS
	TCS1 vs IFH6	2345.385	9	0.06225	4.68955	INS

SGN = Significant; INS = Insignificant

The values of the localised SAR based on the studied phones are presented in Table 5. Among the tested phones, the ITEP has the highest head SAR value. Also, bone has the lowest SAR values among the tissues for all the tested phones. Kargel (2005) noticed that head SAR value will only increase as a mobile phone is held closer to the user's head. This agrees with the empirical relationship between the electric field strength and SAR as expressed in equation 1 above. The differences in transmission power from the transmission tower as well as antenna quality may affect head SAR value. As posited by Chakraborty *et al.* (2013), cell towers have transmission power of 20 W whereas mobile phones operate with transmission power of 1 W or 2 W for GSM-1800/CDMA and GSM-900 respectively. These facts on distance, transmission power, and antenna quality possibly explain why the head SAR obtained at

900 MHz in this study is less in the order of 10^{-4} than the head SAR of 1.8×10^{-3} W/kg at a measured distance of 0.01 m from a 900 MHz mobile phone radiation source as reported by Shalangwa *et al.* (2011). All the values of the head SAR at both frequencies (900 MHz and 1800 MHz) considered in this study are well below the regulated limits stipulated in the ICNIRP (1998) as 2.0 W/kg and FCC (2007) as 1.6 W/kg respectively, the TCS1 has the lowest value possible. Thus, using the phones gives the user assurance of being exposed to the least amount of radiofrequency radiation. A report revealed that increasing use of smartphones affects biochemical processes leading to health problems (ARPANSA, 2017). The possibility of developing deafness migraines, burning skins, headaches, fatigue, hot and itchy ears, high blood pressure due to interference of EMF radiations from a mobile phone with the

electrical impulses that connect two neurons with each other in the ear-skull region has been reported (Mitra *et al.*, 2014). Different scientists

have also argued that mobile phone radiation is too bad for human health (Mohril *et al.*, 2016).

Table 5: SAR values of the human head tissues based on the tested mobile phones

Phone code	Frequency (MHz)	Incident E-Field at 0.05 m (mV/m)	Tissue SAR (W/kg) x 10 ⁻⁸				Head SAR (W/kg) x 10 ⁻⁸
			Skin	Fat	Bone	Brain	
ITEP	1800	22.23 ± 0.02	26.29	3.88	3.56	40.39	74.12
TCS1	900	8.54 ± 0.02	2.85	0.44	0.27	2.67	6.23
IFH6	900	26.84 ± 0.02	28.16	4.31	2.70	26.39	61.56

So, though comparison of the head SAR values for the tested mobile phones with the stipulations in the ICNIRP and FCC suggests no potential harmful effects, thermal heating effects may be evident with the phones especially when used for a long time. This is possible because cosmic radiation, energetic fields of the earth, and man-made technology constantly interfere with the human body since the human body is a form of electromagnetism. For example, Kumar and Bhat (2013) measured the temperatures of different segments of the human head exposed to 45 minutes of talk time with GSM 900 MHz and 1800 MHz mobile phones manufactured with built-in antennas and external antennas. For both GSM 900 and 1800 MHz mobile phones with built-in antennas, they obtained an average temperature change of 0.9 °C for the head segments (which coincides with the ear-lobe region considered in this research). But Taurisano *et al.* (2000) reported an average surface temperature range of 1.0 °C to 2.4 °C of the ear-lobe analysis under exposure to 15 minutes of talking time. It can therefore be inferred that, if prolonged exposure is sustained, higher phone and skin temperature rises are possible. For instance, Straume *et al.* (2005) found that skin temperatures on the cheek increased a further 22 – 30 % when the exposure time was increased from 15 to 30 minutes.

4.0 Conclusion

Findings from this experimental study have shown that mobile phones such as the ITEL Model

1701, Tecno Model S1, and Infinix Model 6 can emit electromagnetic (EM) radiations. The EM parameters (electric field strength, magnetic field strength, and power density) associated with the tested phones varied with the user's distance. Comparatively, the Tecno Model S1 emitted the least proportions of the examined EMF parameters. The SAR values associated with the phones were far less than the regulated limits stipulated by ICNIRP and FCC. However, prolonged exposure to the radiations from the phones might have harmful thermal effects on the users. Perhaps, a good explanation for this may be adduced by investigating the influence of age and proximity of the mobile phones in relation to the surface temperature of the ear-lobe region of the human head through direct contact use of the mobile phones in call reception mode. That notwithstanding, this research has specifically demonstrated that a 0.50 m distance between a mobile phone and its user would significantly reduce the effects of EM radiations from the phone on the user.

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