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*Research Paper*

# Electromagnetic Field Levels Associated with Selected Mobile Phones

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**Abstract:** This work was carried out to examine the possible potential health risks that result from the use of some commonly available mobile phones in Nigeria. The mobile phones subjected to test were Tecno S1, Touching T1, Infinix hot 6 and Itel 1701. Their electric field strength, magnetic field strength and power density varied significantly per call engagement mode at various varied distances of measurement. Also, their computed head SAR values were observed to be below the limit set by the International Conference on Non-Ionising Radiation Protection. From a potential health hazard point of view, Tecno S1 was found to be the safest for use.

***Keywords:*** *Electric field strength, Health problem, Magnetic field strength, Power density, Specific absorption rate.*

## Introduction

Without the use of mobile phones in this 21st century, the world of human activities would be dull and uncoordinated. This is very obvious when considering how the world is being turned into a global village as a result of using such devices for certain purposes. Bhargavi *et al*. (2013) posited that mobile communication involves signal transfer by electromagnetic wave (EMW) through radiofrequency and microwave signals. Based on observation, it has become a common knowledge nowadays that certain mobile phone categories can be employed for a wide range of applications in addition to making of voice calls and text messaging. For example, smartphones can be used to make video calls, schedule tasks, record audio and video signals, take snapshots, navigate locations, and also carry out internet and banking services as well as applications involving security and health. It is noteworthy that mobile phones are no longer the preserve of few wealthy individuals in any society. In other words, due to drastic reduction in cost prices, both young and old can now afford at least one phone for personal use. Eventually, there has been an astronomical increase in the number of phone users. This, in turn, makes the technological advancements in cellular technology/mobile phone applications to be one of the fastest in terms of growth in the last few decades.

Extensive new collection of digital 2019 reports reveals that about 5.11 billion people worldwide use mobile phones (Kemp, 2019). Although the device in question has become a must-own due to the aforementioned advantages, it has been reported that its use has some adverse health effects as a result of exposure to radiofrequency electromagnetic radiations from it. For instance, (Blank & Goodman, 2009) opined that in the course of using mobile phone, electromagnetic wave is transferred to human body with resultant health problems especially at the ear-skull region. Other research reports have it that in the said circumstance, such radiations interfere with the electrical impulses that connect two neurons with each other and can lead to deafness, migraines, high blood pressure, hot and itchy ears, burning skins, headaches and fatique (Bhargavi *et al*., 2013; Mitra *et al*., 2014). In an attempt to address the situation, several international and regional agencies have developed safety limits to serve as guidelines towards safe radiation exposures. However, there may be other cases of related health challenges reported by users but are yet to be scientifically verified and documented.

In recent times, it has been observed that there is unprecedented proliferation of many markets and homes with assorted mobile phones. The substandard or bad ones among them are even being falsely portrayed (by the specification in their user's manual) to possess features that can be utilised to guarantee safety on the part of their users. Also, very many people are in the habit of becoming mobile phone owner (or user) without caring to know about the compliance to safety standards in relation to their phone of interest. Since the utilization of substandard products can cause serious harm, there is no doubt that the radiations emitted in the process of using the said phones can interact with the user's body and cause health problem(s). When considering the activities of smugglers in by-passing

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regulatory authorities to circulate defective products that are not easy to identify by mere physical inspection, the current situation becomes so worrisome these days that public safety concern is expressed to the extent of requiring very urgent attention. This work is, therefore, designed to assess the level of electromagnetic field (EMF) radiations associated with some select low-cost mobile phones that are widely used in Nigeria, so as to ascertain their potential risks to user's health. It is hoped that the findings from this work will be of great benefit to relevant industry and potential users of different mobile phone types/models.

## Method

This work was carried out inside a room in Uyo urban, South-South, Nigeria. Tecno S1, Touching T1, Infinix hot 6 and Itel 1701 were selected and then after removed from their case before each of them was used as the source of radiation in this work. Also, four call engagement modes such as Ringing and Answered call (RA), Ringing and Unanswered call (RU), Vibration and Unanswered call (VU), as well as Silent and Unanswered call (SU) were considered. In the experimental setup (Figure 1) used, the phone under test was clamped such that its transceiver maintained a good line of sight with the sensor of an electrosmog meter (TES-92) employed to measure (in tri-axis mode) the instantaneous values of EMF parameters of the phone. In order to avoid interference effect, the caller was always positioned at a distance of about 10 m from where the setup was mounted. Also, active sources of electromagnetic radiations were put off and kept away from the room. The measurement of every parameter was performed three times for each of the phones and at the same varied distances per call engagement mode. In each case, the mean values of the results were determined and analysed.

Based on the maximum values of electric field strength obtained at 5 cm, the localized specific absorption rate (SAR) of human head was calculated using the relation (Joanna *et al*., 2012; Kumar & Bhat, 2013)

**Figure 1**. Set-up for measurements of EMF parameters of the selected mobile phones.

$$\text{SAR} = \frac{\sigma|E|^2}{2\rho} \qquad 1$$

where $\sigma$ is tissue conductivity, $\rho$ is tissue density and $E$ is electric field strength expressed as (Kumar and Pathak, 2011)

$$E = E_o \, exp\,|-z/\delta| \qquad 2$$

where $E_o$ is incident electric field on the body surface, $\delta$ is skin depth and $z$ is depth of tissue with respect to incident field (Figure 2).

For computation of skin depth, the following equation was used (Sallomi, 2012):

$$\delta = \sqrt{\frac{1}{\pi\mu\sigma f}} \qquad 3$$

where $\mu$ is tissue permeability ($4\pi \times 10^{-7}$ H/m) and $f$ is frequency (900 MHz and 1800 MHz) of the electromagnetic radiations. The values of tissue density and conductivity used in this work were based on the data provided by Stankovic *et al*., (2017) as shown in Table 1.

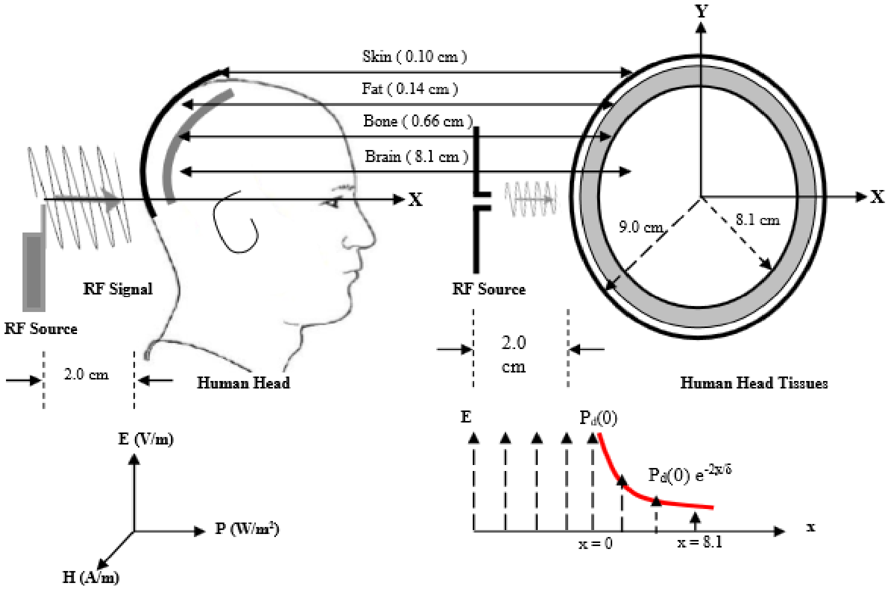



**Figure 2**. Human head model

**Table 1**. Characteristics of tissues at 900 MHz and 1800 MHz

| Tissue | σ (S m$^{-1}$) | ρ (kg m$^{-3}$) |
|---|---|---|
| Skin | 0.867$^{a}$ | 1109 |
| | 1.180$^{b}$ | 1109 |
| Fat | 0.109$^{a}$ | 911 |
| | 0.190$^{b}$ | 911 |
| Bone | 0.143$^{a}$ | 1908 |
| | 0.275$^{b}$ | 1908 |
| Brain | 0.7665$^{a}$ | 1046 |
| | 1.710$^{b}$ | 1046 |

*Source: Stankovic et al. (2017).*

Where: a is value at frequency of 900 MHz and b is value at frequency of 1800 MHz.

## Results and Discussion

The mean values obtained from the measurements of the EMF parameters are registered in Table 2. Also, the computed values of head SAR and the regulated limits specified in electromagnetic guidelines by International Conference on Non-Ionising Radiation Protection (ICNIRP, 1998) are presented in Table 3.

From Table 2, it can be seen that the mean values of the EMF parameters for each call engagement mode decrease with increasing distance from the phone (source of radiation). This simply portrays the fact that even if there is a long-term exposure to the radiation, less effect of it would be experienced by a user whose body is usually at a distance that is reasonably far from the mobile phone used. As evident from the results, the recorded values of magnetic field strength are greater than those obtained under the same conditions for electric field strength. By implication, the selected phones are capable of emitting electromagnetic radiations with greater proportion of magnetic field effect than the electric field counterpart. Irrespective of the mode of engagement, it is crystally clear from the results that the least values of each EMF parameter at all varied distances are obtained with the use of P1. However, at the closest distance (being 5 cm in this study) from the mobile phone, the highest value of electric field strength is obtained in the case of P3 in all the engagement modes, whereas P2 shows such tendency for magnetic field strength except in VU and SU modes. For power density, the highest obtained value is associated with P3 in RA mode, P2 in RU mode and P4 in VU and SU modes. On the whole, the maximum mean power density value in this work (80.76 μW/cm$^2$) is observed to be far less than the minimum value of 0.3 μW/m$^2$ obtained 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 in the two results may be understood to be due to the twin factors of measurement distance, the type and model of phones involved in the study.

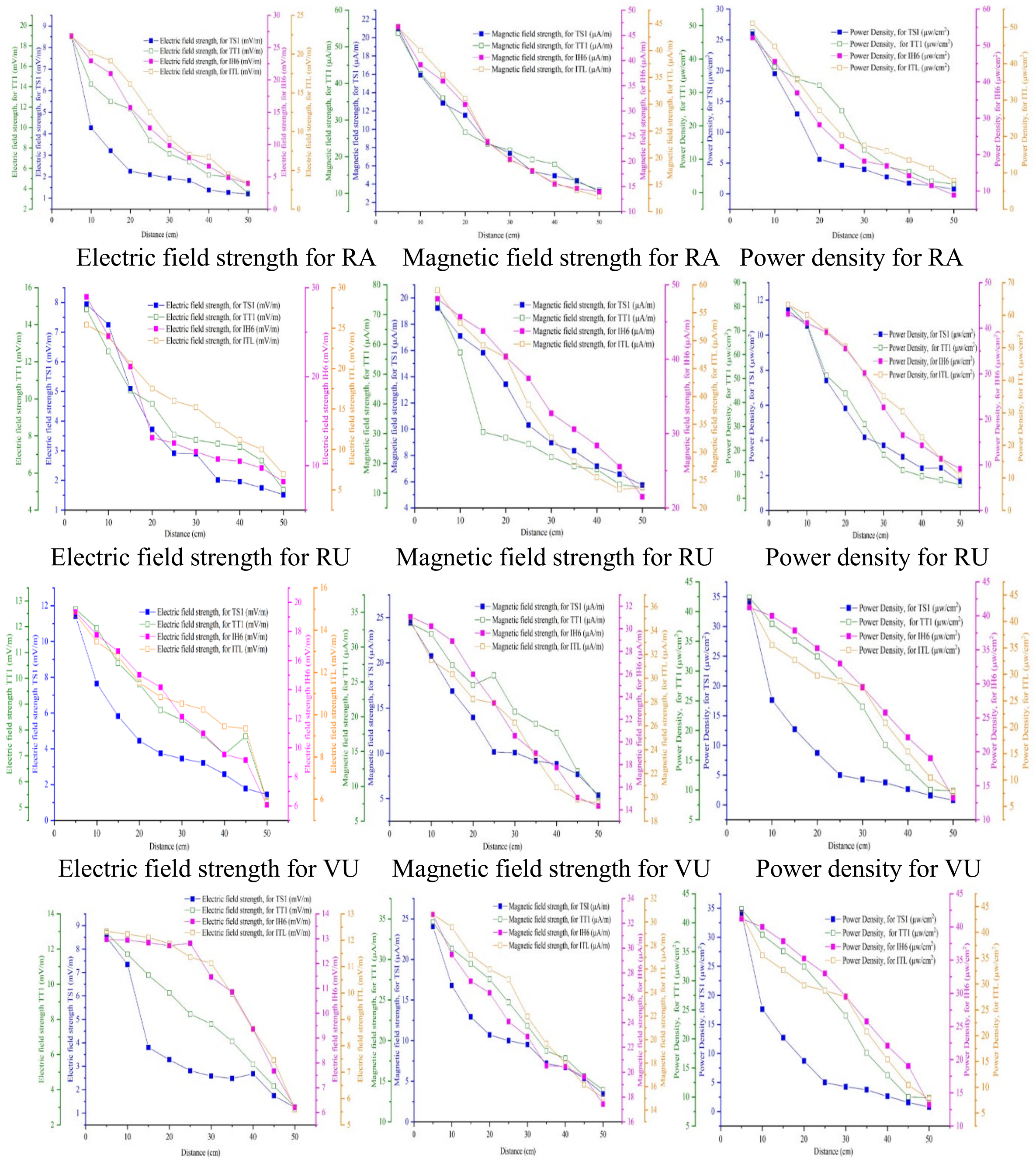
Though the results obtained in this work appear to differ across the engagement modes for each of the phones used, one-way analysis of variance performed at 0.05 level of significance shows that the differences are not significant. This implies that the possibility of experiencing negative health effect does not depend mainly on any of the call modes considered for the selected phones. However, for each of the engagement modes, the same statistical analysis reveals that the results of any of the measured parameters recorded for the phones are significantly different. This may be attributed to differences in the ages, types and/or qualities of the phones.

**Table 2**. Mean values of the measured EMF parameters of the tested phones

| **Oper. mode** | **Distance (cm)** | **Electric field strength (mV/m)** | | | | **Magnetic field strength (µA/m)** | | | | **Power density (µW/cm²)** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | P1 | P2 | P3 | P4 | P1 | P2 | P3 | P4 | P1 | P2 | P3 | P4 |
| RA | 5 | 8.542 | 18.92 | 26.82 | 22.23 | 20.96 | 53.74 | 46.75 | 44.26 | 25.97 | 48.20 | 52.12 | 51.11 |
| RA | 10 | 4.278 | 14.26 | 22.95 | 20.15 | 15.92 | 42.71 | 39.16 | 40.01 | 19.51 | 37.65 | 45.57 | 44.72 |
| RA | 15 | 3.208 | 12.54 | 20.97 | 19.12 | 12.85 | 36.01 | 35.95 | 35.45 | 12.97 | 34.08 | 36.95 | 35.52 |
| RA | 20 | 2.257 | 11.82 | 15.71 | 16.14 | 11.52 | 26.73 | 31.27 | 31.03 | 5.582 | 32.17 | 28.18 | 27.17 |
| RA | 25 | 2.097 | 8.746 | 12.56 | 12.52 | 8.537 | 23.46 | 23.93 | 22.89 | 4.621 | 24.51 | 22.24 | 20.33 |
| RA | 30 | 1.942 | 7.421 | 9.847 | 9.115 | 7.362 | 21.74 | 20.35 | 19.78 | 3.968 | 12.72 | 18.20 | 17.57 |
| RA | 35 | 1.834 | 6.624 | 7.950 | 7.023 | 5.399 | 19.23 | 18.18 | 17.58 | 2.711 | 7.785 | 16.93 | 15.96 |
| RA | 40 | 1.388 | 5.347 | 6.657 | 6.724 | 4.921 | 17.93 | 15.46 | 15.34 | 1.715 | 6.284 | 14.19 | 13.46 |
| RA | 45 | 1.276 | 5.170 | 4.891 | 4.512 | 4.382 | 13.16 | 14.61 | 13.99 | 1.315 | 3.383 | 11.46 | 11.24 |
| RA | 50 | 1.205 | 3.572 | 3.955 | 3.365 | 3.214 | 10.92 | 13.92 | 12.82 | 0.750 | 2.492 | 8.872 | 7.915 |
| RU | 5 | 7.943 | 14.83 | 28.97 | 25.42 | 19.24 | 73.91 | 48.13 | 59.04 | 11.42 | 80.79 | 43.15 | 63.23 |
| RU | 10 | 7.245 | 12.56 | 24.57 | 23.93 | 17.10 | 57.23 | 45.71 | 53.17 | 10.53 | 72.60 | 41.10 | 60.04 |
| RU | 15 | 5.097 | 10.45 | 21.11 | 20.59 | 15.83 | 30.56 | 43.79 | 49.14 | 7.415 | 51.32 | 39.11 | 55.11 |
| RU | 20 | 3.725 | 9.731 | 13.15 | 17.54 | 13.42 | 28.63 | 40.35 | 46.98 | 5.814 | 43.75 | 35.52 | 50.37 |
| RU | 25 | 2.915 | 8.063 | 12.53 | 16.01 | 10.31 | 26.45 | 37.41 | 38.52 | 4.171 | 30.97 | 30.15 | 41.88 |
| RU | 30 | 2.895 | 7.791 | 11.55 | 15.21 | 8.973 | 22.17 | 32.74 | 32.61 | 3.710 | 18.15 | 22.61 | 35.11 |
| RU | 35 | 2.091 | 7.588 | 10.73 | 13.02 | 8.357 | 19.01 | 30.58 | 28.29 | 3.058 | 11.81 | 16.53 | 30.42 |
| RU | 40 | 1.962 | 7.415 | 10.50 | 11.18 | 7.182 | 18.01 | 28.40 | 25.51 | 2.424 | 9.251 | 14.28 | 22.45 |
| RU | 45 | 1.752 | 6.672 | 9.725 | 10.01 | 6.573 | 12.91 | 25.56 | 23.34 | 2.409 | 7.650 | 11.36 | 15.77 |
| RU | 50 | 1.519 | 5.098 | 8.202 | 6.923 | 5.741 | 11.87 | 21.51 | 19.58 | 1.657 | 5.673 | 9.143 | 10.81 |
| VU | 5 | 11.42 | 12.68 | 19.34 | 14.74 | 24.46 | 33.41 | 31.07 | 34.80 | 34.18 | 42.32 | 41.23 | 43.59 |
| VU | 10 | 7.651 | 11.94 | 17.77 | 13.45 | 20.74 | 31.87 | 30.23 | 31.52 | 17.62 | 37.92 | 39.98 | 35.54 |
| VU | 15 | 5.827 | 10.59 | 16.65 | 12.75 | 16.87 | 27.41 | 28.91 | 30.34 | 12.72 | 35.12 | 37.83 | 32.72 |
| VU | 20 | 4.456 | 9.771 | 15.02 | 11.52 | 13.96 | 25.92 | 25.98 | 28.25 | 8.712 | 32.46 | 35.22 | 29.75 |
| VU | 25 | 3.742 | 8.769 | 14.16 | 10.84 | 10.15 | 24.54 | 23.45 | 27.91 | 5.002 | 28.35 | 32.98 | 28.73 |
| VU | 30 | 3.457 | 8.387 | 12.13 | 10.53 | 10.08 | 20.72 | 20.54 | 26.27 | 4.269 | 23.97 | 29.52 | 27.51 |
| VU | 35 | 3.214 | 7.793 | 10.98 | 10.25 | 9.157 | 18.99 | 19.01 | 23.34 | 3.749 | 17.60 | 25.76 | 20.82 |
| VU | 40 | 2.579 | 7.755 | 9.542 | 9.454 | 8.827 | 17.67 | 17.74 | 20.84 | 2.626 | 13.75 | 22.11 | 15.42 |
| VU | 45 | 1.779 | 7.054 | 9.154 | 9.342 | 7.679 | 12.61 | 15.09 | 19.80 | 1.568 | 10.03 | 19.06 | 10.46 |
| VU | 50 | 1.452 | 5.227 | 6.065 | 5.873 | 5.362 | 8.511 | 14.35 | 19.51 | 0.798 | 9.862 | 13.22 | 7.682 |
| SU | 5 | 8.505 | 12.92 | 12.97 | 12.34 | 24.05 | 34.57 | 32.72 | 30.65 | 25.92 | 41.72 | 41.27 | 42.72 |
| SU | 10 | 7.342 | 11.71 | 12.95 | 12.23 | 16.80 | 31.32 | 29.48 | 29.57 | 15.31 | 37.62 | 40.20 | 41.10 |
| SU | 15 | 3.804 | 10.52 | 12.84 | 12.11 | 12.94 | 29.46 | 27.34 | 27.21 | 10.54 | 32.05 | 39.52 | 40.22 |
| SU | 20 | 3.282 | 9.512 | 12.82 | 11.87 | 10.71 | 27.56 | 26.39 | 25.99 | 7.921 | 30.54 | 30.80 | 37.65 |
| SU | 25 | 2.814 | 8.302 | 12.72 | 11.36 | 10.01 | 24.72 | 24.08 | 25.12 | 4.452 | 25.41 | 28.95 | 33.54 |
| SU | 30 | 2.683 | 7.742 | 11.46 | 11.13 | 9.525 | 21.83 | 22.87 | 21.95 | 3.942 | 21.45 | 27.63 | 29.62 |
| SU | 35 | 2.584 | 6.751 | 10.85 | 9.959 | 7.201 | 18.75 | 20.53 | 19.64 | 3.668 | 15.52 | 25.58 | 25.33 |
| SU | 40 | 2.482 | 5.457 | 9.371 | 8.628 | 6.714 | 17.82 | 20.45 | 18.03 | 1.955 | 12.83 | 20.93 | 19.20 |
| SU | 45 | 1.747 | 4.207 | 7.674 | 7.453 | 5.363 | 15.63 | 19.63 | 16.16 | 1.446 | 9.213 | 17.52 | 15.09 |
| SU | 50 | 1.243 | 3.026 | 6.213 | 5.582 | 3.447 | 13.95 | 17.43 | 15.05 | 0.432 | 5.573 | 10.75 | 9.093 |

*P1= Tecno S1, P2 = Touching T1, P3 = Infinix hot 6, and P4 = Itel 1701.*

Figure 3 shows the plots of how the EMF parameters vary with the measured distances from the tested phones per engagement mode. It can be deciphered from them that the electric field strength, magnetic field strength and power density for each of the phones show exponential variations with increase in the distance in question notwithstanding the engagement mode of the phones. The seeming similarity in the power density plots for VU and SU modes justifies the statistically verified fact earlier stated above that there is no significant influence of phone engagement mode on the EMF parameters.



Electric field strength for RA Magnetic field strength for RA Power density for RA

Electric field strength for RU Magnetic field strength for RU Power density for RU

Electric field strength for VU Magnetic field strength for VU Power density for VU

Electric field strength for SU Magnetic field strength for SU Power density for SU

**Figure 3.** Variation of EMF parameters with distances from the tested phones for different call engagement modes (a) Electric field strength (b) Magnetic field strength (c) Power density.

**Table 3**. Computed head SAR values at different operating frequencies of the phones

| Phone type/model | Frequency (MHz) | SAR ($10^{-7}$ W/kg) |
|---|---|---|
| P1 | 900 | 0.97 |
| P2 | 900 | 2.65 |
| P3 | 900 | 6.21 |
| P4 | 1800 | 6.84 |

It can be inferred from a careful observation of the results that the mean values of power density for VU mode are greater than those obtained for the SU mode with respect to the phones used. Moreover, at measurement distance of 5 cm from the phones, Table 3 entries show that the computed head SAR at 900 MHz ranges in value from $0.97\times10^{-7}$ W/kg to $6.21\times10^{-7}$ W/kg with P3 having the highest. Observably, this maximum value of head SAR at 900 MHz and the value of $6.84\times10^{-7}$ W/kg obtained for P4 at 1800 MHz are less in the order of $10^{-4}$ than $1.8\times10^{-3}$ W/kg head SAR value got by Shalangwa *et al*., (2011) and Kumar and Bhat, (2013) at a measured distance of 0.01 m from a 900 MHz mobile phone radiation source. This is, plausibly, due to differences in transmission power from the transmission tower as well as antenna quality. Also, though the calculated head SAR values at both frequencies are well below the regulated limit of 2.0 W/kg stipulated by (ICNIRP, 1998), P1 has the least value possible. This means that with its use, the user can be sure of being exposed to the least amount of radiofrequency radiation. It can be well said, based on equation 1 used in this work, that SAR value varies positively with that of electric field strength. On the strength of this consideration, it follows that the calculated head SAR value will only increase as the mobile phone is held closer to the user's head. This trend enjoys the support of, and resonates with the findings of (Kargel, 2005).

**Conclusion**

It was found in this work that electric field strength, magnetic field strength and power density vary significantly among Tecno S1, Touching T1, Infinix hot 6 and Itel 1701 phone types and models at same distances of measurement. Also, the results obtained revealed that variations in their call engagement modes have no significant effect on the emitted radiations. Again, by having the least value of head SAR, Tecno S1 could be rightly adjudged to be the safest, though all the phones used in this study have head SAR values that are less than the limit stipulated by ICNIRP. Above all, the findings from this work indicate that the selected phones cannot pose serious health problems to their users.

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