International Journal of Engineering and Advanced Technology Studies 13 (1), 1-12, 2025
Print ISSN: 2053-5783(Print)
Online ISSN: 2053-5791(online)
Website: https://www.eajournals.org/
Publication of the European Centre for Research Training and Development -UK

Assessment of the Effect of Mobile Phone Radiations Based on Selected Mobile Devices and Network Providers

Jonathan Olanrewaju Fatokun
Vocational and Technical Education Department
Ekiti State University, Ado - Ekiti

Adewale Dolapo Boyejo
Vocational and Technical Education Department
Ekiti State University, Ado – Ekiti

doi: https://doi.org/10.37745/ijeats.13/vol13n1112 Published February 14, 2025

Citation: Fatokun J.O. and Boyejo A.D. (2025) Assessment of the Effect of Mobile Phone Radiations Based on Selected Mobile Devices and Network Providers, *International Journal of Engineering and Advanced Technology Studies*, 13 (1), 1-12

Abstract: *This paper examines the radiofrequency (RF) radiation emitted by various mobile devices and network providers analyzing how device models, operational states, and proximity to network towers influence radiation exposure. With increasing mobile usage and concern about RF radiation health effect, this study aims to understand variations in radiation levels from different devices and network providers. Finding highlights significant difference in radiation based on device model, usage state (idle vs calling) and proximity to base stations. The diversity of electromagnetic radiation from various network service operators and mobile devices was measured using a Spectran HF-4040 analyzer. The spectrum analyzer has been used along with many mobile devices including the iPhone 7, Samsung A2, Tecno Poison 2 and Infinix Hot S. The Spectran HF4040 analyzer is used to measure the electromagnetic radiation emitted by various types of mobile devices using different SIM cards. Many calls were made from mobile devices without shielding materials to the four selected network operators (MTN, Glo, Airtel and 9mobile). The measurement was compared with the limit value. It was found that: (i) radiation levels from mobile devices were consistently high regardless of differences in network and phone type. As far as radiation levels are concerned (ii) Glo has the highest and Mtn has the lowest. Recommendations include using a cell phone with a low specific absorption rate (SAR), switching to headphones or speakers whenever possible, using a radiation blocker or a bag or special headphones that reduce SAR, and public education campaigns on safety precautions for telephone users to protect from the potentially harmful effects of radiation from mobile technologies.*

Keywords: electromagnetic radiation, mobile devices, specific absorption rate (SAR), spectrum analyzer, service provider,

International Journal of Engineering and Advanced Technology Studies 13 (1), 1-12, 2025
Print ISSN: 2053-5783(Print)
Online ISSN: 2053-5791(online)
Website: https://www.eajournals.org/
Publication of the European Centre for Research Training and Development -UK

INTRODUCTION

The proliferation of mobile devices and network infrastructure has raised concerns over potential health risks associated with exposure to RF radiation. Mobile devices emit radiation during operation, which varies depending on device design, network technology and proximity to cellular towers. This paper focuses on assessing radiation levels from different mobile and network providers, exploring the variation in radiation based on device characteristics and usage conditions. In recent times, there has been rapid development and global use of mobile phone technology in Osun State. While progress on the technology front is crucial, it is also important to consider certain important risks and impacts on human existence. As the use of cell phones has increased tremendously worldwide, the effects of radiation from cell phones and other wireless electronic devices on human health have become a topic of interest and research in many countries. Mobile devices generate radiations from their antennas that are non-ionizing. Long-term effects may not be unexpected since this radiation can be absorbed by the parts of the human body closest to the antennae. The increasing use of mobile phones around the world has generated great interest in researching the effects of electromagnetic radiation (EMR) from mobile phones and other wireless electronic devices on human health. The widespread use of mobile phones also raises concerns about the potential risks they pose to human health.

According to Sajedifar et al (2019), cell phone radiation is electromagnetic radiation that can be absorbed by the human body. Researchers' interest in the topic of cell phone addiction is due to the rapid and dynamic growth of the technology, the enthusiastic reception by the uneducated public, and the potential health problems that may arise from human enthusiasm for this technology. The amount of radiation emitted by mobile phone technology is of great concern to experts, as are the potential health risks. The amount of radiation emitted by a cell phone can be influenced by a number of factors, including the model of the phone, its antenna type, the technology used by the service provider, the connection network, the strength of the incoming signal, and the distance between the phone and the base station (Sajedifar, et al., 2019; Agrawal et al, 2009). The RF radiation level measured in Nigeria by Oluwafemi and Adeoye (2020) ranges from 0.3119 to 0.5407 mW/cm^2. The radiation intensities were considered relatively high enough to affect human health. Abdelati (2015) acclaimed that RF energy from mobile phones has a severe negative effect on human skin. The amount of radiation emitted by a cell phone can be influenced by several factors, including the model of the phone, its antenna type, the technology used by the service provider, the connection network, the strength of the incoming signal, and the distance between the phone and the base station (Sajedifar, et al., 2019; Agrawal et al, 2009).

When it comes to cell phone radiation, there are two major issues that need to be addressed immediately: What are the effects of radio waves on human health? And what health risks are associated with the use of cell phones, cellular devices, microwave ovens, radio and television transmitters, power lines and X-rays? However, several reports from around the world have attempted to estimate the potential links between negative health outcomes and cell phone

radiation (Abdelati, 2015; Jalai, 2014). In 2011, the World Health Organization's (WHO) International Agency for Research on Cancer (IARC) classified wireless radiation as Group 2B, or "possibly carcinogenic to humans" (Miller et al 2019). This suggests that there may be a carcinogenic risk and requires further investigation into the amount of radiation released into the environment, the duration of exposure and the intensity of wireless device use. Due to the increasing penetration of wireless communication, many concerns regarding the security of wireless devices are being discussed these days. Microwaves emitted from cell phones interact with body tissue, generating internal electric and magnetic fields and causing a thermal effect over a period of time when the cell phone is in close proximity to the body (Behari, 2012). Although fear of the potential risk of developing brain cancer or another serious illness is the most common fear among people, testing mobile devices near a user is also important from a technical perspective. Reducing the radiation power absorbed by the user not only reduces potential health risks, but also increases the efficiency of the antennas (Jamshed et al., 2019). Due to these aspects, antenna designers are forced to pay increasing attention to reducing the radiation absorbed by the user.

A complete understanding of the process of how and why the fields generated by the antenna of a mobile terminal are absorbed by the user would make it possible to design the antennas from the outset in such a way that the radiant energy absorbed by the user could be minimized. Antenna size, bandwidth, radiation efficiency and SAR (Specific Absorption Rate) are complexly related, making designing a mobile device antenna that works as desired in all possible environments a major challenge. The everyday use of devices that emit radio frequency (RF) is increasing rapidly. In the vicinity of the antennas, the electric field strengths can reach several hundred volts per meter. Even higher values can be found near professional sources used to process various materials by heating and sometimes by forming plasma discharges in the material. Power sources that generate strong electromagnetic fields are typically found in medical applications and certain workplaces. Medical devices used for magnetic resonance imaging (MRI), diathermy, various types of RF ablation, surgery and diagnosis can cause strong electromagnetic fields at the patient's position or locally in the patient's body (Keshvaer & Lang, 2006). Compared to medical devices, cellular communications generate an average of low levels of electromagnetic fields in publicly accessible areas. However, significantly higher peak load values can occur when using mobile devices.

Several studies have examined mobile RF radiation, revealing a direct relationship between usage state, device model and proximity to network infrastructure. For instance research conducted in Nigeria measured RF radiation across different phone models and observed elevated exposure during active call mode, with power density decreasing at greater distance from the device and network towers. Furthermore, radiation levels near base stations also vary due to environmental factors such as nearby building and other RF sources, which can cause unexpected fluctuation. It has also been suggested in the past that prolonged exposure to cell phone radiation can double the risk of developing a brain tumor on the same side of the head where the device was held (Keshvaer & Lang, 2006). According to studies by Hardell and Carlberg (2014) and Hardell et al (2013) , the World Health Organization (WHO) warned in 2005 that prolonged exposure to electromagnetic

fields (EMF) could be dangerous and could potentially serve as the basis for electromagnetic weapons. When people stay in close proximity to their cell phones for a long period of time, they may experience thermal effects on their body due to the interaction of the radiation with their tissues, resulting in internal electric and magnetic fields (Kaur et al., 2023). Electromagnetic radiation (EMR) is emitted from a variety of electrical systems, including, but not limited to, cell phones, microwave ovens, communications base stations, power lines, electronic devices, and more. Because EMR produces electromagnetic waves at many different frequencies, their strength increases in residential areas. Cosmic rays, gamma rays, and X-rays are examples of radiofrequency waves that are strong enough to trigger ionization (Yang et al., 2021).

According to a comprehensive review of the relevant scientific literature (Sage & Burgio, 2018), long-term radiation exposure can have harmful biological consequences, including the development of chronic diseases, cognitive impairment, and other health problems. Overall, scientific evidence suggests that chronic exposure to radio emissions may have deleterious effects on neurological development, memory learning, attention, concentration, behavioral problems, and sleep quality in fetuses, infants, young children, and adolescents (Davis et al., 2023; Carter et al. 2016; Aldad et al., 2013). According to certain studies, deterioration in sperm quality is associated with cell phone use. Damage to sperm DNA and a weakened testicle are two of the most commonly reported causes of male impotence and reduced fertility. According to Fejes et al., (2005), the amount of time a man owns a cell phone is negatively correlated with the quality of his sperm. Agrawal et al (2009) Found that cell phone use negatively affected semen quality in 361 men who visited an infertility clinic. These results were confirmed, albeit in a smaller sample of men (13 and 27 people, respectively) (Dafdad et al., 2022).

The specific absorption rate (SAR) is a measurement of cell phone radiation that penetrates the human body. The term absorption rate refers to the rate at which a human absorbs energy from a cell phone per unit of tissue volume (Tamminaina & Manikonda, 2023). The specific absorption rate (SAR) for mobile phones depends on the conductivity of the human body and is between 0.12 and 1.6 watts/kg. In addition to the dielectric value of the human body, the angle of the radiation source, the human body and the frequency of exposure also play an important role in determining the biologically significant dose (SAR). Optimal radiofrequency communication and dosimeter depend on the conductivity and relative permittivity of human tissues (Kaur et al., 2023). Frequency influences permittivity and conductivity (Tamminaina & Manikonda, 2023). According to Tamminaina and Manikonda (2023), the electromagnetic fields can be divided into four areas with regard to the energy absorption of the human body as highlighted in the following list.

a) Frequencies from 100 KHz to less than 20 MHz, at which absorption in the trunk decreases rapidly with decreasing frequency and significant absorption may occur in the neck and legs.
b) Frequencies in the range from 20 MHz to 300 MHz, at which relatively high absorption can occur in the whole body, and even to higher values if partial body (e.g., head) resonances are considered.

c) Frequencies in the range from 300 MHz to several GHz, at which significant local, non-uniform absorption occurs.
d) Frequencies above 10 GHz, at which energy absorption occurs primarily at the body surface.

The most important diametric parameter for evaluating the absorption of electromagnetic radiation in humans is the Specific Absorption Rate SAR. SAR is a measure to quantify the electromagnetic energy absorbed by unit mass of tissue.The unit of SAR is watt per kilogram (W/kg) or milliwatt per gram (mW/g) and refers to the time rate of energy absorption of non-ionizing radiation at a specific location in tissue. In practice, SAR is always determined as an average value over a limited tissue mass, usually 1 g or 10 g.

The International Commission on Non-Ionizing Radiation Protection (ICNIRP) in Europe is one of several international authorities responsible for regulating the permissible SAR limit for human tissue exposure. The International Commission on Non-Ionizing Radiation Protection (ICNIRP) has set a standard upper limit for SAR of 2 W/kg for a 10 g human tissue sample. Japan, Brazil and New Zealand are also among the countries that adhere to this regulation. The SAR limits in the United States are 1.6 W/kg per 1 g of human tissue, as set by the Federal Communications Commission (FCC) (Kong et al., 2011). The current norm is followed not only by the United States (Husni, et al., 2013), but also by Canada, Australia, and Taiwan. According to the ICNIRP regulations (Husni, et al., 2013), the Malaysian Communications and Multimedia Commission (MCMC) has regulated the safe SAR limit for mobile phones in the country.

The aim of this study was to examine the differences in electromagnetic radiation levels across a range of service providers and mobile devices in Nigeria, given concerns about the health effects of prolonged exposure to mobile phones. This is done to make consumers aware of the properties of radiation, possible side effects and safety precautions against prolonged exposure. The emission was reported by Sajedifar et al (2019) regarding network technology, calling mode and battery level. They measured readings at 1, 5, 10, 15, 20, 30, 50, 60, 70, 80 and 100% battery life using 2G technology in Call, Called and Chat modes. Sajedifar et al (2019) and Oluwafemi and Adeoye (2020) found that the highest levels of electromagnetic radiation were recorded only during calls made on a cell phone with a battery charge of one percent or when the battery was fully charged. However, the research found no statistically significant difference between radiations in call and chat mode.

Therefore, several factors ignored by Sajedifar et al (2019) were taken into account in this investigation. Therein, we add variables like phone model and service provider technology. On major service providers (MTN, Glo, Airtel, and 9mobile) in Nigeria, phone models such as the iPhone 7, Samsung A2, Infinix Hot S, and Tecnopouvoir 2 were tested. The Main purpose study is to investigate the effect of electromagnetic radiations of mobile equipment on users in Osun State, Nigeria. Specifically, the study intends to:

1. find out the variations of electromagnetic radiations of network providers in Osun state Nigeria;
2. determine the difference in the impact of electromagnetic radiation from different mobile devices.

To achieve the above stated aim, the task is to measure electromagnetic radiation generated by mobile equipment using the major service providers SIM cards, with the aim of Spectran HF4040 analyzer. The study was guided by two research questions that were raised as follows, (1) What is the relationship between electromagnetic radiations in different network providers and its effect on the users in Osun state Nigeria? and (2) What is the difference in the impact of electromagnetic radiation in various mobile equipment and network provider?

METHODOLOGY

In this part, we describe the techniques we used to collect and analyze the information for this study. in other words, our methodology. The variation in electromagnetic radiation from Nigeria's leading network service providers was measured using a Spectran HF-4040 portable RF spectrum analyzer. The Spectrum Analyzer is capable of analyzing signals from 100 MHz to 4 GHz at average levels of -90 dBm to 0 dBm. The normal accuracy is 3 dB and the smallest achievable sampling time is 100 ms. The analyzer has a minimum filter bandwidth of 100 kHz and a maximum of 50 MHz. The analyzer includes both the HypeloG 7040 EMC antenna and high-performance digital signal processor (DSP).

In terms of radiation types and values, major network service providers such as MTN, Glo, Airtel and 9 Mobile have been taken into account. For the various mobile devices and service providers included in the study, radiation levels were measured in both standby and call modes. While measuring the radiation, calls were made to the SIM cards (Subscriber Identity Module) of the selected service providers. During the test, SIM cards from mobile devices such as iPhone 7, Samsung A2, Tecno PoweR2 and Infinix Hot S were hosted. However, all mobile devices were used as test environments for SIM cards from different service providers. Electrical and magnetic units were used to classify the radiations and bar graphs of the values were created for investigation purposes. Repeated measurements were taken while these particular phone models were used as mobile stations

For the measurement, the required frequency was set to the custom setting of the Spectran HF-4040 analyzer. The following additional experimental settings were made: 10-millisecond sweep, Attenuation-Auto, Count-1, Level-90 dB, and Antenna Type-HL7040. Figures 1 and 2 provide an overview of the Spectran HF4040 analyzer and its experimental setup for measurement respectively.

Figure 1: The Set up for Spectran HF4040 (Google Image Report: https//www.bhphotovideo.com/images/images…)

Table 1 shows the average measurements of magnetic and electric radiations. Magnetic and electric field radiations were simultaneously recorded, and their combined bar graphs are shown

in Figures 2 and 3. The radiations from mobile phones are visible in the surroundings, as shown in Table 1 and the two figures. Depending on the type of mobile device (phone) being used and the service provider, there is a significant concentration of radiations (magnetic field and electric field) in and around the mobile device.

MTN is the service provider with the lowest average magnetic and electrical radiation. As a mobile station, the iPhone 7 consumes 18.44 A/m at 2.64 V/m; the Samsung A2 Duo consumes 10.03 A/m at 0.06 V/m; the Infinix Hot S consumes 55.58 A/m at 4.58 V/m; and the TecnoPouvoir 2 consumes 8.44 A/m at 1.78 V/m. However, when using an iPhone 7 as a mobile station, the average radiation exposure on the Glo network was highest at 78.97 A/m, 5.46 V/m; 212.19 A/m, 0.28 V/m with the Samsung A2 Duo; 106.04 A/m, 6.32 V/m with the Infinix Hot S; and 33.17 A/m, 3.54 V/m with the TecnoPouvoir 2.

On average, the Samsung A2 Duo mobile station delivered the most consistent electrical radiation across networks when considering mobile devices. However, using the Infinix Hot S as a mobile station resulted in the greatest electric field radiation. When used as a mobile station, the Infinix Hot S gave the highest average value for magnetic radiation, while the TecnoPouvoir 2 had the lowest value.

Table 1: Average Magnetic and Electric Radiations

Devices (cell Phones) → **Network Provider** ↓	I-Phone 7 Stat		Samsung Mobile		Infinix Mobile		Tecno Po Mobile	
	Magnetic Field Radiation	Electric Field Radiation	Magnetic Field Radiation	Electric Field Radiation	Magnetic Field Radiation	Electric Field Radiation	Magnetic Field Radiation	Electric Field Radiation
	(A/m)	(V/m)	(A/m)	(V/m)	(A/m)	(V/m)	(A/m)	(V/m)
AIRTEL	47.2	4.22	29.5	0.11	88.17	5.77	42.02	3.98
GLO	78.97	5.46	212.19	0.28	106.04	6.32	33.17	3.54
MTN	18.44	2.64	10.03	0.06	55.58	4.58	8.44	1.78
9MOBILE	25.10	3.08	54.7	0.14	96.02	6.02	13.10	2.22

This study's findings corroborate previous findings that mobile devices emit radiation even when not in use. The sort of mobile devices (phone) used, among other things, affects how the radiations behave.

International Journal of Engineering and Advanced Technology Studies 13 (1), 1-12, 2025
Print ISSN: 2053-5783(Print)
Online ISSN: 2053-5791(online)
Website: https://www.eajournals.org/
Publication of the European Centre for Research Training and Development -UK

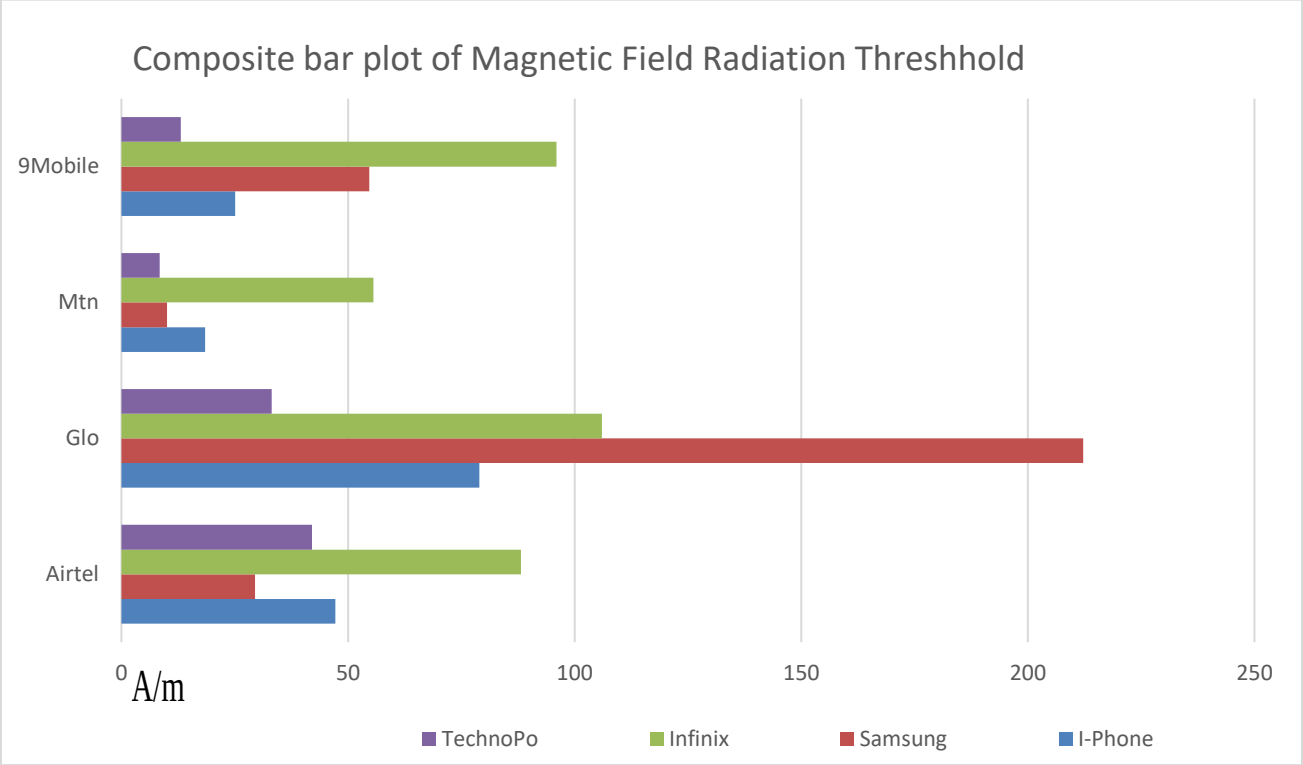

Figure 2: Composite bar plot of Magnetic Field Radiation

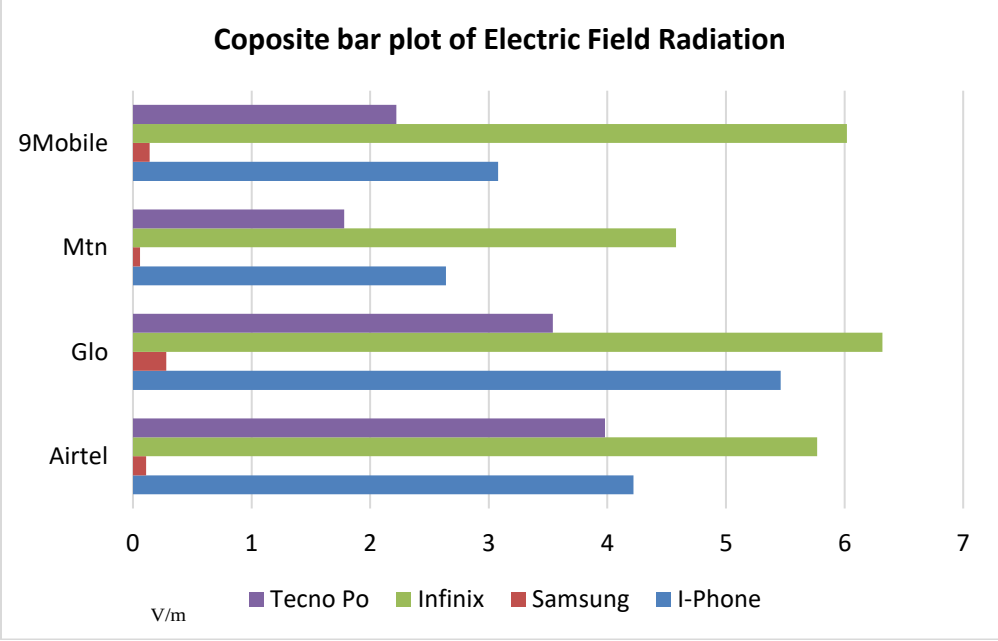

Figure 4: Composite bar plot of Electric Field Radiation

CONCLUSION

From literature it has been found that excessive exposure to electromagnetic radiation from mobile technology has negative effects on people's health and the environment. The study further clarifiesthat the level of electromagnetic radiation occurring in a mobile network system is influenced by a number of different factors, including the model of mobile devices deployed and the mobile technology used by the service provider. Even when mobile devices are not in use, they still emit some radiation as they periodically turn to the antenna closest to the operator for updates and instructions.

Cell phone users should take safety precautions such as: Such as choosing reputable models with documented health and safety ratings (relatively low SAR), minimizing self-exposure by optimizing usage time when using cell phones, and keeping cell phones away from the body by using headphones whenever possible. In addition, calls can be made over a loudspeaker when possible, and a bag can be used to block electromagnetic radiation, or special headphones can be used to reduce exposure to specific absorption rate (SAR). In summary, mobile operators should regularly inspect and maintain their base station equipment and mobile phone users should always take all necessary safety precautions when using their devices.

Recommendation

Based on the outcome of this research following are therefore recommended.

1. The Federal Communication Commission's (FCC) current requirements of 1.6W/kg for microwave radiation from mobile equipment must be rigorously adhered to.
2. Too much exposure to mobile device radiation is harmful, hence the public has to be made more aware of this fact.
3. Mobile devices should be maintained at arm's length from people at all times.
4. When you get a call on your mobile device, you can put it on the speakerphone or the headset.

Overall, prevention is preferable to treatment, hence substantial and ongoing public education initiatives are necessary to educate users on the preventative actions that may be taken to protect themselves from the potential health dangers associated with the ever-changing mobile communication system

REFERENCES

Abdelati, M. (2015). Electromagnetic radiation from mobile phone base stations at Gaza. *IUG Journal of Natural Studies, 13(2)*, 129–146.

Agrawal, A., Desai, N. R., Makker, K., & Varghese, A. (2009). Effect of radio frequency electromagnetic waves (RF-EMW) from cellular phones on human ejaculated semen: An in vitro pilot study. *Journal of Fertility and Sterility, 92(4)*, 1318–1325.

Aldad, T. S., Gan, G., Gao, X. B., & Taylor, H. S. (2013). Fetal radio frequency radiation exposure from 800–1900 MHz-rated cellular telephones affects neurodevelopment and behaviour in mice. *Report 2, Article No. 312*.

Behari, J. (2012). Evidence for mobile phone radiation exposure effect on reproductive pattern of rats: Role of ROS. *Journal of Electromagnet Biology and Medicine, 31*, 213–222.

Carter, B. D., Recs, L., Hak, D., & Bhaitonachagee, D. (2016). Electromagnetic radiation filter for coaxially fed hot chassis television receiver. *JAMA Pediatrics, 170(12)*, 1202–1208.

Dafdad, F., Bamdad, K., & Samanipour, M. (2022). The effect of electromagnetic waves emitted from the tablet connected to internet on count and motility of male rat sperms. *Pars Journal of Medical Sciences, 16(2)*, 42–48.

Davis, D., Birnbaum, L., Ben-Ishai, P., Taylor, H., Sears, M., Butler, T., & Scarato, T. (2023). Wireless technologies, non-ionizing electromagnetic fields and children: Identifying and reducing health risks. *Current Problems in Pediatric and Adolescent Health Care, 101*, 374.

Fejes, I., Zavaczk, Z., & Szollosi, Z. (2005). Is there a relationship between cell phone use and semen quality? *Journal of Reproductive Systems, 51(5)*, 385–393.

Hardell, L., & Carlberg, M. (2014). Case-control study of the association between malignant brain tumors diagnosed between 2007 and 2009 and mobile and cordless phone use. *International Journal of Oncology, 43(6)*, 1833–1845.

Hardell, L., Walker, M., Walhjalt, B., Friedman, L. S., & Richter, E. D. (2013). Secret ties to industry and conflicting interests in cancer research. *American Journal of Industrial Medicine, 50(2)*, 27–33.

Husni, N. A., Islam, M. T., Faruque, M. R. I., & Misran, N. (2013). Effects of electromagnetic absorption towards human head due to variation of its dielectric properties at 900, 1800, and 1900 MHz with different antenna substrates. *Progress in Electromagnetic Research, 138*, 367–388.

Jalal, J. A. H. (2014). Reduction of cell phone electromagnetic radiation effect on human body. *International Journal of Science, 3*, 19–23.

Jamshed, M. A., Heliot, F., & Brown, T. W. (2019). A survey on electromagnetic risk assessment and evaluation mechanism for future wireless communication systems. *IEEE Journal of Electromagnetics, RF and Microwaves in Medicine and Biology, 4(1)*, 24–36.

Kaur, P., Rai, U., & Singh, R. (2023). Genotoxic risks to male reproductive health from radiofrequency radiation. *Cells, 12(4)*, 594.

Keshvaer, J., & Lang, S. (2006). Comparison of radio frequency energy absorption in ear and eye region of children and adults at 900, 1800, and 2450 MHz. *Physics in Medicine and Biology, 5008*, 4355–4369.

Kong, S. L., Li, G., Loh, S. L., Sung, W., & Liu, E. T. (2011). Cellular reprogramming by the conjoint action of ERa-FOXAl and GATA3 to a Lingard-inducible growth state. *Molecular Systems Biology, 7(1)*, 526–540.

Miller, A. B., Sears, M. E., Morgan, L. L., Davis, D. L., Hardell, L., Oremus, M., & Soskolne, C. L. (2019). Risks to health and well-being from radio-frequency radiation emitted by cell phones and other wireless devices. *Frontiers in Public Health, 7*, 223.

Oluwafemi, I. B., & Adeoye, O. J. (2020). Mobile phone radiofrequency radiation assessment based on call-related factors and physical condition from selected mobile phones. *European Journal of Engineering and Technology Research, 5(3)*, 343–347.

Sage, C., & Burgio, E. (2018). Electromagnetic fields, pulsed radiofrequency radiation, and epigenetics: How wireless technology may affect childhood development. *Child Development*.

Sajedifar, J., Nasiri, P., Monazzam, M. R., Shamsipour, M., & Ramezani, R. (2019). The effect of battery charge levels of mobile phone on the amount of electromagnetic waves emission. *Journal of Environmental Health Science and Engineering, 17(1)*, 151–159. https://doi.org/10.1007/s40201

Tamminaina, G., & Manikonda, R. (2023). Investigation on performance of four-port MIMO antenna using electromagnetic band gap for 5G communication. *Progress in Electromagnetics Research M, 119*, 51–62.

Yang, L., Zhang, C., Chen, Z. Y., Li, C. S., & Wu, T. N. (2021). Functional and network analyses of human exposure to long-term evolution signal. *Environmental Science and Pollution Research International, 28(1)*, 5755–5773. https://doi.org/10.1007/s11356-020-10728-w