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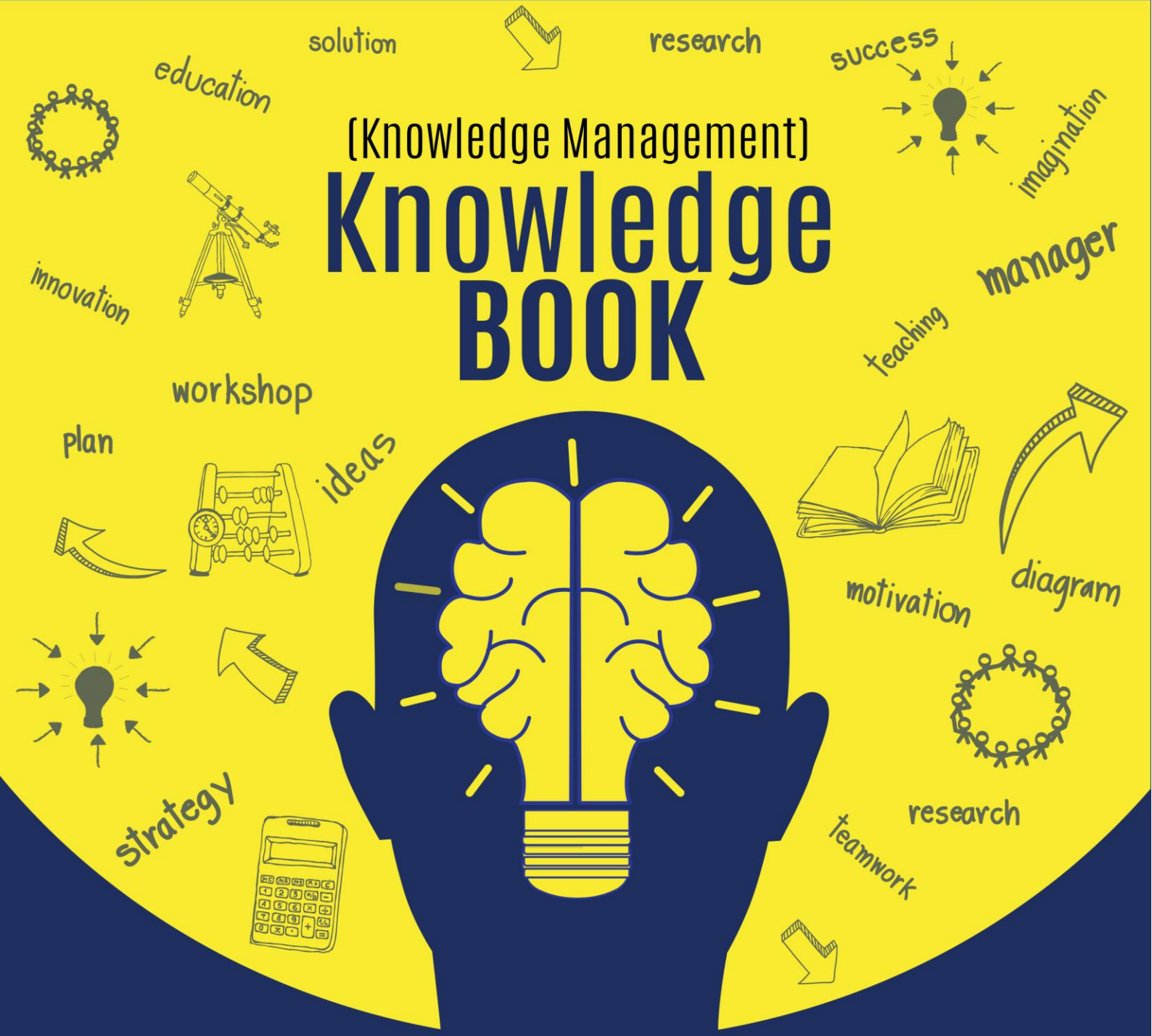

Smartphone and Radiation

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SMARTPHONE AND RADIATION

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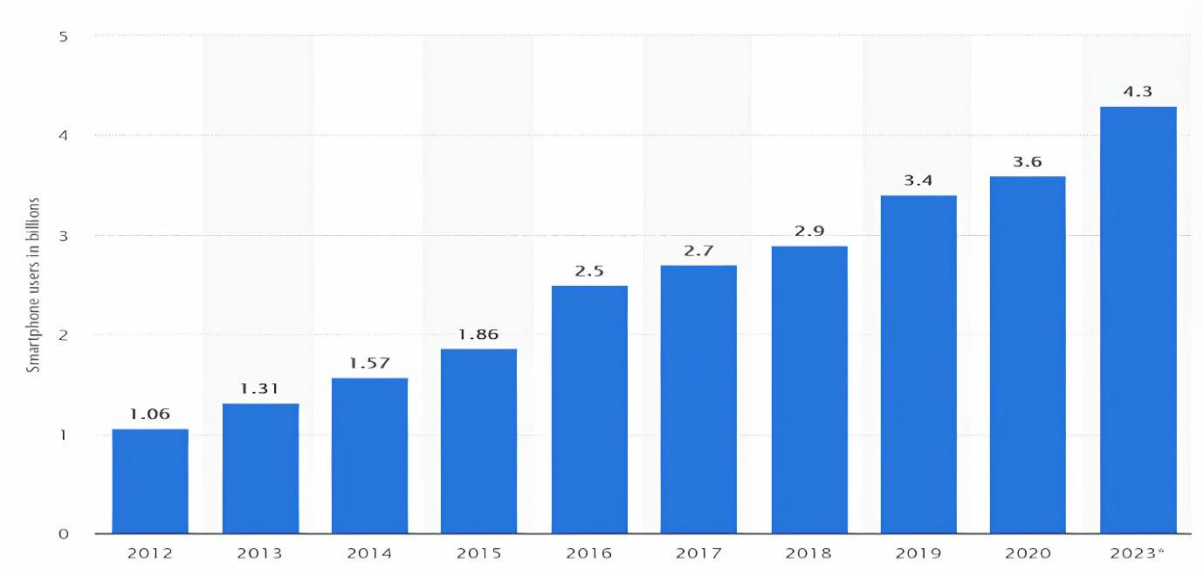
Chapter 1: Introduction to Smartphones

1.1 Overview of Smartphones

Smartphone is a mobile phone that allows us to do more than performing phone calls and send text messages. We can use the smartphones to browse the Internet and run software programs like a computer. Smartphones use a touch screen to allow users to interact with them. There are thousands of smartphone applications (apps) including games, personal-use, and business-use programs that all run on the stated phone.

1.2 Smartphone usage in the world

The number of smartphone users worldwide today surpasses three billion and is forecasted to further grow by several hundred million in the next few years. As shown in the Figure 1 below, the number of smartphone users worldwide in 2020 was at 3.6 billion users, with the figure is projected to increase to 4.3 billion in 2023. China, India, and the United States are the countries with the highest number of smartphone users, with a combined 1.46 billion users. According to Statista, the current number of smartphone users in the world today is 3.8 billion, and this means 48.33% of the world's population owns a smartphone. This figure is up considerably from 2016 when there were only 2.5 billion users, 33.58% of that year's global population. In 2021, including both smart and feature phones, the current number of mobile phone users is 4.88 billion, which makes 62.07% of people in the world a mobile or a cell phone owner. Feature phones are the basic cell phones without apps and complex OS systems, which are more prominent in developing countries.

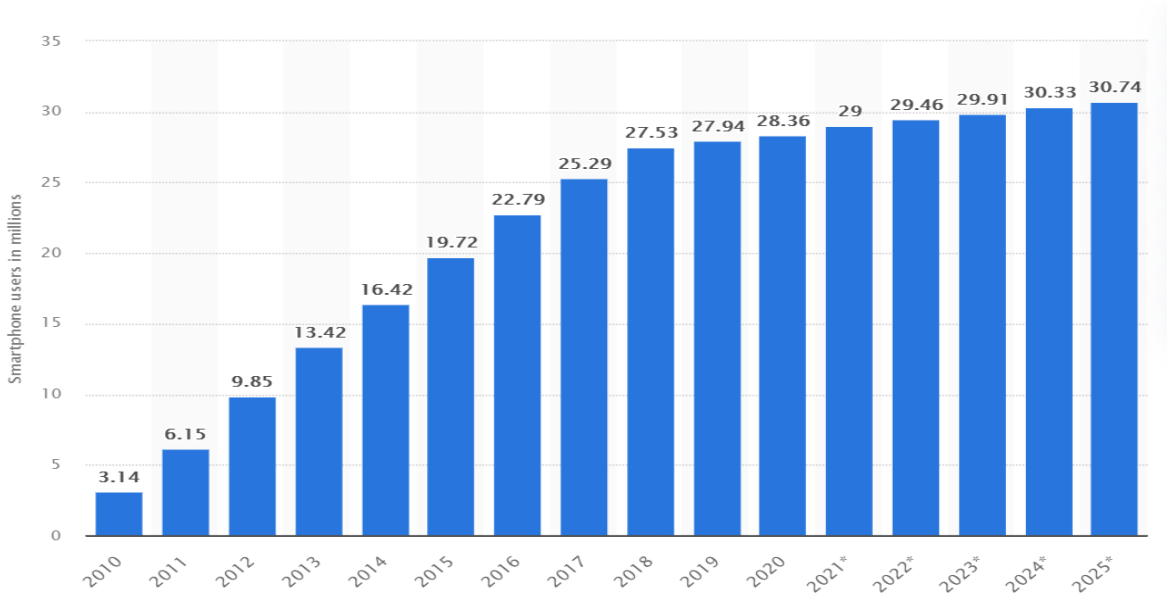


Source: Statista 2021

Figure 1: Smartphones users worldwide

1.3 Smartphone users in Malaysia

For 2020, the number of smartphone users in Malaysia was at 28.36 million. With a growing population, the number of smartphone users in Malaysia is expected to reach over 33 million by 2024 as shown in Figure 2. Almost everybody in Malaysia owns a smartphone. However, the younger generation tend to own smartphones more than the older generation. In a survey conducted on smartphone ownership, only 30 percent of the respondents who were aged 65 years old and above had a smartphone. Income and education also seemed to have impact on digital connectivity, including smartphone ownership. A survey showed that about 95 percent of respondents who earned at least RM5, 000 and had tertiary education or more owned a smartphone.



Source: Statista 2021

Figure 2: Number of Smartphone Users in Malaysia

Chapter 2: Radiation from Smartphones

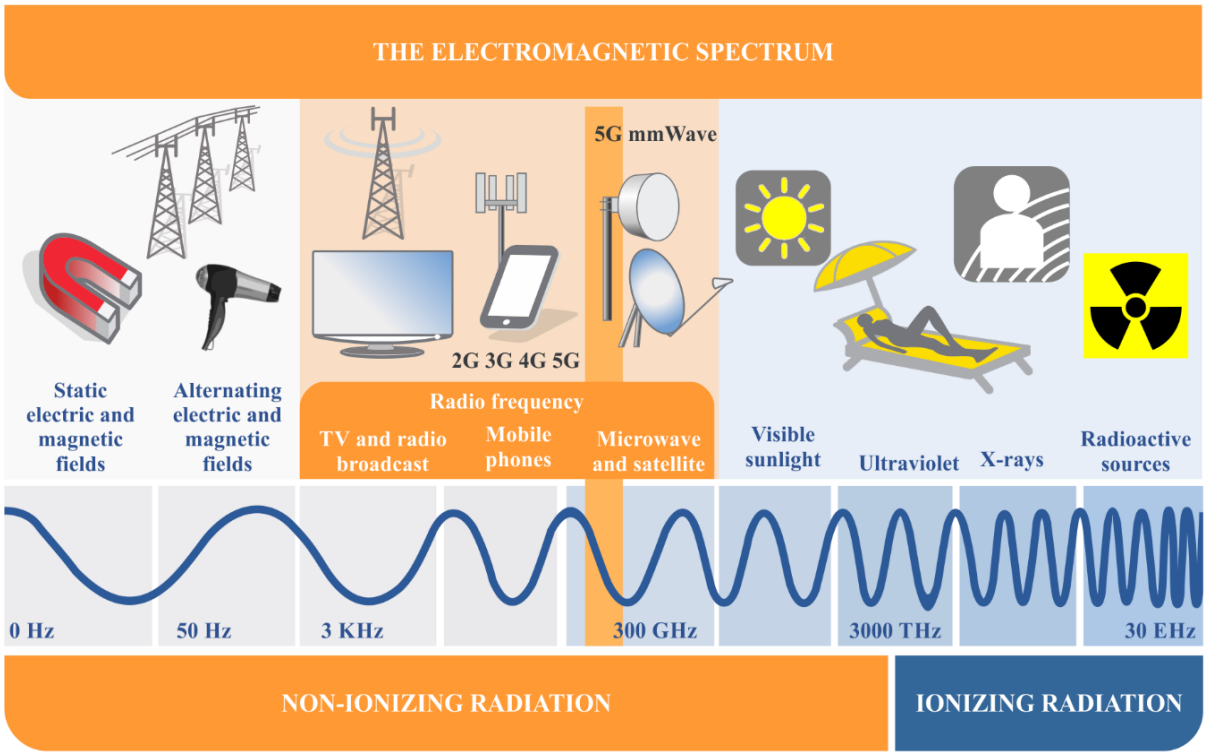
2.1 Non-Ionizing Radiation (NIR) from Smartphones

Smartphones are low powered two-way radio. It contains both a transmitter and a receiver and uses Radio Frequency (RF) Electromagnetic fields (EMF) to send and receive calls, access the internet and send messages, and data.

Electromagnetic Spectrum

Electromagnetic fields (EMF) have existed in different forms since the birth of the universe. EMF differ from each other in relation to frequency, and visible light is their most familiar form.

Electric and magnetic fields are part of the electromagnetic spectrum which extends from static electric and magnetic fields, through Radio Frequency (RF), Infrared Radiation (IR) and visible light to x-ray and gamma ray as shown in Figure 3 below.



Source: International Telecommunication Union (ITU) 2021

Figure 3: Electromagnetic Spectrum

Electromagnetic radiation at frequencies below the UV band are classified as "Non-Ionizing Radiation" (NIR) because they lack the energy to release electrons i.e., to ionize or effect changes in atomic structure. Radio Frequency fields are Non-Ionizing Radiations. A part of the electromagnetic spectrum extending from the 3 kHz

frequency to 300 GHz is referred as radio frequency (RF). Television and radio transmitters (including base stations) as well as microwaves, mobile telephones, smartphones and radars produce RF fields. These fields are used to transmit information and form the basis of telecommunications as well as radio and television broadcasting all over the world. Many devices installed or available at home such as cordless phones, Wi-Fi, tablets, smart camera, smart watches and other wireless devices also transmit EMF at radio frequencies

2.2 RF Radiation Measuring Instruments

In order to determine and evaluate the RF radiation from the smartphones, two main equipment were used to perform the safety assessment from the smartphones; which are the NARDA Broadband Meter (NBM 550) with probe EF0691 (100kHz-6GHz) and Selective Radio Meter SRM 3000 series with Antenna Model K-0818 (27MHz-3GHz). The SRM was used to detect the frequency the smartphone was transmitting.

Figure 4: RF Radiation Measuring Instruments: NARDA Broadband Meter

Figure 5: RF Radiation Measuring Instruments: SRM 3006

Chapter 3: RF Radiation Safety Assessment from Smartphones

3.1 Methodology

A broadband electromagnetic field meter NBM 550 with isotropic probe EF0691 (100kHz-6GHz) was used for the investigations. Measurements were performed at a 2 cm distance from the probe to the smartphones. The electric field strength was measured in units of Volt per meter (V/m). It was ensured that there was no external RF source close with the working area in the lab in which the assessment was conducted. It should be noted that the operating frequency for all the smartphone were in the range of 900 MHz to 2.7 GHz. Based on the recommended guidelines for public, the electric field reference level or the exposure limit for this frequency range is 61 V/m taking into consideration the highest operating frequency. The setup for the RF radiation safety measurement from smartphones is shown in Figure 6. The smartphone was placed on the holder and the electric field strength from each smartphone was recorded. The exposure of RF electric field strength radiated from the 5 different smartphone brands namely Brand S, Brand I, Brand H, Brand R and Brand O was measured.

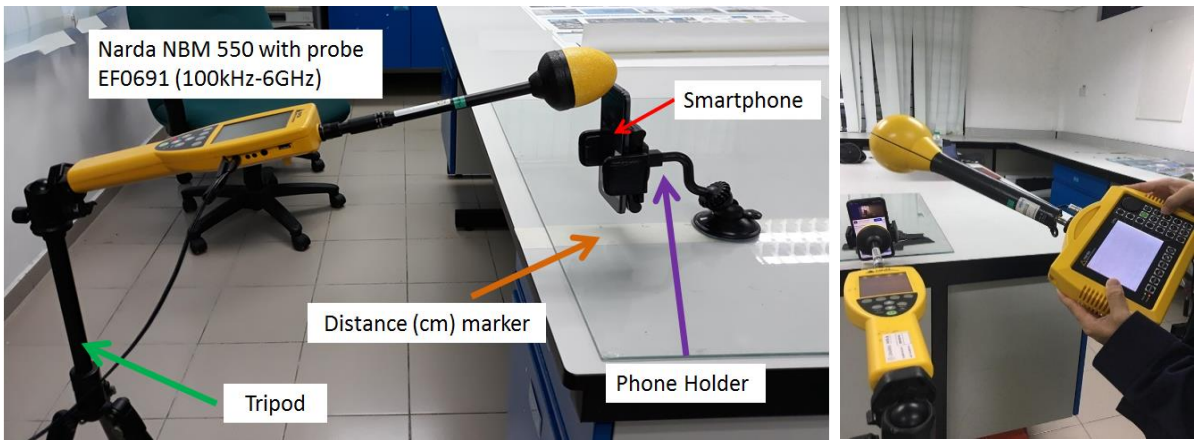


Figure 6: Equipment setup for RFR measurement (E-Field measurement)

For the study, the measurements were conducted at 5 different smartphone modes namely at “Standby” mode, “Outgoing call” mode, “Incoming call” mode, “Web Browsing” mode and “Video Streaming” mode. The “Standby” mode is defined as when the phone is idle and the data has been turned off. The “Outgoing call” mode is defined as when the user performed a call and with a talk time duration of 10 minutes, and the “Incoming call” mode is when the user received a call with a talk time duration of 10 minutes.

It should be noted that the call made and received was via the normal voice call and not utilizing the data or video call. The “Web Browsing” mode is defined as when the user was accessing the internet and browsing through websites, and for this study, various news channel and popular social media websites were browsed for 30 minutes when performing the measurement. The “Video Streaming” mode is defined when the user was streaming a particular video from any video streaming websites and for this study the video from “YouTube” have been streamed for 30 minutes when performing the measurement.

The RF field strength measurements were made at the battery percentages of 1-10%, 11-20%, 21-30%, 31-40%, 41-50%, 51-60%, 61-70%, 71-80%, 81-90%, and 91-100% respectively for all the modes. This criteria of choosing the difference in battery percentages for every 10% was to comprehensively evaluate the changes at the stated battery percentages. In addition, the RF field strength measurements were made at network connectivity percentages less than 25%, 25% to less than or equals to 50%, 50% to less than or equals to 75%, and 75% to 100%.

It should be noted that different smartphones have different signal bar indicators. For instance, a full bar network signal of a particular brand of a smartphone is 4 bars indicating a network connectivity rate of 100%, and a full bar network signal of another brand of phone is 5 bars. Therefore, for the uniformity of measurement, all the network connectivity was converted into percentages. Figure 7 shows the summary of the steps and description on the measurement procedure.

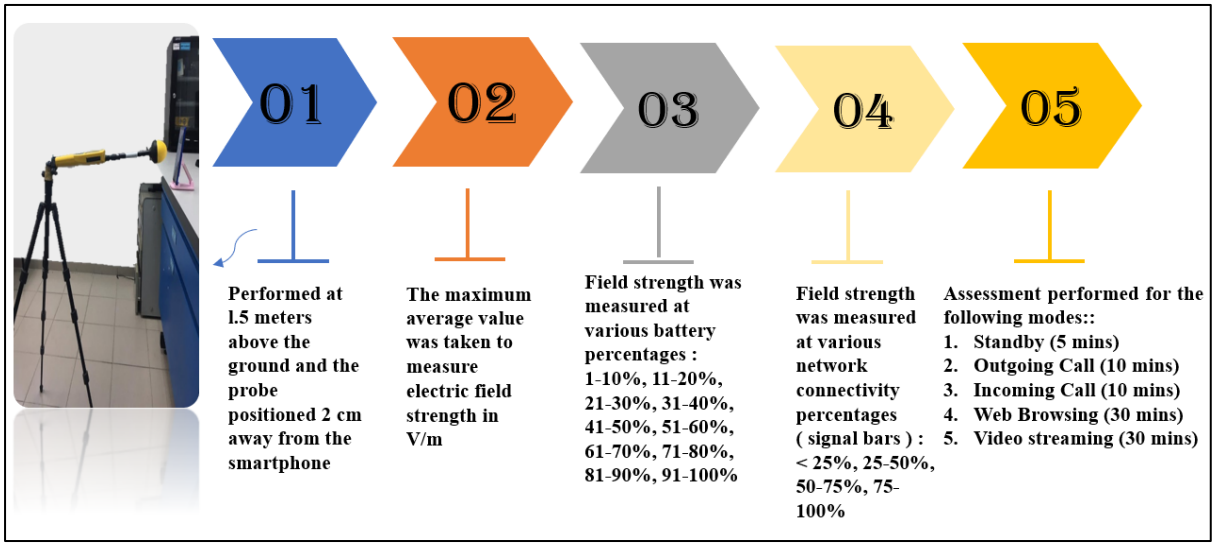


Figure 7: Summary of the steps and flow of measurement

3.2 Results

Results: Battery Percentage

The recorded maximum electric field strength recorded for the five different modes for five different smartphone brands on different battery percentages are shown from Figure 8 to to Figure 12. The maximum electric field strength was compared with the reference level stipulated under the International Commission on Non-Ionizing Radiation Protection (ICNIRP) guidelines (ICNIRP 2020) and Multimedia Commission (MCMC) Mandatory Standard (MCMC 2010). The summary of the results is described in Table 1.

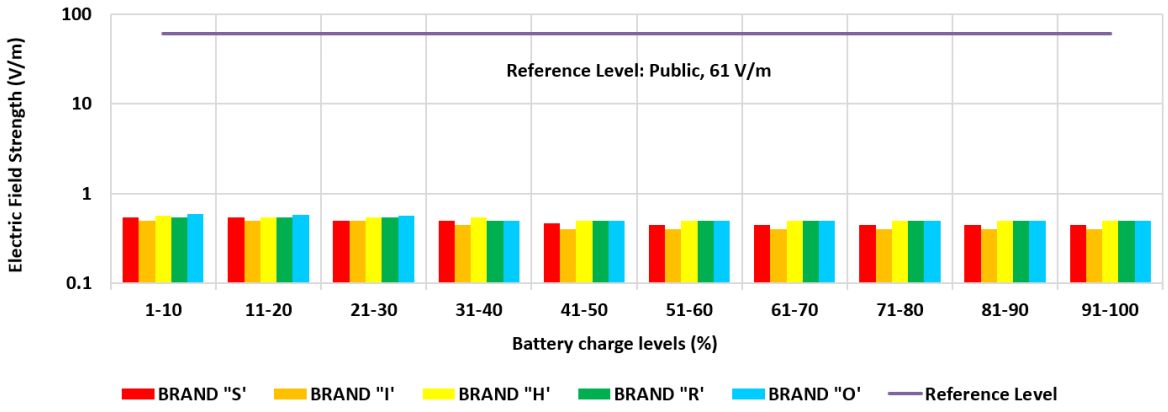


Figure 8: Plot of electric field strength during “Standby” Mode at different battery percentages

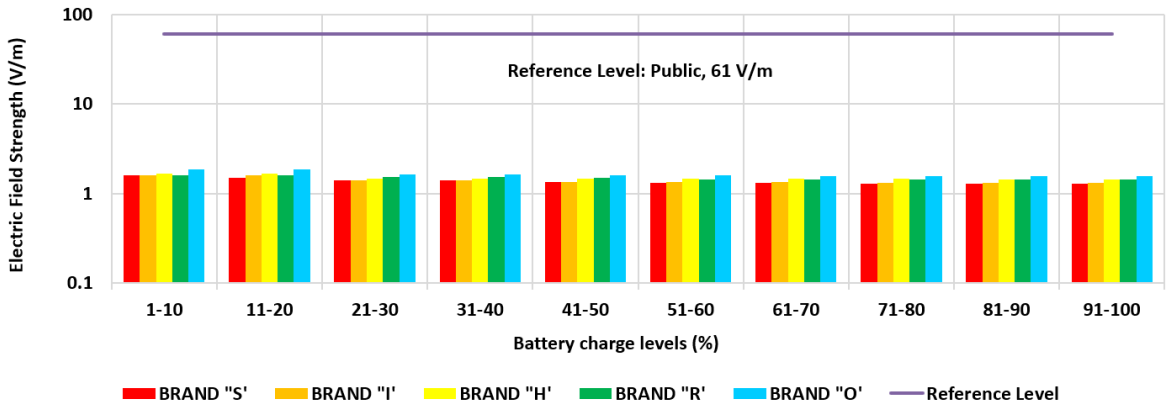


Figure 9: Plot of electric field strength during “Outgoing Call” Mode at different battery percentages

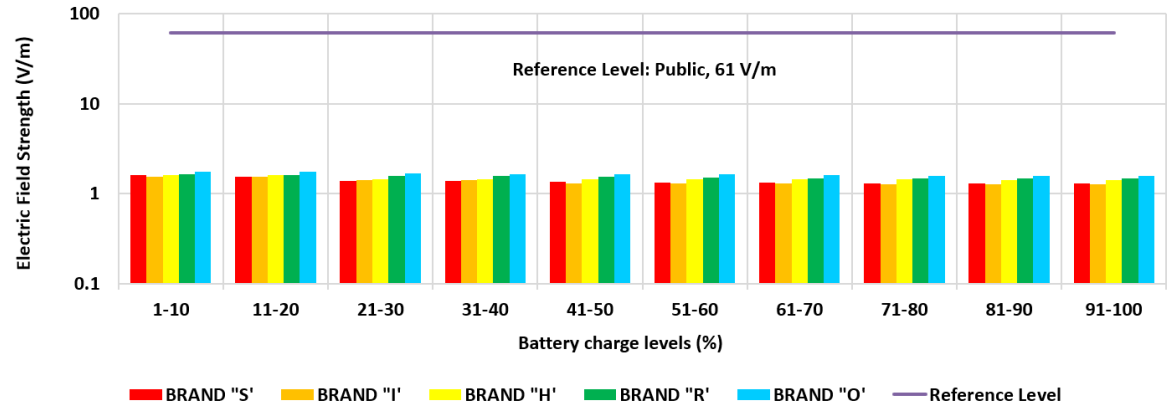


Figure 10: Plot of electric field strength during “Incoming Call” Mode at different battery percentages

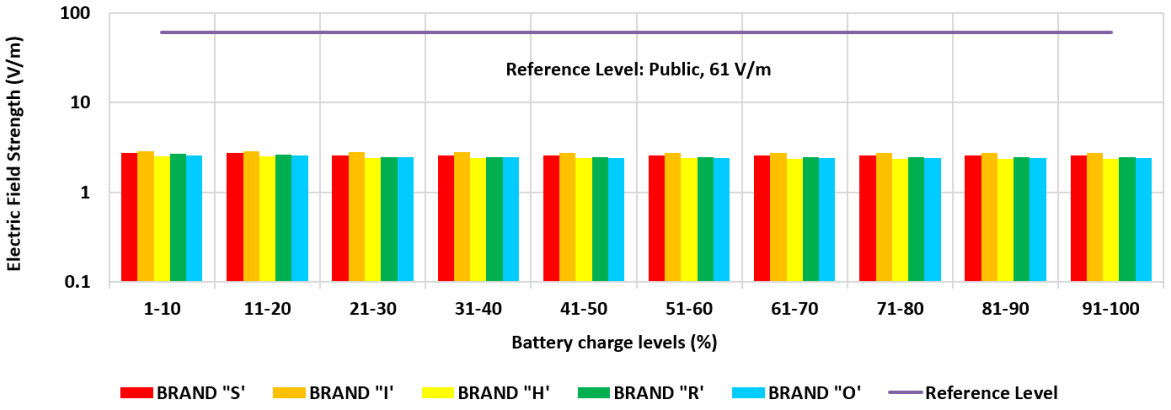


Figure 11: Plot of electric field strength during “Web Browsing” Mode at different battery percentages

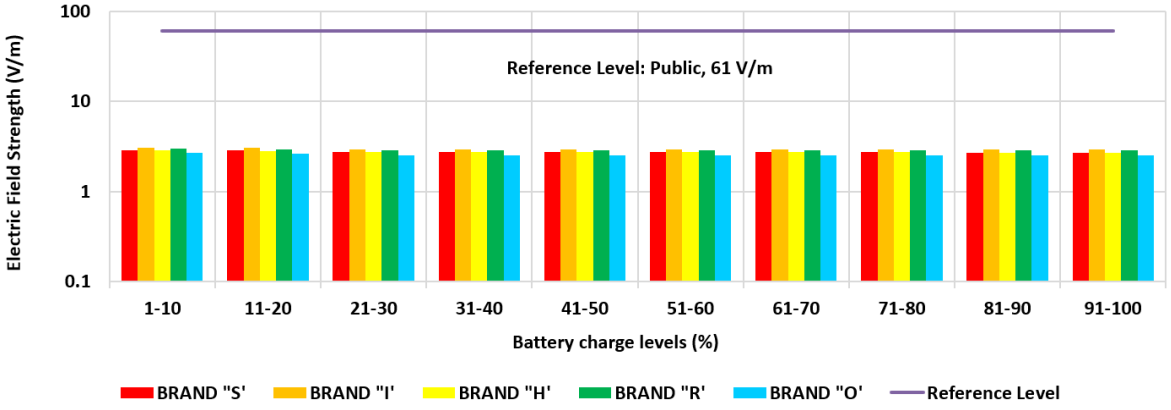
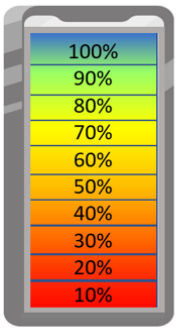


Figure 12: Plot of electric field strength during “Video Streaming” Mode at different battery percentages

Table 1: Difference between highest and lowest E-Field Strengths (V/m) on different Smartphone modes.



E-Field Strength / SP Brand	Standby (V/m)	Outgoing Call (V/m)	Incoming Call (V/m)	Web Browsing (V/m)	Video Streaming (V/m)	Max Difference (%)
Brand "S"	0.45/0.55	1.30/1.60	1.30/1.60	2.56/2.78	2.72/2.90	0.30 V/m (23%)
Brand "I"	0.40/0.50	1.32/1.62	1.27/1.55	2.76/2.88	2.94/3.10	0.30 V/m (23%)
Brand "H"	0.50/0.57	1.45/1.69	1.42/1.62	2.42/2.59	2.72/2.86	0.24 V/m (17%)
Brand "R"	0.50/0.54	1.44/1.61	1.46/1.63	2.47/2.69	2.86/2.99	0.17 V/m (12%)
Brand "O"	0.50/0.60	1.56/1.87	1.57/1.75	2.38/2.55	2.52/2.69	0.31 V/m (20%)

Note: The value in RED denotes the highest strength recorded and in BLUE denotes the lowest strength

Results: Network Connectivity Percentage

The recorded maximum electric field strength recorded for the five different modes for the five different smartphone brands on different network connectivity percentages are shown from Figure 13 to Figure 17. The maximum electric field strength was compared with the reference level stipulated under the International Commission on Non-Ionizing Radiation Protection (ICNIRP) guidelines (ICNIRP 2020) and Multimedia Commission (MCMC) Mandatory Standard (MCMC 2010). The summary of the results is described in Table 2.

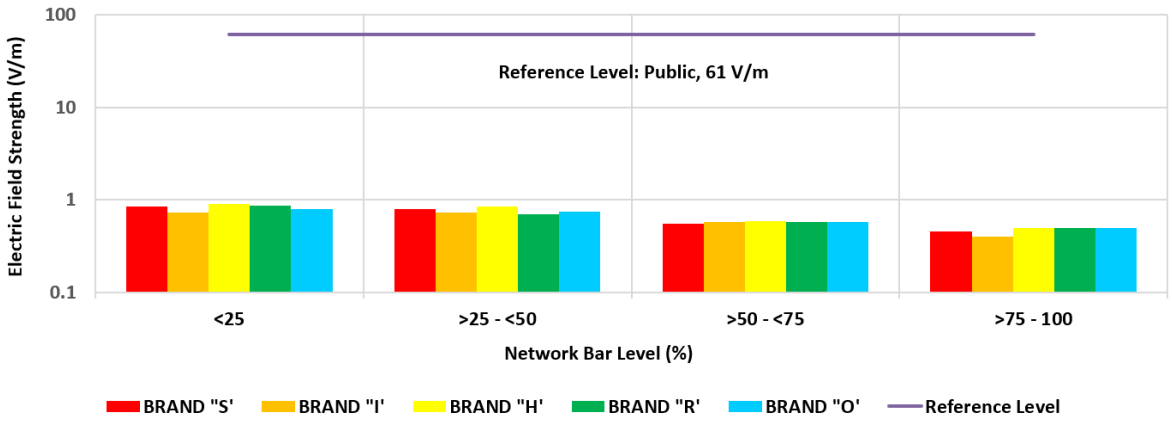


Figure 13: Plot of electric field strength during "Standby" Mode at different network percentages

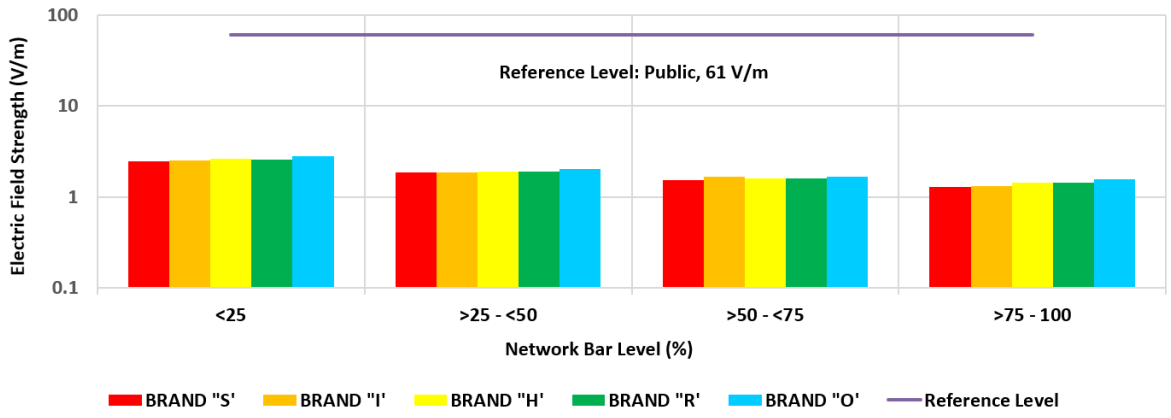


Figure 14: Plot of electric field strength during “Outgoing Call” Mode at different network percentages

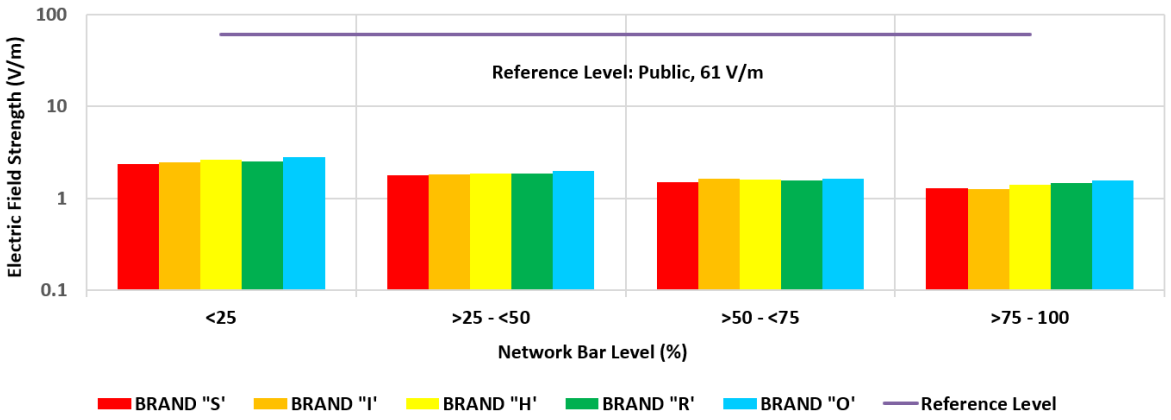


Figure 15: Plot of electric field strength during “Incoming Call” Mode at different network percentages

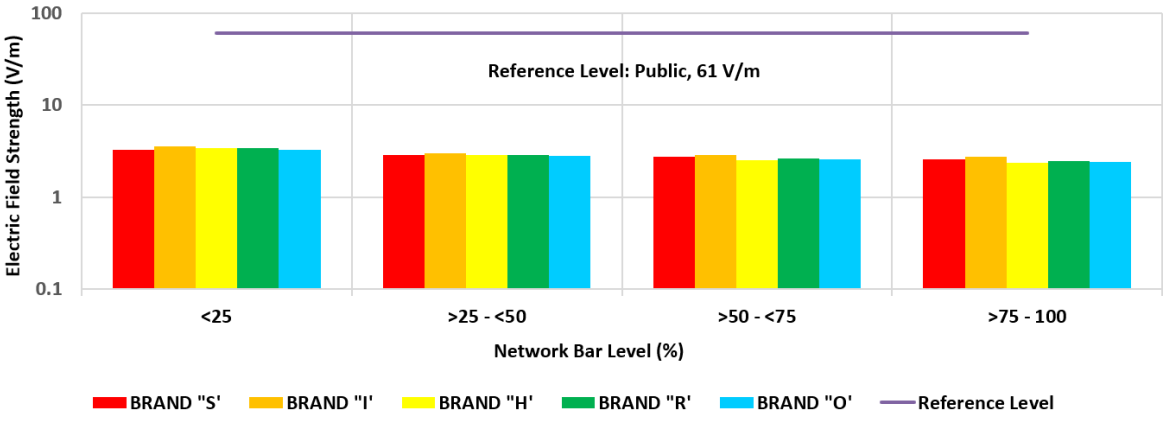


Figure 16: Plot of electric field strength during “Web Browsing” Mode at different network percentages

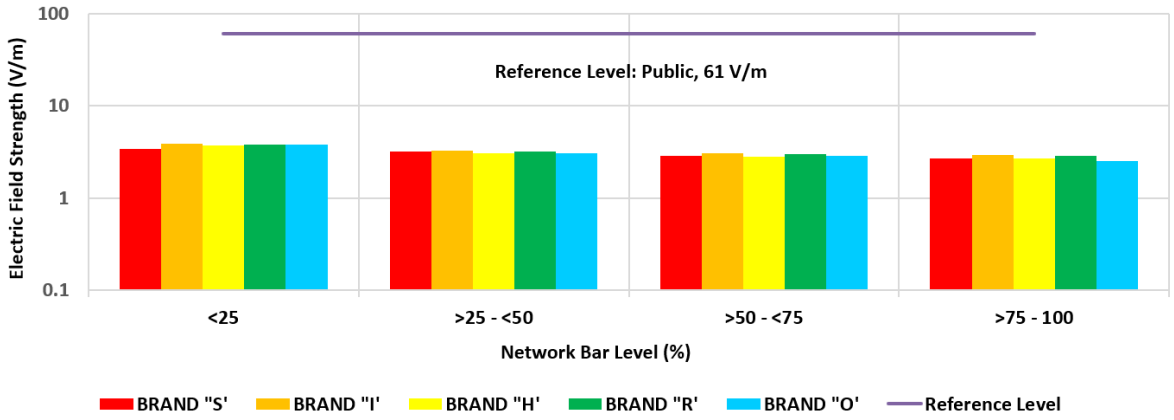
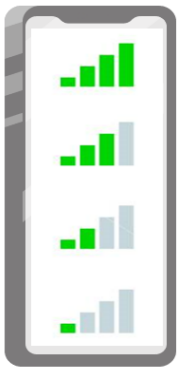


Figure 17: Plot of electric field strength during “Video Streaming” Mode at different network percentages

Table 2: Difference between highest and lowest E-Field Strengths (V/m) on different Smartphone modes.



E-Field Strength / SP Brand	Standby (V/m)	Outgoing Call (V/m)	Incoming Call (V/m)	Web Browsing (V/m)	Video Streaming (V/m)	Max Difference (%)
Brand “S”	0.45/0.84	1.30/2.45	1.30/2.38	2.56/3.25	2.72/3.45	1.15 V/m (89%)
Brand “I”	0.40/0.73	1.32/2.53	1.27/2.50	2.76/3.55	2.94/3.89	1.23 V/m (97%)
Brand “H”	0.50/0.90	1.45/2.65	1.42/2.66	2.38/3.40	2.72/3.75	1.24 V/m (87%)
Brand “R”	0.50/0.86	1.44/2.58	1.46/2.51	2.47/3.45	2.86/3.82	1.14 V/m (79%)
Brand “O”	0.50/0.79	1.58/2.84	1.57/2.79	2.42/3.29	2.52/3.79	1.27 V/m (80%)

Note: The value in RED denotes the highest strength recorded and in BLUE denotes the lowest strength

3.3 Discussion

This study aimed to measure the level of smartphone radiation at different battery percentages and network signal bars or the network connectivity percentages. The lowest RF electric field strength was detected when the smartphone was on “Standby” mode. During this mode, the device was not consuming any resources from the network, and hence is just periodically listening to the signals around so it knows which cell (frequency, timeslot, modulation) to use when it needs to "go online". In other word, the phone is always in contact with a nearby cell phone tower when it is on, thus some radiation is always emitted. The highest radiation level was detected when the smartphone was on “Web Browsing” and “Video Streaming’ mode. This is because both the modes required cellular data to utilize it, knowing that by turning data on, the phone will constantly be communicating with servers and satellites. As more mobile data was used, the radiation will be the greatest. The changes in the level of radiation in terms of electric field strength for all the modes on different battery percentages is very minimal and insignificant. It should be noted that for all the modes, the measured electric field strength was the highest at the lowest battery percentage (less than 10%), but the changes are very minimal with a maximum difference of 0.30 V/m between the highest and lowest radiation level. Moreover, there is only little evidence that proves mobile smartphones will emit higher radiation when the battery is low. In addition, all the results obtained were below the reference level stated under the International Commission on Non-Ionizing Radiation Protection (ICNIRP) guidelines (ICNIRP 2020) and Multimedia Commission (MCMC) Mandatory Standard (MCMC 2010). Moreover, many researchers claimed that there is no obvious relationship between them. The battery has very little effect to do with radio frequency radiations from the mobile phone (Sajedifar 2019).

The link between smartphones phones and high radiation comes from the phone attempting to establish a better network connection in poor signal areas. This study showed that a network connectivity percentage of less than 25% generates the highest radiation emitted from the smartphone for all the modes. The changes detected were quite significant with a maximum difference of 1.27 V/m between the highest and lowest radiation level measured. According to Wall et al., radiation levels under weak signal (1-2 display bars) at a distance of 48 cm from the phone were the same or greater than those detected under strong signal (4-5 display bars) at a distance of 4cm (Wall et al. 2019). This is because a weak signal uses more power in an attempt to connect with a cell tower, hence increasing the radiation level.

3.4 Conclusion

The research conducted has shown that, the highest radiation emitted from a smartphone was during poor signal coverage or specifically at network connectivity percentage of less than 25%. The changes in terms of RF electric field strength are very minimal for all the modes on different battery percentages, thus showing that the battery has an insignificant relationship with the increase in RF radiation level. In addition, all the RF radiation measured at different modes on different battery percentages and network connectivity is below the reference level or the permissible exposure limit for the public. Therefore, it is suggested to use the smartphone at a good signal coverage area in order to reduce the RF radiation level and at the same time maintaining good call quality

3.5 Summary

The scientific evidence indicates Radio Frequency (RF) exposures that are at or below current ICNIRP safety limits do not cause health problems. There is no established health benefit from reducing an individual's RF exposure from cell phones. Nevertheless, some people still have concerns about RF energy, and there are some simple actions that could help reduce an individual's RF energy exposure from cell phones. Some of the suggested ways to reduce the RF exposure from smartphones and an appropriate usage of smartphones are as following:

i. **Increase Distance**
   The most effective way to reduce exposure is to increase the distance between the smartphone and the user by using phone accessories such as headphones, hands free kits and speaker option

ii. **Limit the duration of smartphone usage**
   Generally, the higher the duration the usage of any wireless products such as smartphones, the more you are exposed to the RF radiation.

iii. **Use smartphones where receptions are good**
   Smartphones use the lowest possible power when in a good reception or coverage area. This is naturally when we are close to a mobile base station, the phone only has to transmit over a short distance back to the nearest base station. Mobile networks automatically adjust the phone and base station power required to maintain a connection. Therefore, smartphones produce the lowest EMF when in a good coverage area and close to a base station

iv. **Avoid using smartphones when driving, walking and crossing the road**
   Arguably the most important safety usage of smartphone

Reference

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