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The Effect of Proximity Sensor & Grip Sensor Use on Specific Absorption Rate (SAR) in Smartphones

Emirhan AYDIN[1*]

[1] *Mimar Sinan Mah., 103. Cad. No:72, Kapaklı, Tekidağ, Türkiye*

Keywords

Smartphone
Proximity Sensor
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Specific Absorption Rate (SAR)
Long Term Evolution (LTE)
5G New Radio

Abstract

Today, with the contribution of the new generation of communication technologies, many smart devices are produced. Almost every electronic device, including smart phones, smart watches, wireless headphones, tablets, emits some form of radiation. While most of this electromagnetic radiation is harmless, some of it can have potential health effects, depending on the frequency of use over long periods of time and in close usage. Specific Absorption Rate is a measure of how much human body tissue absorbs energy when the body is exposed to radiation. This measurement helps determine whether a device is safe for regular use. The SAR value may vary depending on the antenna and schematic design of the smartphone. To support high band requirements for 5G smartphones, more RF antennas required to be added in PCB design. When designing smartphones, designers also need to design proximity-grip sensors that accurately meet the industry's Specific Absorption Rate (SAR) requirements. In this study, the effects of proximity and grip sensors used in smartphones on LTE and 5G NR SAR values are investigated. During these measurements, a combination of Grip and Proximity Sensors were alternately turned on and off. Although the proximity sensor and grip sensor are not mainly used to optimize SAR values, it is foreseen that they may have indirect effects on SAR. In this context, SAR measurements were made in 3D environment for different frequencies. As a result of this study, it was observed that the grip-proximity sensors used in smartphones significantly reduce the SAR value and transfer less energy to the users in close range use. The effect of using the proximity sensor on the SAR rate was measured to be approximately 8%, while the effect of using the Grip Sensor was observed to be approximately 10%.

Cite

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Author ID (ORCID Number)

0009-0007-7703-7054 Emirhan AYDIN

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1. INTRODUCTION

The wireless industry is driven not only by customer demand for services, but also by the technology available. In this respect, the wireless industry is one of the most rapidly changing industries in the world. New products and services are introduced as quickly as they are designed and developed. Changes in technology standards also force rapid change. The technology itself is divided and defined by different generations:

The first-generation cell phones used analog technology with frequency modulation. This was rapidly abandoned as it was determined that carriers could not provide enough services to meet the demand. As a result, the first generation was quickly replaced with a second-generation (2G) digital cell phone technology.

*Corresponding Author, e-mail: e.aydin@samsung.com

Multiple 2G standards were developed worldwide. These include GSM and the original CDMA. Although 2G technology is still in use today around the world, it is slowly fading away. This allows operators to repurpose their spectrum for greater subscriber capacity and higher data rates. Cell phones originally were designed primarily as voice telephones, but it was quickly discovered that it was possible to use them for data purposes. For 2G phones, data rates were slow, thereby limiting the functions to simple applications such as texting and e-mail.

Third-generation (3G) cell phones continued to use standard digital voice techniques but also developed high-speed data capability. New modulation and access methods were created and standards were ratified. Third-generation phones rapidly became popular, and over a period of several years' carriers adopted the new technology and built out their networks.

The fourth generation (4G) has brought about the creation of a single standard or family of standards that all carriers could adopt. This 4G technology is known as Long Term Evolution (LTE), and it is slowly being adopted in one form or another by all U.S. and worldwide carriers. The 4G systems and phones have led to much higher data rates and amazing new cell phone capabilities, particularly that of being able to receive and generate video. Technology advances have given us not only the high-speed data capability necessary for video but also large, color touch screens, making the cell phone a more popular consumer product than ever.

The main purpose of 5G is to make the cellular and data services available over a wider range and to provide even higher data speeds. 5G uses higher frequencies and wider bandwidths to achieve even higher data rates. (Rappaport et al, 2013). With semiconductor technology still viable at ever smaller IC feature sizes, operation well into the hundreds of GHz is possible. 5G frequency bands are categorized into two groups based on the frequency spectrum. Sub 6GHz range of the radio frequency spectrum is known as frequency range 1 (FR1). Any LTE/5G frequency band under the 6GHz range is categorized under the FR1 group. Frequency bands in the millimeter wave (above 24GHz) spectrum are categorized under FR2. Due to the higher bandwidth of millimeter waves, these bands can achieve gigabits per second speed on a 5G network (Morgado et al., 2018).

Although the radiation associated with 5G technology is non-ionizing (radio frequency (RF) waves, has a longer wavelength, frequency, and energy), with the increasing development of systems based on mmWave technologies, it has become important to assess any adverse health effects caused by electromagnetic fields (Wu et al., 2015; Morelli et al., 2021). To protect the human body from exposure to mmW radiation, many countries set safety guidelines standards, such as those set by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) and the Institute of Electrical and Electronics Engineers (IEEE) and the Federal Communications Commission (FCC).

Most of the studies about the exposure assessment of the human body to RF radiation in complicated exposure conditions used numerical approaches such as numerical analysis based on the finite-difference time-domain method (Jeladze et al., 2019; Siervo et al., 2018). A large number of dosimetry studies above 6 GHz have been conducted, with the main purpose to establish the correlation between different dosimetric parameters such as the specific absorption rate (SAR), absorbed power density, and the skin surface temperature elevation (Diao et al., 2020; Li et al., 2019; Nakae et al., 2020; Neufeld et al., 2018, Morelli et al., 2021).

Guraliuc et al. (2017) presented a detailed numerical dosimetry study with a 60GHz antenna module for two representative human body exposure scenarios in 5G small cells by using a numeric model of a human adult head and a human hand holding a smartphone. For the numerical analysis, the finite integration technique was implemented together with a finite element method which was used for a better characterization of the antenna. The SAR absorbed power and the equivalent incident power density were used as dosimetric parameters. It was found that maximum absorption occurs at users' ears during telephone conversation and fingertips during browsing on the internet.

Hamed and Maqsood (2018) evaluated SAR 1g and point SAR (without mass averaging) at frequencies of 28, 40, and 60 GHz to investigate the SAR distributions due to radiating source antennas in single and layered human tissues using the FDTD method. It was concluded from the results that at the radiated power of 20 and 24 dBm, the SAR levels without mass averaging in the tissues at 28 GHz were lower than those at 40 GHz and 60 GHz.

In recent work, Tian et al. (2023) set up mobile phone model with 5G/4G patch antenna, real human head and DBS model using COMSOL Multiphysics. They calculated the specific absorption rate (SAR) of different layers of head tissues with the mobile phone at different distances from the human head, as well as the temperature change rule of the head and the DBS irradiated by the antenna for 30 min. The simulation results showed that at the frequency of 3.5 GHz, the EMF radiation from the mobile phone to the head was usually greater than that at 2.4 GHz.

For smartphone manufacturers, SAR is important to consider when designing antennas. There are a number of factors that have an impact on the SAR value, such as the size, location, radiation power, and type of antenna being used. In addition to these, some of the hardware features used in smart phones allow the phone to consume less power while in use, which indirectly reduces the rate at which EM waves interact with the human body.

In this study, the 3D SAR test environment is used to simulate the functions of the proximity and grip sensors on mobile phones and their effects on SAR levels. Comparing the data obtained at the end of the study, it is observed that the use of external sensor structures has significant effects on the SAR value. The proximity sensor helps to reduce the amount of electromagnetic energy that is generated by thermal energy by turning off the screen of the smartphone when you bring the phone closer to your ear to make a call. This means the phone heats up less and transmits less EM energy to the human body. On the other hand, the Grip Sensor detects whether the user is holding the smartphone and limits the (Tx power) signal power sent from the smartphone to the base station using the antenna sensing structures used in its design and working with a lower Tx signal power supports the generation of less EM wave energy on the user body and reduces SAR values.

2. MATERIAL AND METHOD

All mobile devices that use advanced antenna structures are sources of electromagnetic radiation to a greater or lesser extent. The source of this radiation is the antenna structures used in the mobile device. To understand the results of this study, it is important to explain the principles of antennas, electric and magnetic fields, and electromagnetic energy.

2.1. Antenna Structure and Electromagnetic Field

An RF signal generated by a transmitter is sent into free space and eventually picked up by a receiver in wireless communication systems. Since a radio signal consists of both electric and magnetic fields, it is called an electromagnetic wave. Whenever voltage is applied to the antenna, an electric field is created and, at the same time, a magnetic field is created by the flow of current in the antenna. These electric and magnetic fields are radiated out from the antenna and propagate through space at the speed of light.

In Figure 1, the half-wave dipole antenna is connected to the transmitter by the transmission line that was used to form the antenna. In most practical applications, the antenna is remote from the transmitter and receiver. A transmission line is used to transfer energy between the antenna and the transmitter or receiver.

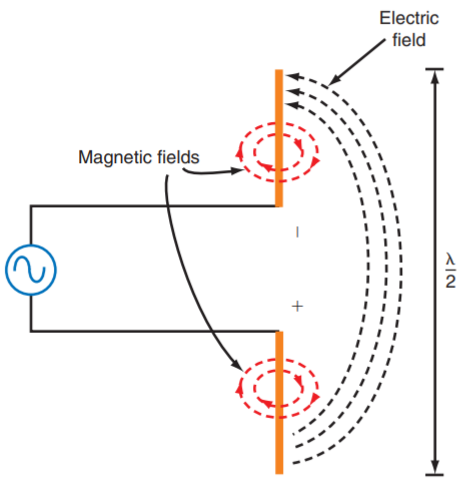

Figure 1. *The electric and magnetic fields around the transmission line*

The electric and magnetic fields produced by the antenna are at right angles to each other and both are perpendicular to the direction of wave propagation. Figure 2 shows the variation in the strength of the electric and magnetic fields as it moves out from the antenna.

2.2. Electromagnetic Radiation and EM Spectrum

Electromagnetic waves are oscillating signals whose electric and magnetic field amplitudes change at a certain rate. The strength of the field goes up and down, and the polarity of the field reverses a certain number of times per second. The electromagnetic waves are in sinusoidal signal form. The frequency of these waves is measured in cycles per second (cps) or hertz (Hz). The electromagnetic spectrum is the range of electromagnetic signals which includes all frequencies. The full electromagnetic spectrum including frequency and wavelength is shown in Figure 2.

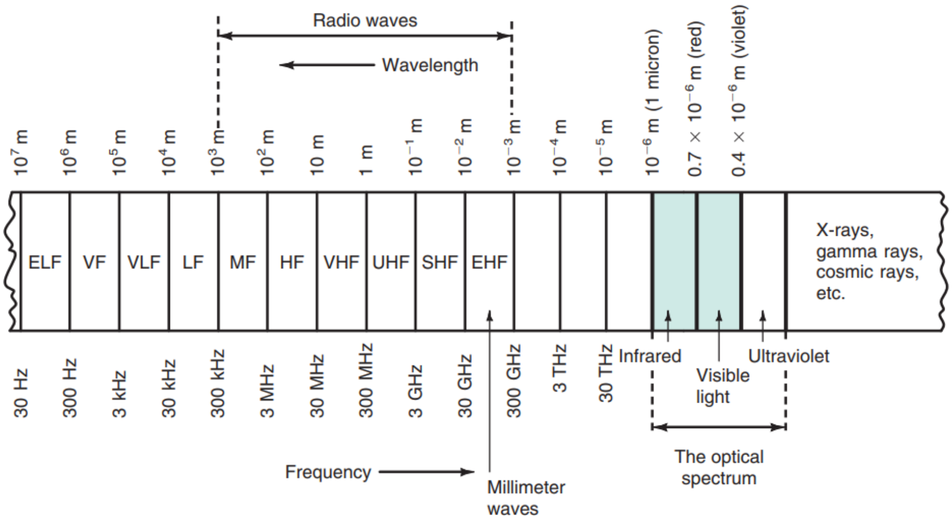

Figure 2. *The electromagnetic spectrum*

Ultra-High Frequency (UHF) is introduced from 300MHz to 3GHz and used for mobile telephony and services, as well as for military purposes. Electromagnetic signals with frequencies higher than 30 GHz are called millimeter waves. This range is increasingly used for satellite communications and mobile communications, although the equipment used to generate and receive signals in this range is extremely complex and expensive. EHF frequencies are also used for FR2 in 5G NR technology.

A photon has an energy (E) proportional to its frequency (f). This is given by Equation (1):

$$E = hf = \frac{hc}{\lambda}, \qquad h = 6.62607015 \times 10^{-34}\, J.s, \qquad c \cong 3 \times 10^{8}\, m.s^{-1} \tag{1}$$

where the **h** is the Planck constant, **λ** is the wavelength, and **c** is the speed of light. This is also known as the Planck-Einstein equation. The energy of the photon will be proportional to the frequency of the electromagnetic waves, in other words, the high-frequency photon has more energy. The use of high-frequency communication technologies such as 4G (LTE) and 5G NR in smart phones leads to an excessive emission of electromagnetic energy during their use.

2.3. SAR Methodology and Global Regulations

The Specific Absorption Rate (SAR) is an exposure standard for wireless devices used to assess the hazards posed by radio frequency (RF) waves. It is a measure of the energy absorbed by human tissue when exposed to a radiofrequency (RF) electromagnetic field per unit mass (Hamed & Maqsood, 2018; Sabbah et al., 2011).

The SAR is proportional to the square of the value of the electric field strength induced in the body when the human body is exposed to a radio frequency field.

SAR values are calculated by averaging either the whole body or a small sample (1g or 10g of tissue). The higher the SAR, the more radiation is absorbed in the tissues and the greater the effect on the human body (Koukiou, 2024; Rosenqvist et al., 2021). The SAR is a measure of the energy absorbed by a mass placed in a volume with the same mass density (p) as the tissue and units of SAR are expressed in watts per kilogram (W/kg) (Hamed & Maqsood, 2018).

$$SAR_i = \frac{P_i}{\rho_i} = \sigma \frac{|E|^2}{\rho_i} \ \mathrm{W/kg} \tag{2}$$

When the antenna is close to the human model at low power levels, relatively high field strengths would be estimated in the vicinity of the antenna, as shown in Figure 3. When the antenna is very close to the human tissue, the field distribution on the human tissue is usually measured in the vicinity of the antenna (Hamed & Maqsood, 2018).

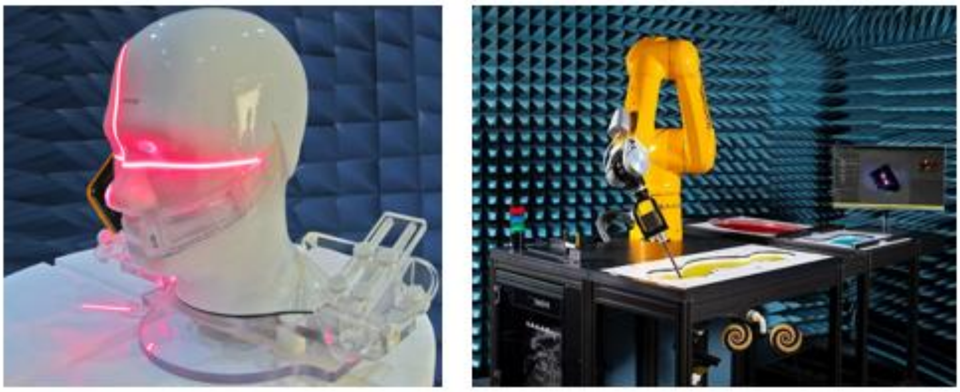

Figure 3. *An overview of SAR measurement setup*

There are two ways to calculate SAR: one is called Point SAR and the other called Mass or Volume Averaging SAR. The point SAR is not averaged and defines the maximum SAR of all meshes, and the point SAR for each mesh is calculated by dividing the absorbed power in each mesh by the mesh weight. In the case of averaged SAR values, a cube with a defined mass, e.g. 1 g or 10 g, is used for each point, and the power loss density is integrated over this cube. This is done by dividing the integrated power loss by the mass of the cube (Aly & Piket-May, 2014). The restriction limits of the SAR for the general public are given in Table 1.

Table 1. *SAR exposure standards and limits*

Standard	SAR Limit (W/kg)	Averaging mass for SAR
ICNIRP (Global)	2.0 (f < 10 GHz)	10 g of tissues
FCC/ANSI	1.6 (f < 6 GHz)	1 g of tissues

2.4. Smartphone Sensing System Overview

To enhance functionality, user experience, and device performance, today's smartphones are equipped with a variety of sensors. The following technical information is provided for the proximity and grip sensors that are the focus of this study.

2.4.1. Proximity Sensor Overview

A proximity sensor in a smartphone is a type of sensor that detects the presence of objects or the distance between the phone and nearby objects, typically at very close ranges (~2 centimeters). It is often used to detect when the user brings the phone close to their face or ear, such as during a phone call. The proximity sensor helps to enhance the functionality of the smartphone by automatically adjusting the behavior of the device in response to a physical presence or movement.

Proximity sensors are generally based on the working principles of infrared (IR) or capacitive sensing. The most common type of proximity sensor used in smartphones uses infrared light to detect the presence of objects in the vicinity. An infrared transmitter emits infrared and an infrared detector receives the reflected light upon encountering an object. That allows the phone to register the closeness of the object. The sensor remains inactive when no object is detected.

Capacitive proximity sensing works on the basis of electrical capacitance. Proximity sensing works by detecting the change in capacitance caused by the proximity of a conductive subject. Even without direct contact, this allows the phone to sense the proximity of the object.

The proximity sensor is usually located below the screen as indicated in Figure 4. It is not visible to the user when looking at the screen. The proximity sensor helps conserve battery life by turning off the display when the phone is close to an object (such as your face). When you bring the phone closer to your ear, it has an indirect effect on the SAR values by reducing the heating problems on user’s face that can occur due to the thermal energy.

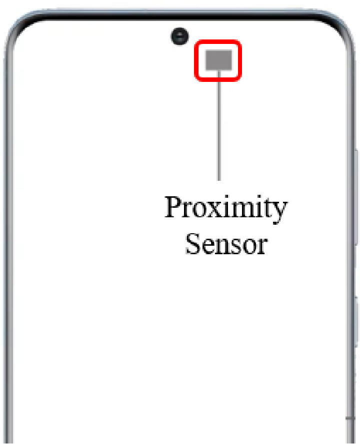

Figure 4. *Enable Proximity Sensor by moving phone to the ear*

2.4.2. Grip Sensor Overview

A grip sensor in a smartphone is a sensor that detects how the user holds or grips the device. It can measure pressure, position, or force exerted by the user's fingers on the device. It is typically located around the edges or frame of the device. Grip sensors are not as common as other smartphone sensors. However, they are becoming increasingly important in certain advanced smartphones.

A grip sensor's operating principle is based on detecting pressure or position changes from the user's hand. Pressure sensors measure the pressure that is applied to certain parts of the phone, often on the edges or the back of the phone. They can detect how firmly the user is holding the device and can trigger certain functions based on the amount of force that is being applied.

On the other hand, the use of the grip sensor in smart phones allows the recognition of the phone when it is in the hand of the user. During data and voice communication, the Tx power emitted by the device is limited and less Tx power will be emitted by smartphones. This has a positive effect on the SAR values. It also helps us to meet the specifications set by the regulations (Figure 5).

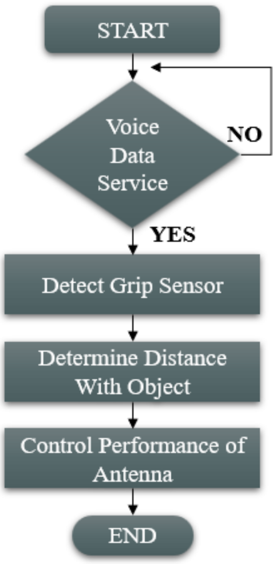

Figure 5. *Flow diagram of controlling antenna performance by using a grip sensor*

2.5. DUT (Device Under Test) Specifications

Antenna placement is a critical aspect of any device under test (DUT) because it has a significant impact on the performance of the antenna system. Antenna placement has an impact on how well the antenna can transmit or receive signals. Optimal antenna placement will ensure that the antenna is in a position where it can maintain an effective level of signal strength and signal quality. Poor antenna placement can result in reduced coverage, reduced reception (Rx) or signal interference.

The frequency response of the device can also be affected by antenna placement. In some cases, the performance at certain frequencies can be optimized by adjusting the placement. Antenna placement is critical to ensuring that the device under test meets the required standards for regulatory testing (e.g. SAR testing, FCC compliance). Antenna placement must follow specific guidelines in order to simulate the real-world use scenarios that occur during certification testing. In this study, SAR (Specific Absorption Rate) was measured for 2G, 3G, 4G and 5G technologies by using a reference 5G model. Figure 6 shows the antenna placements of the tested model.

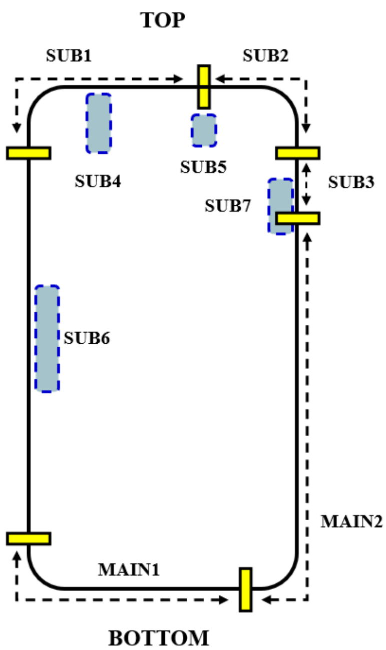

Figure 6. *Rear (Back side) view of DUT, illustrate antenna placements*

The above antenna structures are used for the following basic bands and technologies. The SAR measurements were also carried out based on the antenna patterns that were specified in Figure 6 and Table 2.

Table 2. *Supported band list for DUT*

Antenna	Tx	Rx	PRx	DRx	Supported Band List
MAIN1	O	O	N/A	N/A	GSM 850/900, WCDMA B5/8, LTE B5/8/12/17/20/26/28, NR n5/8/20/26/28/71
MAIN2	O	O	N/A	O	GSM 1800/1900, WCDMA B1/2/4 LTE B1/2/3/7/25/38/40/41, NR n1/3/7/38/40/41/66/77/78
SUB1	N/A	N/A	N/A	O	GSM 850/900, WCDMA B5/8 LTE B5/8/12/17/20/26/28/38/40/41, NR n5/7/8/20/28/38/40/41
SUB2	O	O	O	O	GSM 1800/1900, WCDMA B1/2/4, GPS, Wi-Fi1_5G LTE B1/2/3/4/7/25/38/40/41 NR n1/3/7/38/40/41/66/77/78
SUB3	N/A	N/A	O	N/A	LTE B1/3/4/66, NR n1/3/7/38/40/41/66, Wi-Fi1_2.4G
SUB4	N/A	N/A	N/A	O	NR n77/78
SUB5	O	O	N/A	N/A	Wi-Fi2_2.4G / 5G
SUB6	N/A	N/A	N/A	O	LTE B1/3/4/66, NR n1/3/66
SUB7	N/A	N/A	O	N/A	NR n77/78

3. RESULTS AND DISCUSSION

In Türkiye, the Information and Communication Technologies Authority (ICTA), known as BTK (Bilgi Teknolojileri ve İletişim Kurumu), regulates the Specific Absorption Rate (SAR) standard for mobile phones and wireless devices. Türkiye's SAR limits are consistent with international standards, primarily based on International Commission on Non-Ionizing Radiation Protection (ICNIRP) guidelines, which are widely accepted worldwide, including the European Union. Türkiye is not a member of the EU. However, Türkiye aligned its regulations with the EU standards, which are similar to the ICNIRP standards. Compliance with these SAR limits for telecommunications equipment in Türkiye is monitored and regulated by the BTK. Manufacturers are required to ensure that their products are in compliance with the SAR limits before they can be sold in Türkiye.

In this study, SAR measurements were performed by simulating the following combinations with introduced bads listed in Table 2. The combinations that are used for the grip sensor and the proximity sensor are the following. We used MT8821C Radio Communication Analyzer and E5515C 8960 Series 10 Wireless Communications Test Set in our measurements.

- **a.** Grip Sensor ON, Proximity Sensor ON
- **b.** Grip Sensor OFF, Proximity Sensor ON
- **c.** Grip Sensor ON, Proximity Sensor OFF
- **d.** Grip Sensor OFF, Proximity Sensor OFF

GSM900 SAR measurement results in W/kg included in Table 3. GSM900 operates in the frequency range of 890 MHz to 915 MHz (uplink) and 935 MHz to 960 MHz (downlink). According to the measured values, having the Grip Sensor OFF has a negative effect on SAR, if Grip sensor in OFF state, SAR increasing around 0,02 W/kg. The SAR values measured for both the grip sensor and the proximity sensor in the "ON" state are the minimum values as expected.

Table 3. *GSM900 & DCS1800 SAR measurement results*

<table>
<tr><th rowspan="2">Mode</th><th colspan="2">Antenna</th><th rowspan="2">Sensor Mode</th><th colspan="2">Measurement</th><th colspan="2">Improvement</th></tr>
<tr><th>GSM900</th><th>DCS1800</th><th>GSM900</th><th>DCS1800</th><th>GSM900</th><th>DCS1800</th></tr>
<tr><td rowspan="4">Voice</td><td rowspan="4">MAIN1</td><td rowspan="4">MAIN2</td><td>Grip On - Proximity ON</td><td>0,353</td><td>0,303</td><td rowspan="4">6%</td><td rowspan="4">4%</td></tr>
<tr><td>Grip OFF - Proximity ON</td><td>0,378</td><td>0,328</td></tr>
<tr><td>Grip On - Proximity OFF</td><td>0,367</td><td>0,316</td></tr>
<tr><td>Grip OFF - Proximity OFF</td><td>0,416</td><td>0,346</td></tr>
</table>

DCS1800 operates in the frequency range of 1710 MHz to 1785 MHz (uplink) and 1805 MHz to 1880 MHz (downlink). Lower frequencies (such as GSM 900MHz) tend to go deeper into the human body, particularly near the skin. Signals at higher frequencies (such as DCS1800) tend to be absorbed more strongly at the surface of the skin, resulting in a shallower penetration depth. Handsets operating at 1800 MHz typically operate at lower power, which results in lower SAR levels.

UMTS Band 1, also known as WCDMA Band 1, operates in the frequency range of 1920 MHz to 1980 MHz for the uplink and 2110 MHz to 2170 MHz for the downlink. This band is typically used for 3G (Universal Mobile Telecommunications System) communication. UMTS devices have higher transmitting power compared to 2G, as they are designed to provide higher data rates and support more advanced services. However, UMTS operates at higher frequencies than GSM (especially in Band 1, which is around 2 GHz). This means that the energy tends to be absorbed closer to the skin rather than deeper into the tissue. Due to these reasons, it measured very closer to DCS1800 SAR values, as shown in Table 4.

UMTS Band 8 (WCDMA Band 8) operates in the frequency range of 880 MHz to 915 MHz for uplink and 925 MHz to 960 MHz for downlink. UMTS Band 8 (B8) operates at a lower frequency (about 900MHz), typically causing more penetration. The lower frequency allows the signal to travel further and pass through tissue more effectively than higher frequency. Table 4 shows the UMTS Band 8 SAR measurement results. UMTS Band 8 has deeper tissue penetration, leading to more energy absorption by the body.

Table 4. *UMTS B1 & UMTS B8 SAR Measurement results*

Mode	Antenna		Sensor Mode	Measurement		Improvement	
	UMTS B1	UMTS B8		UMTS B1	UMTS B8	UMTS B1	UMTS B8
Voice	MAIN2	MAIN2	Grip On - Proximity ON	0,296	0,388	3%	8%
			Grip OFF - Proximity ON	0,318	0,436		
			Grip On - Proximity OFF	0,307	0,417		
			Grip OFF - Proximity OFF	0,329	0,463		

LTE B1 operates in the frequency range of 1920 MHz to 1980 MHz for uplink and 2110 MHz to 2170 MHz for downlink. LTE B1 operates at a higher frequency. This means that it tends to have slightly worse propagation (range and indoor coverage) due to higher path loss. However, it compensates with better data throughput and more efficient frequency reuse. According to measurement result, LTE B1 has higher SAR value compared to 2G and UMTS network (Table 5).

Table 5. *LTE B1 SAR Measurement results*

Band	Mode	Antenna	Sensor Mode	Measurement	DIFF	Improvement
LTE B1	Voice	MAIN2	Grip ON - Proximity ON	0,517	0,112	11%
			Grip OFF - Proximity ON	0,598		
			Grip ON - Proximity OFF	0,563		
			Grip OFF - Proximity OFF	0,629		

In order to overcome propagation losses, mobile devices typically use higher output power at lower frequency bands. Higher frequencies generally result in a higher power density in the tissues of the human body. LTE B3 operates in the 1.7 GHz to 1.8 GHz range, which is lower than LTE B1. While the mobile phone is operating in the LTE B3 mode, it emits slightly less power, which results in a lower SAR value as shown in Table 6.

Table 6. *LTE B3 SAR Measurement results*

Band	Mode	Antenna	Sensor Mode	Measurement	DIFF	Improvement
LTE B3	Voice	MAIN2	Grip ON - Proximity ON	0,545	0,066	7%
			Grip OFF - Proximity ON	0,588		
			Grip ON - Proximity OFF	0,577		
			Grip OFF - Proximity OFF	0,611		

LTE B8 operates in the 900MHz band, commonly deployed in 4G-LTE in Europe, parts of Asia and Africa. Both LTE B8 (900 MHz) and LTE B5 (850 MHz) operate at relatively low frequencies, and devices using these bands typically transmit at similar power levels. Table 7 shows SAR measurement results for LTE B8.

Table 7. *LTE B8 SAR Measurement results*

Band	Mode	Antenna	Sensor Mode	Measurement	DIFF	Improvement
LTE B8	Voice	MAIN1	Grip ON - Proximity ON	0,461	0,075	8%
			Grip OFF - Proximity ON	0,521		
			Grip ON - Proximity OFF	0,492		
			Grip OFF - Proximity OFF	0,536		

LTE B40 is used for time division duplex (TDD) LTE deployments and operates in the 2.3 GHz to 2.4 GHz frequency range. LTE B40 is a higher band, 2,3GHz-2,4GHz, than lower band frequencies, such as Band 5 or Band 8. This means that the radio waves in LTE B40 are more superficially absorbed by the skin and outer layers of the body than they are more deeply penetrating (Table 8).

Table 8. *LTE B40 SAR Measurement results*

Band	Mode	Antenna	Sensor Mode	Measurement	DIFF	Improvement
LTE B40	Voice	MAIN2	Grip ON - Proximity ON	0,688	0,073	7%
			Grip OFF - Proximity ON	0,733		
			Grip ON - Proximity OFF	0,705		
			Grip OFF - Proximity OFF	0,761		

NR n78 is a part of the mid-band spectrum (also referred to as Sub-6 GHz) and is commonly used for 5G services in many regions worldwide. n78 band operates between 3.3 GHz and 3.8 GHz, tend to lead to higher surface absorption of radio waves compared to lower-frequency bands like LTE Band 40. Higher frequencies are absorbed more by the skin and outer layers of the body, while lower frequencies penetrate deeper into the body tissue. Since 5G NR typically operates at higher frequencies, n78 bands generally results in higher surface absorption of radio waves. Devices operating in this band often have to transmit at higher power to cover urban areas and provide high-speed internet, leading to potentially higher SAR values (Table 9).

Table 9. *NR n78 SAR Measurement results*

Band	Mode	Antenna	Sensor Mode	Measurement	DIFF	Improvement
NR n78	Voice	SUB2	Grip ON - Proximity ON	0,844	0,09	9%
			Grip OFF - Proximity ON	0,901		
			Grip ON - Proximity OFF	0,867		
			Grip OFF - Proximity OFF	0,934		

4. CONCLUSION

Specific absorption rate (SAR) measurements play a critical role in the assessment of potential risks to human health from electromagnetic radiation, particularly from high-frequency devices such as cell phones, wireless communication systems, and other emerging technologies. At high frequencies, including the millimeter wave and 5G bands, the interaction between RF radiation and biological tissue is different from that at lower frequencies, raising concerns about potential health effects such as thermal heating, tissue damage, and long-term exposure risks.

While the current evidence from scientific studies suggests that exposure levels within established safety limits do not pose a significant risk to human health, there are still uncertainties about the cumulative effects of long-term exposure, particularly in vulnerable populations such as children and pregnant women. The increasing prevalence and use of higher-frequency devices requires continued research to better understand the biological effects of RF radiation. Therefore, all design parameters must be carefully considered before the introduction of a new mobile phone to the market. Some sensors used in mobile phones ensure that devices operating at high frequencies emit less radiation, resulting in lower SAR levels for users.

In this study, the effects of the use of the grip sensor and the proximity sensor on the SAR values are realized in 4 different scenarios for different communication technologies. Both grip sensors and proximity sensors contribute indirectly to reducing SAR in mobile phones. However, their effect is primarily through optimized power management. Specifically, proximity sensing can actively reduce transmission power when the phone is near the head of the user, directly reducing SAR. Grip sensors, while helpful in managing the behavior of the phone, have a less direct impact on SAR, but they can contribute to power adjustment based on the way the device is being held. As shown in Figure 7, we achieved best case with both sensors are in ON state, provides from 5% to 11% improvement on SAR values with different frequencies. It is important to use these sensors in future smartphones as a standard hardware component.

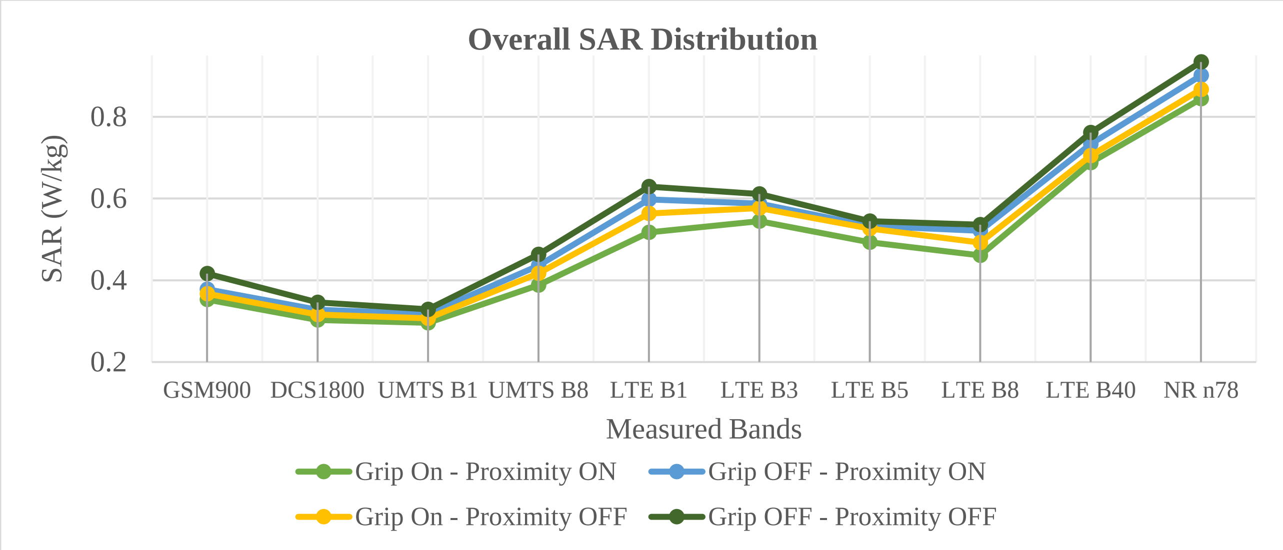

Figure 7. *Overall SAR measurement results, for 2G, UMTS, LTE and 5G NR*

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CONFLICT OF INTEREST

The author declares no conflict of interest.

REFERENCES

Aly, A., & Piket-May, M. (2014). FDTD Computation for Sar Induced in Human Head Due to Exposure to EMF from Mobile Phone. Advanced Computing: An International Journal, 5, 01-12. https://doi.org/10.5121/acij.2014.5601

Diao, Y., Rashed, E. A., & Hirata, A. (2020). Assessment of absorbed power density and temperature rise for nonplanar body model under electromagnetic exposure above 6 GHz. Physics in medicine and biology, 65(22), 224001. https://doi.org/10.1088/1361-6560/abbdb7

Guraliuc, A. R., Zhadobov, M., Sauleau, R., Marnat, L., & Dussopt, L. (2017). Near-Field User Exposure in Forthcoming 5G Scenarios in the 60 GHz Band. IEEE Transactions on Antennas and Propagation, 65(12, 1), 6606–6615. https://doi.org/10.1109/TAP.2017.2754473

Hamed, T.B., & Maqsood, M. (2018). SAR Calculation & Temperature Response of Human Body Exposure to Electromagnetic Radiations at 28, 40 and 60 GHz mmWave Frequencies. Progress in Electromagnetics Research M, 73, 47-59. https://doi.org/10.2528/PIERM18061102

Jeladze, V., Nozadze, T., Petoev-Darsavelidze, I., & Partsvania, B. (2019). Mobile phone antenna-matching study with different finger positions on an inhomogeneous human model. Electromagnetic biology and medicine, 38(4), 297–306. https://doi.org/10.1080/15368378.2019.1641721

Koukiou, G. (2024). SAR Features and Techniques for Urban Planning—A Review. Remote Sensing, 16(11), 1923. https://doi.org/10.3390/rs16111923

Li, K., Sasaki, K., Watanabe, S., & Shirai, H. (2019). Relationship between power density and surface temperature elevation for human skin exposure to electromagnetic waves with oblique incidence angle from 6 GHz to 1 THz. Physics in medicine and biology, 64(6), 065016. https://doi.org/10.1088/1361-6560/ab057a

Morelli, M. S., Gallucci, S., Siervo, B., & Hartwig, V. (2021). Numerical Analysis of Electromagnetic Field Exposure from 5G Mobile Communications at 28 GHZ in Adults and Children Users for Real-World Exposure Scenarios. International Journal of Environmental Research and Public Health, 18(3), 1073. https://doi.org/10.3390/ijerph18031073

Morgado, A., Huq, K. M. S., Rodriguez, J., & Mumtaz, S. (2018). A survey of 5G technologies: regulatory, standardization and industrial perspectives. Digital Communications and Networks, 4(2), 87-97. https://doi.org/10.1016/j.dcan.2017.09.010

Nakae, T., Funahashi, D., Higashiyama, J., Onishi, T., & Hirata, A. (2020). Skin temperature elevation for incident power densities from dipole arrays at 28 GHz. IEEE Access, 8, 26863-26871. https://doi.org/10.1109/ACCESS.2020.2970219

Neufeld, E., Carrasco, E., Murbach, M., Balzano, Q., Christ, A., & Kuster, N. (2018). Theoretical and numerical assessment of maximally allowable power-density averaging area for conservative electromagnetic exposure assessment above 6 GHz. Bioelectromagnetics, 39(8), 617–630. https://doi.org/10.1002/bem.22147

Rappaport, T.T., Sun, S., Mayzus, R., Zhao, H., Azar, Y., Wang, K., Wong, G.N., Schulz, J.K., Samimi, M., & Gutierrez, F. (2013). Millimeter Wave Mobile Communications for 5G Cellular: It Will Work! IEEE Access, 1, 335-349. https://doi.org/10.1109/ACCESS.2013.2260813

Rosenqvist, A., Jones, C. E., Rignot, E., Simons, M., Siqueira, P., & Tadono, T. (2021). A review of SAR observation requirements for global and targeted science applications. In 2021 IEEE International Geoscience and Remote Sensing Symposium IGARSS (pp. 1745-1748). IEEE. https://doi.org/10.1109/IGARSS47720.2021.9553966

Sabbah, A.I., Dib, N.I., & Al-Nimr, M.A. (2011). Evaluation of specific absorption rate and temperature elevation in a multi-layered human head model exposed to radio frequency radiation using the finite-difference time domain method. Iet Microwaves Antennas & Propagation, 5, 1073-1080. https://doi.org/10.1049/iet-map.2010.0172

Siervo, B., Morelli, M. S., Landini, L., & Hartwig, V. (2018). Numerical evaluation of human exposure to WiMax patch antenna in tablet or laptop. Bioelectromagnetics, 39(5), 414-422. https://doi.org/10.1002/bem.22128

Tian, R., Wu, Y. -Q., Lu, M., & Miao, X. -F. (2023). Specific Absorption Rate and Temperature Distributions in the Human Head with Implanted Deep Brain Stimulation Subjected to Mobile Phone Electromagnetic Radiation. Electronics, 12(21), 4389. https://doi.org/10.3390/electronics12214389

Wu, T., Rappaport, T. S., & Collins, C. M. (2015). Safe for Generations to Come. IEEE microwave magazine, 16(2), 65–84. https://doi.org/10.1109/MMM.2014.2377587