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STUDY UPON THE INFLUENCE OF MOBILE PHONE COMMUNICATION TECHNOLOGY ON SAR DISTRIBUTION

BY

PETRONELA-CAMELIA OPREA*, MARIUS VALERIAN PĂULEȚ and ALEXANDRU SĂLCEANU

“Gheorghe Asachi” Technical University of Iași,
Faculty of Electrical Engineering, Iași, Romania

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Abstract. From the multitude of electromagnetic field sources that are part of our daily environment, wireless communications occupy a dominant position. Among the devices that use this type of communications, the closest to our hearts (both literally and figuratively) is the mobile phone. This accumulation of radio frequency electromagnetic waves is absorbed (partially) by the bodies they encounter, resulting in their heating. This unwanted increase in temperature is most faithfully illustrated by the distribution of the Specific Absorption Rate (SAR) parameter. The most accurate results can be provided by "in silico" tests, simulations performed with the help of human phantoms obtained with the help of slices provided by Computer Tomograph (CT) and Magnetic Resonance Imaging (MRI) technologies. In our paper, comparative results of the SAR distribution obtained around the heart are presented, for 6 distinct situations. Conclusions and useful recommendations are presented, resulted from these simulations developed in CST Studio Suite.

Keywords: Specific Absorption Rate, CEM, simulation, CST Studio Suite, Hugo.

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*Corresponding author; *e-mail*: petronela-camelia.oprea@student.tuiasi.ro

1. Introduction

Even though modern technology is quite safe and technologically advanced, electromagnetic field problems are still important. These are the themes that the great majority of authors worldwide are concentrating on. SAR is one of the indicators that is used to determine the exposure level to non-ionizing radiation. To identify this parameter, a full set of instruments are now available.

Multiple studies have demonstrated that the most frequently used simulation software is SIMULIA CST Studio Suite.

The authors (Hamblin *et al*., 2007) examine how a GSM900 mobile phone (217 Hz modulation, 2 W peak output power) affects the SAR distribution at the head when EEG electrode caps are used. SAR measurements were performed with a precise robotic device in a phantom anthropomorph. By the time the research concluded, it had been found that the presence of electrode leads reduces the SAR distribution (10 g) and that the effect's degree changes depending on how the leads are oriented in relation to the source radio frequency (RF).

Another study (Pšenáková *et al*., 2017) analyses the SAR distribution in the multi-layer skin structure using the CST Studio Suite software simulation software, explaining that the effect of electromagnetic fields is present when a human model has a cochlear implant.

Wang *et al.* (2012) note in their study that the entities set limits for the maximum local, partial and body of RF energy in order to verify that RF energy absorbed by human subjects during an MRI is not causing any negative impacts on the patient, including local thermal damage or whole-body thermal regulation challenges. As a result, various scenarios of numerical computations of the partial-body and local peak SAR distributions were examined and simulated.

The authors of the study (Takeo *et al*., 2020) used an internal software based on the finite difference time domain method to evaluate human exposure to RF around a smart meter. A simulated half-wavelength dipole antenna was set up around the level of the human head, from where spatially averaged SAR distribution values (10 g) were calculated.

In one of his studies (Cazacu *et al*., 2015) demonstrates that the SAR distribution is evaluated using ANSYS/HFSS, a separate simulation software. The values obtained for all three frequencies correspond to the ICNIRP standards.

2. Methodology

The simulation software CST Studio Suite Version 2022, which was used by the authors in this study, was used to simulate the time domain illustrated in Fig. 1. The pulse offered to this signal has a duration of approximately 1.2 ns.

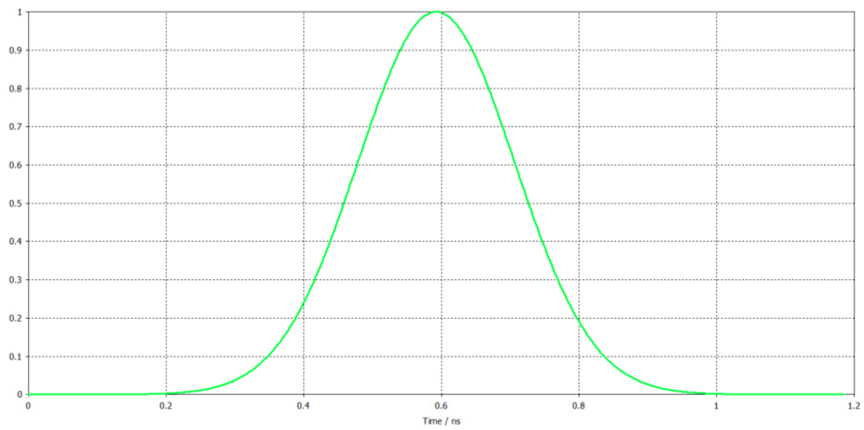


Fig. 1 – Excitation signal.

The SAR is defined as the energy absorbed by the human body related to a particular mass and time, according to Eq. (1):

$$SAR = \frac{d}{dt}\left(\frac{dW}{dm}\right) = \frac{d}{dt}\left(\frac{dW}{\rho dV}\right) \quad (1)$$

values can also be calculated according to other formulas correlated with the electrical fields from a point in the human body according to Eq. (2):

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

σ – tissue conductivity [S/m], ρ – tissue mass density [kg/m^3], E – RMS electric field intensity [V/m].

So, SAR represents the measure of the amount of energy transformed into thermal energy that is absorbed by the human body during the use of a device. This measure is expressed in W/kg and reflects the maximum exposure level allowed for a public user in a specific time frame. The SAR limits for Europe are specified in the European Specification 59005 of 1998 and refer to the knowledge transposed in the Guidelines ICNIRP.

3. Modeling

3.1. Introducing the CST Studio Suite

CST Studio Suite is a set of advanced software tools used for simulation and analysis in various applications. In Fig. 2 are described the steps for making a simulated model in CST Studio:

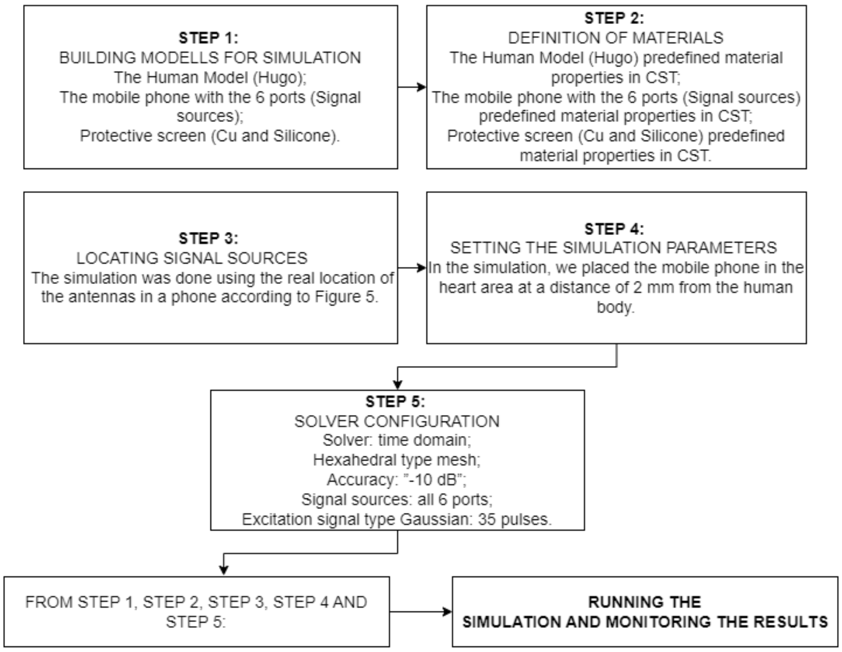


Fig. 2 – Steps to make the simulation model in CST.

3.2. Model development in CST Studio Suite

We utilized the Hugo model, a predefined model for the human body in the CST simulation environment. All of the internal organs and their associated mechanical, thermal, magnetic and electrical properties appear in this model. This model presented following parameters for the skin surface:

- Voxel Data/Skin
- Type: Normal
- Epsilon: 69.45
- Electric conductivity: 0.507 [S/m]
- Magnetic permeability: 1
- Rho: 1100 [kg/m ^{3}]
- Thermal conductivity: 0.3 [W/K*m]
- Specific heat: 3500 [J/K*kg]
- Diffusivity: 7.79221*10 $^{-8}$ [m ^{2}/s]
- Bloodflow: 9000 [W*K*m ^{3}]
- Metabolic rate: 2000 [W/m ^{3}]

Hugo has the following characteristics: Gender-Male, Height-180 cm, Weight-103 Kg, Age-38 years, as in Fig. 3:

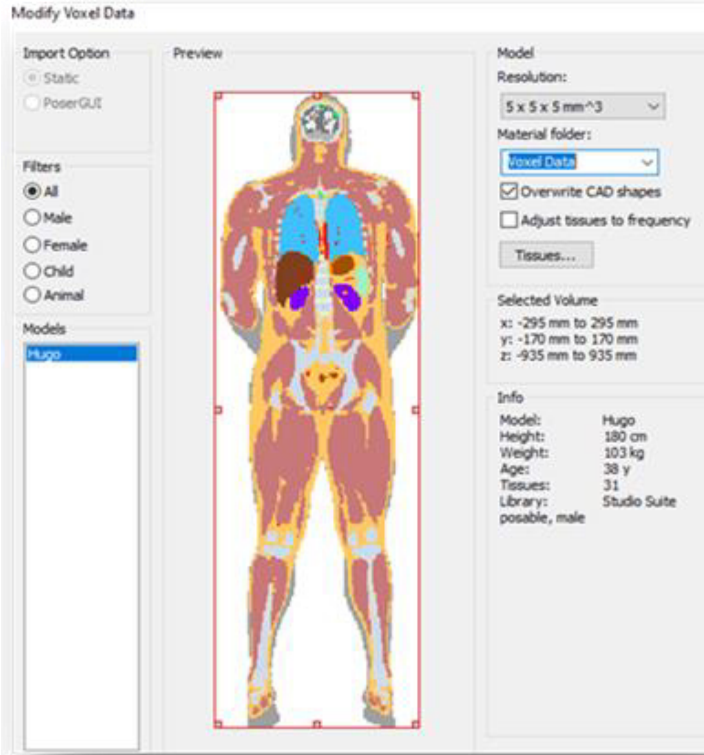


Fig. 3 – Building the Hugo model in CST Studio Suite.

Hugo has the following form in CST Studio Suite as in Fig. 4:

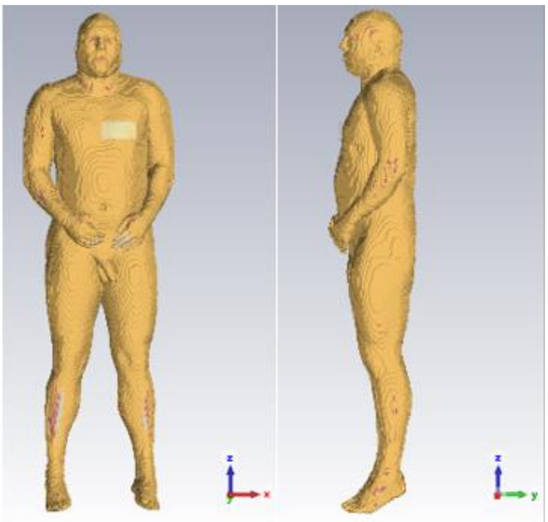


Fig. 4 – The model Hugo in CST Studio Suite.

The signal sources used in the simulation are the 6 ports of the mobile phone. We considered the cumulative effect of the simultaneous operation of the 6 ports resulting in maximum SAR values. It is true that the SAR parameter is influenced by and of the distance between the mobile phone and the closest relay. In other words, a longer distance between the mobile phone and the relay requires the phone to send a stronger signal in order to keep the connection going. This might raise the transmitting power and as a result, the SAR distribution. The longer the distance between the phone and the relay, the weaker the signal, requiring the phone to increase power to compensate; nonetheless, this has an indirect effect on the SAR distribution. The distance between the mobile phone and the nearest relay was not considered in this study.

We made sure that the phone's settings and data always follow the strictest SAR dissemination guidelines set forth by international regulations. As a result, even in the unlikely event that SAR dispersion briefly increases as a result of a greater distance between the mobile device and the closest relay, it stays within safe bounds.

The location of the 6 ports it is shown in Fig. 5:

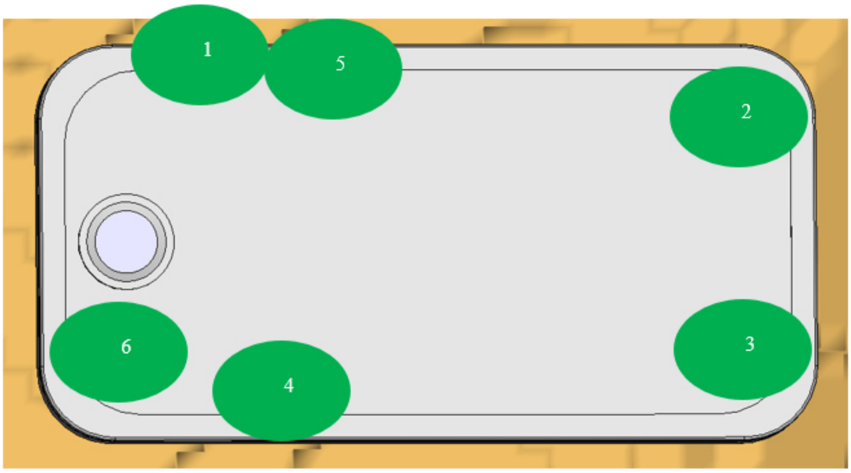


Fig. 5 – Location of the ports on the mobile phone.

The parameters for the 6 ports are defined as follows:

Port 1 is an E-GSM type port that works on the 900 MHz frequency and uses FDD transmission/reception mode (With split frequencies, 2 frequencies are used, one for transmission, one for reception, so it can work simultaneously, gaining it speeds up data transmission).

Port 2 and **port 3** are DCS-GSM type ports working on 1800 MHz frequency and using FDD transmission/reception mode.

Port 4 and **port 5** are Wi-Fi ports that work on the 2.4 GHz and 5 GHz frequencies.

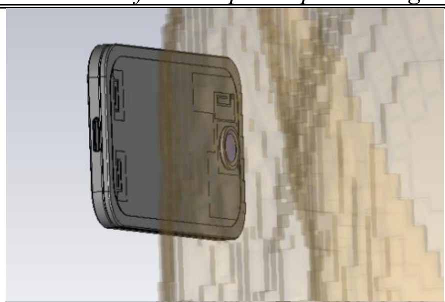
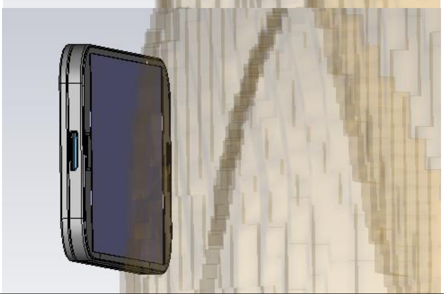
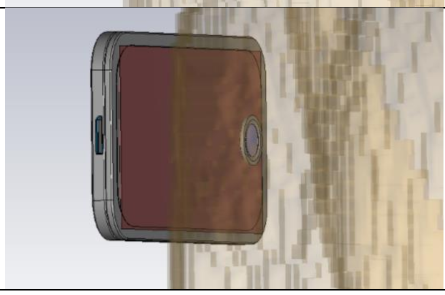
Port 6 is an E-UTRA 7 type port that works on the 2.6 GHz frequency and can be used in FDD or TDD transmission/reception mode (time-division, one frequency is used for both transmission and reception, the disadvantage of the method is that information is sent for a while and then waiting for the response to be received).

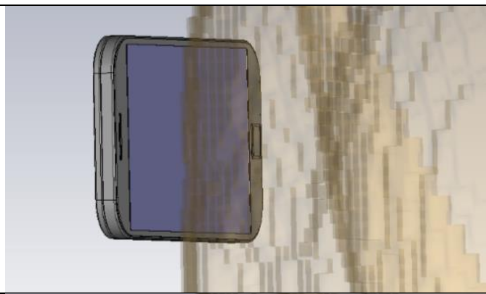
The ports of mobile phone emit simultaneously and they contribute to exposure to electromagnetic radiation. However, the maximum values for SAR are limited by regulations and are calculated so that, even when multiple systems emit simultaneously, they don't exceed safety limits.

For comparative values the phone was positioned around the heart in 6 distinct cases under the same conditions. Table 1 describes and illustrates the 6 cases:

Table 1

Description and illustration of the 6 cases of mobile phone positioning

Case 1 Without screen- rear towards the heart	
Case 2 Without screen- display towards the heart	
Case 3 With Cooper screen rear towards the heart	

Case 4 With Cooper screen display towards the heart	
Case 5 With Silicone screen rear towards the heart	
Case 6 With Silicone screen display towards the heart	

We added a protective screen of Cu/Silicone foil on the mobile phone case. This screen has a thickness of 0.5 mm. It has the following properties defined in CST:

- Phone: Metal Screen
- Material: Cooper
- Material Set: Default
- Type: Lossy metal
- Magnetic permeability: 1
- Electric conductivity: 5.96*10 7 [S/m]
- Rho: 8930 [kg/m^3]
- Thermal conductivity: 401 [W/K*m]
- Specific heat: 390 [J/K*kg]
- Diffusivity: 0.000115141 [m^2 /s]
- Young's modulus: 120 [kN/mm^2]
- Poisson's ratio: 0.33
- Thermal expansion: 17 [10^{-6} /K]

- Silicon (loss free)
- Type: Normal
- Epsilon: 11.9
- Magnetic permeability: 1
- Rho: 2330 [kg/m^3]
- Thermal conductivity: 148 [W/K*m]
- Specific heat: 700 [J/K*kg]
- Diffusivity: 9.07419e-05 [m^2 /s]
- Young's modulus: 112 [kN/mm^2]
- Thermal expansion: 5.1 [10^{-6} /K]

4. Numerical Simulation

For every of the six ports, we have successively simulated the operation (communication). Of course, we have selected the transmission frequency that that particular technology primarily uses for each port. The distance between the mobile phone and the Hugo’s skin has been considered 2 mm. After performing simulation, CST provides images in which the color code suggests very intuitively the temperature distribution, an example being offered by Fig.6. At the same time, it also provides numerical data, which allows extracting the maximum values for SAR.

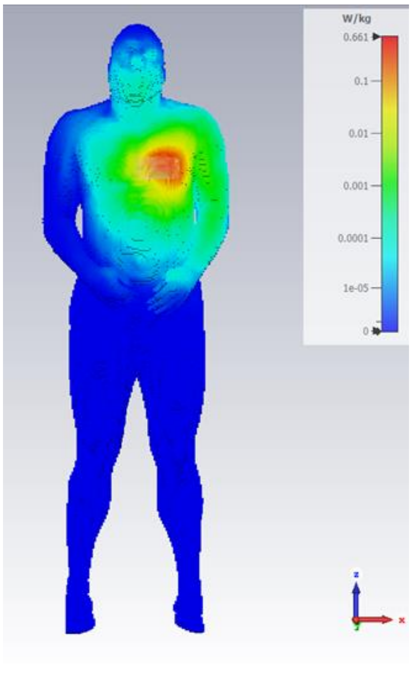


Fig. 6 – The temperature distribution on Hugo in CST.

To each communication port of the phone with the corresponding carrier frequency and the maximum values recorded for SAR (the six compared situations) have been introduced and are presented in the Table 2.

Table 2

Description and illustration parameter of the 6 cases of mobile phone

Ports	Freq. (MHz)	SAR max [W/kg]						(%)
		Without screen		With Copper screen		With Silicone screen		
		Rear towards the heart	Display towards the heart	Rear towards the heart	Display towards the heart	Rear towards the heart	Display towards the heart	
P [1]	900	0.1528	0.0869	0.1021	0.0698	0.1423	0.1004	93.12
P [2]	1800	0.1623	0.0034	0.0291	0.0053	0.3021	0.1002	56.87
P [3]	1800	0.1480	0.0014	0.0113	0.0034	0.3445	0.0914	70.63
P [4]	2400	0.5531	0.0913	0.5032	0.1878	0.9149	0.6475	43.95
P [5]	5000	0.4762	0.0867	0.2398	0.1924	0.0395	0.0131	40.40
P [6]	2600	0.2568	0.0280	0.2208	0.1020	0.3045	0.1367	49.71

5. Conclusions

As previously stated, the simulation findings demonstrate that the SAR values are far lower than the recognized limit of 2 W/kg, showing that the mobile phone's design complies with the safety regulations. When conductive foil (copper), is used on the rear of a mobile phone, the SAR distribution is significantly reduced (by 40–90%) as compared to silicone foil and cases without screens. This shows that including conductive materials into mobile phone case designs may help lower users' exposure to SAR.

One way to further reduce SAR spread is the suggestion to create silicone casings with good conductive qualities by adding copper or graphite wires. The total SAR exposure can be reduced by strengthening the casing's thermal and electrically conductive qualities, providing the user with a safer experience without sacrificing the mobile device's performance.

Future developments in this field of research may result in the creation of cutting-edge mobile phone accessories that prioritize user security and welfare. Manufacturers may provide consumers with goods that not only comply with regulations but also surpass safety standards by investigating novel materials, designs and technologies. This approach promotes a more sustainable and healthful usage of mobile devices.

This approach demonstrates a commitment to innovation and user-centered design principles and is in keeping with the telecom industry's ongoing efforts for better the safety and performance of mobile devices. A viable approach for improving user experience and well-being in the digital era is the development of safer and more effective cell phone accessories through the use of complex materials, interdisciplinary collaboration and simulation tools.

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STUDIU PRIVIND INFLUENȚA UNEI CARCASE DE PROTECȚIE A TELEFONULUI MOBIL ASUPRA DISTRIBUȚIEI SAR

(Rezumat)

Din multitudinea de surse de câmp electromagnetic care fac parte din mediul nostru zilnic, comunicațiile wireless ocupă o poziție dominantă. Dintre dispozitivele care folosesc acest tip de comunicații, cel mai apropiat de inimile noastre (atât la propriu, cât și la figurat) este telefonul mobil. Această acumulare de unde electromagnetice de radiofrecvență este absorbită (parțial) de corpurile pe care le întâlnesc, rezultând încălzirea acestora. Această creştere nedorită a temperaturii este cel mai fidel ilustrată de distribuția parametrului Specific Absorbtion Rate (SAR). Cele mai precise rezultate pot fi furnizate de teste „in silico”, simulări efectuate cu ajutorul fantomelor umane obținute cu ajutorul slice-urilor furnizate de tehnologiile Tomografie computerizată (CT) și Imagistica prin rezonanță magnetică (IRM). În lucrarea noastră sunt prezentate rezultate comparative ale distribuției SAR obținute în jurul inimii, pentru 6 situații distincte. Sunt prezentate concluzii și recomandări utile, rezultate în urma acestor simulări dezvoltate în CST Studio Suite.