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Multilayer Case Influence upon SAR Evaluation

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***Abstract* – The nowadays problem of human exposure to different types of electromagnetic field sources is a challenging one and should be considered an up to date issue due to actual trends, growth and progress of mobile communications technology. We have developed an experimental study over the measured values of specific absorption rate (SAR) for a new generation smartphone device, (frequencies in the range GSM-900 and GSM-1800), using a SATIMO-COMOSAR dosimetry system, provided by LICETER laboratory of ANCOM Romania. The measured SAR values have been compared (for the same exposure scenarios) with those obtained in the case when the mobile phone is protected by a multilayer case. Supplementary, a comparison of the SAR values obtained by direct measurements with those from international and local standards has been also done. Conclusions have been drawn for considered exposure scenarios cases.**

***Keywords* – SAR, Kuka robot, SATIMO-COMOSAR, LICETER, smartphone, ANCOM.**

I. INTRODUCTION

Aiming to protect the humans against different electromagnetic field sources, various countries around the world have already proposed and recommended various safety standards and regulations. The actual standards for human exposure establish, according to various frequency domain, different methods and measures for defining the so called basic restrictions and safety limits: internal induced current density or electric field (up to 100 kHz) respectively localized SAR (from 100 kHz up to 10 GHz) and power density (from 10 GHz to 300 GHz.

As concerning the penetration of electromagnetic radiations in the human body for different values of radio frequencies, limits for the specific absorption rate (SAR) have been imposed: 0.08 W/kg on average for the whole human body, respectively 2 W/kg for SAR located in the head or trunk area in case of general public exposure. These SAR values are averaged over 6 minute exposure time and 10 g of tissue. [1], [2], [3], [4].

The aim of this paper is to determine and compare the SAR values, obtained from direct measurements by using a SATIMO COMOSAR dosimetry system. For a new generation smartphone, two exposure scenarios: with, respectively without multilayer protective case. Mainly we proposed to know if there is a SAR reduction due to this case.

The SAR values have been determined for different positions of the mobile phone related to a physical model of the human head, with or without case.

The shape of the head of the SAM physical model has been derived in a percentage of 90% from the shape of an adult male head; its dimensions have been reported in [5]. The shape of the ears has been adapted to represent the flattened ears of a phone user.

Various studies propose different kind of shield for mobile phones to reduce the amount of power absorbed in the head, aiming to minimize the health effects. [6], [7].

Moreover, researches focused on SAR reduction due to the type of antennas (PIFA or Helical), placed at the top or at the bottom of the device, have been also carried out [8], [9], [10].

The SAR values determined from direct measurements using the calibrated SATIMO-COMOSAR dosimetry system for different exposure scenarios have been compared with the corresponding values accepted by international and local standards.

II. MATERIAL AND METHODS

The dosimetric quantity used for the evaluation of the absorption of the incident energy by the tissue is the Specific Absorption Rate (SAR). The SAR quantity is a parameter introduced for measuring the rate of energy absorbed by human body when it is exposed to a radio frequency electromagnetic field, the formula being given by the equation (1):

$$SAR_l = \frac{\sigma}{2\rho_m}\left|\vec{E}_i\right|^2 \quad (1)$$

where ρ_m is the density of the matter in an elementary volume, σ is the electric conductivity, SAR_l represents a local quantity, [11].

A. The SATIMO-COMOSAR system for SAR evaluation

The dosimetry evaluation system used for our measurements is competent to determine the distribution of SAR inside a human head phantom. The system uses the SAM phantom (Specific Anthropomorphic Mannequin), [12], a model in accordance with American and European standards [13], [14].

Dosimetry assessment can be done both for the situations when the mobile phone is positioned by the right or by the left ear.

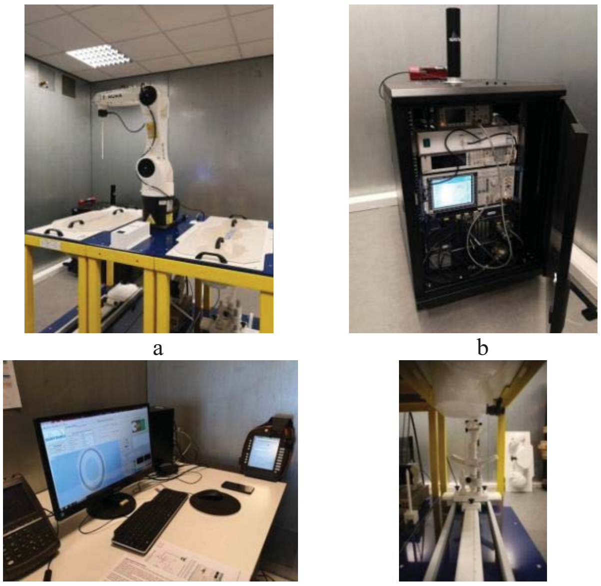
The main components of the system used by us, Fig. 1, are: Kuka KR5 robot with his specific controller Kuka KRC2sr, [15] with electric field probe (calibrated before the measurement process), the SAM twin phantom, the liquids that simulate the human tissue for specific frequencies, a clamping devices for the mobile phone under test, a signal generator Rohde & Schwarz CMU 200 (a GSM base simulator that can control the output power and frequency) and a desktop PC running OpenSAR software, [16].

SAM phantom structure is made out from low loss and low permittivity material, embedded in wood.

The electric field (immersive probe inside the liquid simulating the dielectric properties of the head for different frequencies) is a triple dipole type (model EP96 – SATIMO). E-field probe provides an omni-directional response.

The clamping device for holding the mobile phone is made from a low permittivity and low losses material and has no influence over the measured SAR values. The clamping device can be moved along three orthogonal axes Ox, Oy, Oz and it can be rotated around the phantom ear for precise positioning of the phone.

The OpenSAR software controls all robot movements, it determines local SAR values and, as post processing application, it calculates SAR values, averaged on 10 g or 1 g of tissue.



a b c d

Fig. 1. The SATIMO-COMOSAR system used for SAR measurements: (a) COMOSAR test bench and KUKA robot, (b) signal generator Rohde & Schwarz CMU 200, (c) computing unit with OPENSAR software installed for testing system control (d) the fastening system used to secure the measuring equipment

B. The SAR measuring procedure

All the phases describing the SAR measurement procedure are widely depicted in SR EN 62209-1: 2007 [17].

We have chosen Huawei P20 Pro (released on market at the beginning of 2018) as representative of up-to-date generation smartphone.

The SAR evaluation for different frequencies has been done for each radio channel: low, middle and respectively high.

Two positions, detailed in Fig.2 have been considered: the normal position (when the phone is on the cheek plane) and the tilt position (when the phone is tilted with 15 degrees angle toward cheek plane). One measurement location (of the SAM phantom) has been selected: the right ear.

The SAR evaluation has been done for two frequencies (GSM-900 and GSM-1800 bandwidth), 897 MHz and respectively 1747 MHz.

The mobile phone will be used with its internal transmitter, antenna, battery and all accessories supplied by the manufacturer. It is important as the battery to be fully charged before each test for every case of exposure scenario taken into consideration.

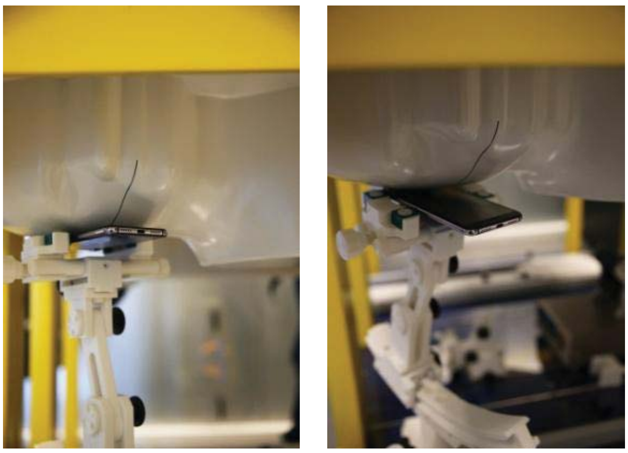


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Fig. 2. The cheek (a) and the tilt (b) positions of the Huawei P20 Pro mobile phone on the right side (ear) of SAM phantom

In Fig. 3 is presented the front and the back side of Huawei P20 Pro mobile phone when the device is inserted in a multilayer protective case made from hard plastic material.

For every position of mobile phone tested for SAR evaluation in this paper related to the right part of the SAM model, the following conditions should be fulfilled:

- existence of permanent radio connection between the base station simulator and mobile phone device at maximum power;
- SAR measurement must be done in a network of equally spaced points on a surface located at a constant distance from the inner surface of the phantom;
- measurement of the SAR values in equidistant points,

in a cube located over the place where the maximum value of the field was found by the probe who scan inside the phantom;

- calculation of the measured SAR average value for 1 and 10 grams, followed by comparison with the limit.
- any others perturbation sources must be avoided inside the test room or in immediate vicinity.

a b

Fig. 3. The front side (a) and the back side (b) of the Huawei P20 Pro mobile protected by a multilayered protective case

Fig. 4 shows a human user holding the Huawei P20 Pro mobile phone with the protective case in the cheek position, respectively the tilt position, the two real situation of exposure.

a b

Fig. 4. Huawei P20 Pro phone with a protective case in the cheek position (a) and the tilt position (b) towards the user's head

III. RESULTS AND DISCUSSIONS

Operating procedure used during these measurements: a GSM communication has been established between the mobile phone under test and the base station simulator CMU200.

The "Right – Cheek" GSM 900 experimental conditions include: phantom – right head; mobile phone position – cheek; signal – TDMA (crest factor: 8.0); channel – middle; frequency – 897.59 MHz (uplink); relative permittivity (real part) – 41.5; relative permittivity (imaginary part) – 19.4; conductivity (S/m) – 0.967.

The "Right – Tilt" GSM 900 experimental conditions include: phantom – right head; mobile phone position – tilt (tilted with 15 degrees against cheek position); signal – TDMA (crest factor: 8.0); channel – middle; frequency – 897.59 MHz (uplink); relative permittivity (real part) – 41.5; relative permittivity (imaginary part) – 19.4; conductivity (S/m) – 0.967.

The "Right – Cheek" GSM 1800 experimental conditions include: phantom – right head; mobile phone position – cheek; signal – TDMA (crest factor: 8.0); channel – middle; frequency – 1747.4 MHz (uplink); relative permittivity (real part) – 40.102; relative permittivity (imaginary part) – 14.096; conductivity (S/m) – 1.368.

The "Right – Tilt" GSM 1800 experimental conditions include: phantom – right head; mobile phone position – tilt (tilted with 15 degrees against cheek position); signal – TDMA (crest factor: 8.0); channel – middle; frequency – 1747.4 MHz (uplink); relative permittivity (real part) – 40.102; relative permittivity (imaginary part) – 14.096; conductivity (S/m) – 1.368.

The SAR values for the HUAWEI P20 Pro mobile phone subject to dosimetric evaluation are shown in Table 1 for the right side of the SAM phantom.

Table 1. SAR values for different position of Huawei P20 PRO mobile phone relative to the right part of SAM phantom for two GSM frequencies.

Bandwidth	Channel	Position	SAR 10g [W/kg]	SAR 1g [W/kg]
GSM 900	Middle	Right–Cheek	0.2854	0.4149
GSM 900	Middle	Right–Tilt	0.1375	0.1945
GSM 1800	Middle	Right–Cheek	0.1365	0.2282
GSM 1800	Middle	Right – Tilt	0.0422	0.0713

The comparative values of the SAR calculated for 10 g of tissue, between the two phone placement positions in relation to the right side of the physical SAM model, for the two selected working frequencies, are presented in Table 2.

The SAR values for the HUAWEI P20 Pro mobile phone protected by a multilayer plastic case are shown in Table 3 for the right side of the SAM phantom, for both frequencies.

Table 2. Comparison of the SAR 10g values for different position of Huawei P20 PRO phone relative to the right part of SAM Phantom.

Bandwidth	Channel	Position	SAR 10g [W/kg]
GSM 900	Middle	Right–Cheek vs Tilt	2.07
GSM 1800	Middle	Right– Cheek vs Tilt	3.23

Table 3. SAR values for different position of Huawei P20 PRO phone with the multilayer protective case relative to the right part of SAM Phantom

Bandwidth	Channel	Position	SAR 10g [W/kg]	SAR 1g [W/kg]
GSM 900	Middle	Right–Cheek	0,1007	0,1525
GSM 900	Middle	Right–Tilt	0,0323	0,0443
GSM 1800	Middle	Right–Cheek	0,0348	0,0574
GSM 1800	Middle	Right – Tilt	0,0140	0,0235

The comparative graphical distribution of SAR values (averaged on 10g tissue) following the dosimetric evaluation of the Huawei P20 Pro (with or without protective case) is shown in Fig.5. Four situations have been considered: cheek and tilt positions, for both frequencies of interest!

How the SAR values recorded by the dosimetric evaluation of the Huawei P20 Pro (with and without case) is synthesized in Table 4 (for cheek and respectively tilt positions).

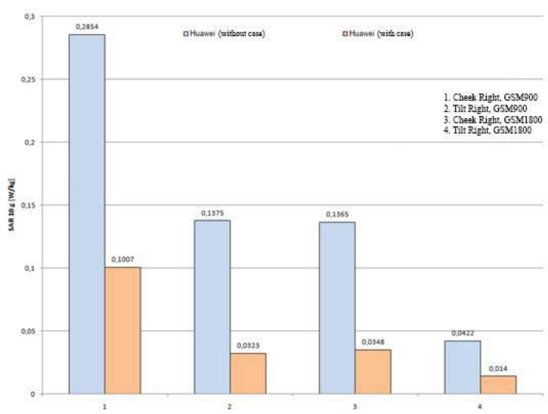

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Fig. 5. Comparative graphical distribution of SAR values (10 g of tissue) for the dosimetric evaluation of the Huawei P20 Pro: with and without multilayer protective case.

Table 4. Comparisons between SAR values (10 g) given by dosimetric evaluation of HUAWEI P20 PRO (provided or not with a protective case)

Bandwidth	Position	SAR 10g [W/kg]		
		Huawei (no case)	Huawei (with case)	Huawei (no case vs with case)
GSM 900	Right Cheek	0.2854	0.1007	2.83
GSM 900	Right Tilt	0.1375	0.0323	4.25
GSM 1800	Right Cheek	0.1365	0.0348	3.92
GSM 1800	Right Tilt	0.0422	0.0140	3.01

The maximum value of this SAR has been represented by OpenSAR software in 2D graphical representation as a rectangular surface for the right part of SAM phantom, according to the position of the phone.

Around the red marked area, the software draws a “surface” SAR, which corresponds to different points inside the phantom.

In Fig. 6 is represented the surface SAR for Huawei P20 Pro phone, without case, on the Right – Cheek position for 897,59 MHz frequency.

The OpenSAR software can also restrict the surface where the maximum value of SAR 10g have been found to a specific volume concentrated around this maximum value of SAR determined during the scan process inside SAM phantom.

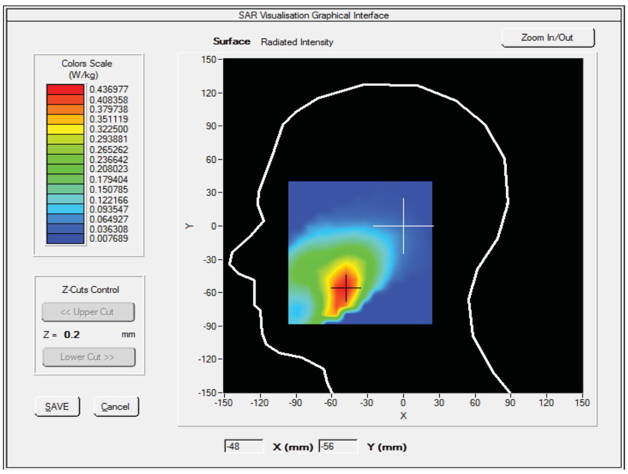

Fig. 6. Surface SAR, Huawei P20 Pro phone without protective multilayer case

In Fig. 7 is represented the volume SAR for Huawei, P20 Pro phones without multilayer protective case on the Right – Cheek position, GSM-900 frequency band.

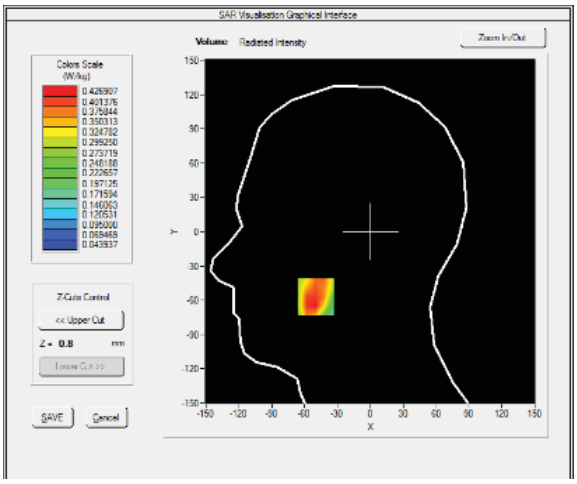

Fig. 7. Volume SAR for Huawei P20 Pro mobile phone without protective multilayer case

IV. CONCLUSIONS

This paper presents a set of SAR direct measurements performed with a SATIMO-COMOSAR dosimetry system for a new generation smartphone, HUAWEI P20 Pro, for different exposure scenarios.

We have also determined the SAR values when Huawei mobile phone was provided with a multilayer plastic protective case.

Examination of data presented in the tables and figures has shown that results are generally consistent with other tests performed by different accredited laboratories.

As a solid conclusion, the cheek SAR values are higher than tilt SAR ones; 1-g SAR values are higher than 10-g SAR values. Also, the 900-MHz SAR values are higher than 1800-MHz SARs. These findings have theoretical support and are in good agreement with most of the other results revealed in literature.

As a first recommendation, the tilt position should be preferred.

Supplementary for this device, the designers placed the antenna at the bottom part of the device, to be farther away from the user's brain. This is a major advantage versus the older mobile phones with position of their antenna on the top of the device.

As in principle expected, the lowest values of SAR had been recorded when the phone was provided with protective case.

Regarding the use of a protective casing, it is important that the material from which is made to be good absorbent; the protective cases having conducting insertions should be avoided, mainly due to unexpected and uncontrolled reflections. Future studies on this topic should involve testing different types of cases, to comparatively track their impact on SAR values.

Contrariwise, the transmission efficiency of the phone provided with protective case decreases. As a shortcoming, in this situation the battery will run out faster because it will try to give more power to ensure coverage, respectively a better signal reception.

A general conclusion could be the following: a combination of factors such as the positioning of the antenna, the size of the device, the relative position to the human head, equipping the phone with a protective case, can lead to lower SAR values, regardless of the type of mobile terminal.

The dosimetry evaluation here presented demonstrates that SAR maxim values for 10 g of tissue are considerably smaller than the limit of 2 W/kg (head region), imposed by actual European specific standards for electromagnetic protection and safeness.

Anyway, in real, daily environment, the SAR values might vary depending on propagation conditions and on the way in which the phone is effectively used.

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