Evaluation of the error induced by an incorrect positioning of the handset against the SAM phantom for SAR calculations

***Vikass Monebhurrun*[1]*, Man-Faï Wong*[2]*, Azeddine Gati*[2] *and Joe Wiart*[2]

[1]Department of Electromagnetics, DRE-L2S, SUPELEC, 3 rue Joliot-Curie, 91192 Gif-sur-Yvette Cedex France
e-mail: vikass.monebhurrun@supelec.fr

[2]Orange Labs R&D, RESA/SAFE, 38-40 rue du Général Leclerc, 92794 Issy-Les-Moulineaux Cedex 9, France
e-mail : manfai.wong@orange-ftgroup.com, azeddine.gati@orange-ftgroup.com, joe.wiart@orange-ftgroup.com

Abstract

Inter-laboratory comparisons of Specific Absorption Rate (SAR) calculations sometimes show discrepancies between the results. An incorrect positioning of the handset against the head phantom may be one of the possible causes of the observed discrepancies. In order to evaluate the error induced by an incorrect positioning of the device, two commercially available mobile phones with different antenna configurations –one with a built-in PIFA (Planar Inverted-F Antenna) and the other with an external helicoidal antenna– are herein selected for SAR calculations using the SAM (Specific Anthropomorphic Mannequin) head phantom. Using the initial handset/phantom position defined by international dosimetric standards as the reference configuration considered to be correct, several incorrect but nonetheless acceptable handset/phantom configurations are generated and the computed SAR values compared. Results show that deviations with respect to the reference positions may induce up to about 8% difference in the maximum 10°g averaged SAR values in the case of the mobile phone with the external helicoidal antenna.

1. Introduction

Currently the SAR (Specific Absorption Rate) compliance of mobile phones is based on measurement procedures developed by international standards such as IEEE1528 [1] and IEC62209-1 [2]. The SAM (Specific Anthropomorphic Mannequin) head phantom filled with an appropriate tissue equivalent liquid is adopted for the SAR measurements of four intended use positions of the mobile phone against the head: left/cheek, left/tilt, right/cheek and right/tilt positions. An overall uncertainty of up to 30 % for the maximum averaged 10 g SAR value is tolerated by the measurement standards. Furthermore, the SAR compliance test of a mobile phone proves to be time-consuming and costly. For example, the SAR compliance test of a triple-band mobile phone –GSM (Global System for Mobile communication) 900 MHz, GSM 1800 MHz and UMTS (Universal Mobile Telecommunication System)– requires one and half day using currently available standard dosimetric test facilities.

The availability of fast computers at low cost and user-friendly electromagnetic software paves the way for numerical dosimetry. However the accurate numerical modeling of CAD (Computer-Aided Design)-based mobile phones is still a challenging task. Indeed, even when the actual CAD model of the mobile phone is available, the electromagnetic simulation is not straightforward because most electromagnetic solvers cannot easily handle the complexity of the CAD model which is usually developed for mechanical engineering purposes. The presence of tiny elements or curvatures in the CAD model produces a relatively high mesh density which slows down the computational time. Typically, when applying the Finite Difference Time Domain (FDTD) technique –which is nowadays commonly adopted for numerical dosimetry– the mesh density generated by the mobile phone alone actually dictates the overall mesh density obtained in the presence of the SAM phantom. The voxel size should be much smaller than the typical recommended value of about a tenth of the wavelength in the tissue equivalent liquid.

Nonetheless it is worth to note that, even though the CAD model may visually look rather similar to the real mobile phone, the electromagnetic solver only handles a discretized version of the model. In fact, for efficient SAR calculations, it may sometimes be more appropriate to numerically reconstruct the mobile phone model rather than use the original CAD model. This approach was previously applied to reconstruct the numerical model of a commercially available PIFA-based mobile phone which was validated using experimental data [3]. The reconstructed numerical model was simplified by taking account the relative electromagnetic contribution of the different components of the mobile phone.

978-1-4244-6051-9/11/$26.00 ©2011 IEEE

Obviously, in order to gain confidence in the numerical simulation results, the accuracy of the SAR calculations –more specifically, the uncertainty– should be assessed. Usually the numerical simulation results are assumed to be correct after a convergence analysis is performed but the uncertainty of the SAR calculation is rarely stated. Discrepancies between numerical simulation results have often been observed during inter-laboratory comparisons of Specific Absorption Rate (SAR) calculations. One international comparison on SAR calculations observed that a possible cause of discrepancy could be an incorrect positioning of the handset with respect to the phantom [4]. When SAR calculations are performed using inhomogeneous head models, the positioning error may be amplified because of the presence of irregularities along the surface of the head model and undefined reference points which help to position the handset correctly. However, even in the case of the SAM phantom for which reference positions are clearly defined in the international standards, significant deviations in the SAR values have been observed [5].

In order to evaluate the uncertainty due to the positioning of the handset with respect to the SAM phantom, two commercially available mobile phones are herein selected for SAR calculations.

2. Numerical simulations

Numerical dosimetry is usually tackled using electromagnetic solvers based on time domain methods such as FDTD. A commercial package of the TLM (Transmission Line Matrix) method is herein adopted for the numerical simulations [6,7]. Figure 1(a) shows the typical mesh generated when the mobile phone is considered alone. Figure 1(b) shows the mesh generated when the mobile phone is positioned against the SAM phantom. For optimized SAR calculations, a maximum cell size of a tenth of a wavelength in the tissue equivalent liquid is imposed. However, in order to correctly account for the tiny elements present inside the mobile phone, the cell size is usually well below the maximum value.

Fig. 1. Typical mesh generated: (a) mobile phone alone (left), and (b) mobile phone positioned against the SAM phantom (right).

The two commercially available dual-band –900 MHz/1800 MHz– mobile phones selected for the numerical simulations are shown placed against the SAM phantom for the left/cheek position in Fig. 2(a) and (b), respectively. The numerical models are obtained by reconstructing the typical components present in the mobile phone such as the PCB (printed circuit board), the battery, the casing, etc. The first numerical model is the previously validated model of the PIFA-based barphone [3]. The second numerical model is another barphone with an external helicoidal antenna. For both numerical models, the PCB is modeled as a thin conducting plate i.e. the dielectric substrate and electronic circuits are not considered. The dielectric casing of the mobile phones (not shown in the figures) is drawn to have planar faces so that a more accurate positioning of the device against the phantom can be achieved (the actual casing of the devices are non-planar). The exact values of the dielectric properties of the different materials are unknown: approximate values are therefore applied.

The detailed procedure to position the mobile phone against the SAM phantom is described in the international SAR measurement standards which constitute the reference documents. Briefly, the procedure is as follows: two imaginary lines –the vertical centerline and the horizontal line– are defined for the mobile phone as shown in Fig 3(a). The vertical centerline passes through two points –top (point T) and bottom (point B) midpoints– on the front side of the mobile phone. The horizontal line passes through the acoustic output of the mobile phone (point A). The three points RE (right ear), LE (left ear) and M (mouth) describe the reference plane for the SAM phantom (see Fig. 3(b)). When the mobile phone is positioned against the phantom, point A is found on the virtual extension line which passes through points RE and LE. The vertical line of the mobile phone should be in the reference plane of the SAM phantom. Additionally, for the cheek position, the mobile phone is rotated towards the phantom until a contact is achieved.

Fig. 3(c) shows the initial position –considered to be correct– of the mobile phone positioned against the SAM phantom for the left/cheek configuration. In order to evaluate the uncertainty due to the mobile phone/phantom positioning, several new configurations are derived from the initial configuration by performing ±1 degree rotations of the phantom about the x, y or z axis (the mobile phone is not rotated to avoid stair casing effects). The rotations are pursued until the mobile phone/phantom position is found to be visually incorrect. Obviously, appropriate translations are also performed to ensure that no part of the mobile phone penetrates the SAM phantom. The same procedure is applied for the other mobile phone/phantom positions i.e. left/tilt, right/cheek and right/tilt.

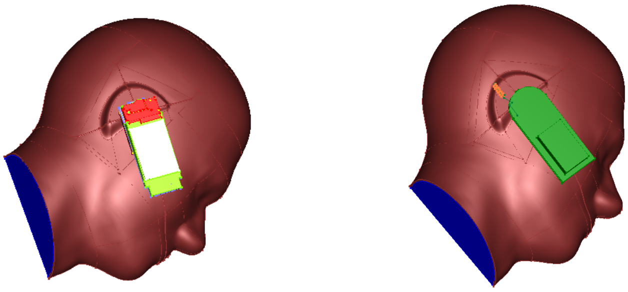

Fig. 2. (a) PIFA-based commercial mobile phone positioned against SAM phantom (left), and (b) commercial mobile phone with external helicoidal antenna positioned against the SAM phantom (right).

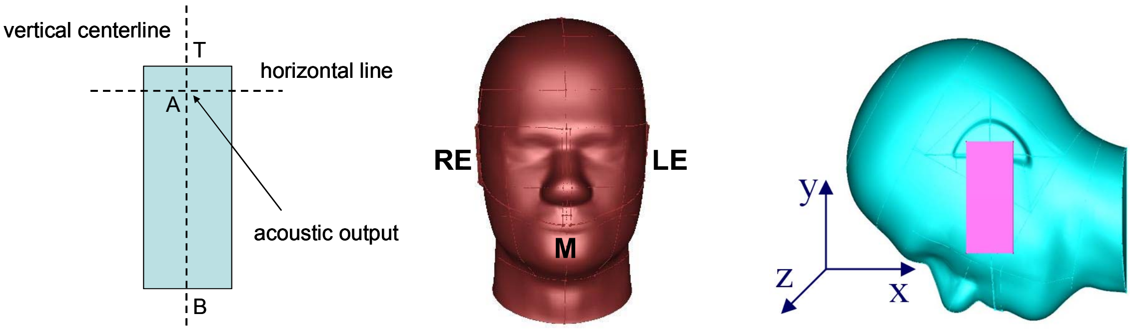

Fig. 3. (a) Virtual reference lines for the mobile phone (left), (b) reference points for the SAM phantom (middle), and (c) positioning of the mobile phone against the SAM phantom for the left/cheek configuration (side view) (right).

3. Results

The influence of the different components of the PIFA-based mobile phone and the TLM mesh density on the return loss and SAR calculations is discussed elsewhere [5]. A first set of numerical simulations are performed for the four intended use positions which constitute the reference values. Further simulations are undertaken for small deviations of the position of the mobile phones as described previously: For comparable results, the same mesh is applied for all the numerical simulations with a given mobile phone model.

The SAR calculation results show that for rotations of both mobile phones about the z-axis, the error in the SAR value is about 1 %. For rotations about the y-axis, the error is relatively higher. However a maximum error of about 5 % is observed for rotations of the PIFA-based mobile phone about the x-axis. In the case of the mobile phone with the helicoidal antenna, an error of about 8 % is obtained.

5. Conclusion

Two commercially available mobile phone models were employed to evaluate the error induced in SAR calculations due to incorrect positioning of the mobile phone against the SAM phantom. The SAR results show that for deviations of the position of the mobile phone such that the distance between the antenna element and the tissue equivalent liquid is practically the same (e.g. 1 degree rotations in a plane parallel to the sagittal plane), the error in the SAR value is about 1 %. For other deviations of the mobile phone position (e.g. 1 degree rotations perpendicular to the sagittal plane), the error in the SAR value rises to about 5 %. The investigation undertaken herein may help explain the discrepancies sometimes observed during inter-laboratory computational SAR comparisons.

7. References

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