NUMERICAL MODELLING OF MOBILE PHONES FOR SAR CALCULATIONS: FROM GENERIC TO REALISTIC COMMERCIAL MODELS

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ABSTRACT

Accurate numerical modelling of commercially available mobile phones is not an immediate task. A commercial phone model with a planar inverted-F antenna is considered for SAR (Specific Absorption Rate) calculations. Time domain methods are employed for the numerical simulations. The influence of basic components of the phone such as the battery, the earpiece and the casing on the return loss of the antenna is investigated. Dipoles, monopoles and the commercial phone model are considered in the presence of a head phantom for various intended use positions. Results of SAR calculations are compared at several frequencies currently used for mobile communications.

INTRODUCTION

Nowadays mobile phone compliance testing is routinely performed in a standard dosimetric test facility. The so-called SAM (Specific Anthropomorphic Mannequin) phantom filled with the appropriate tissue equivalent liquid is employed to measure the SAR (Specific Absorption Rate) for typical intended mobile phone use positions defined by the standard [1]. The representativity of the tissue equivalent liquid used for such measurements was previously investigated through numerical simulations [2]. A generic mobile phone model – a quarter-wave monopole antenna over a metallic box of size 110 mm x 60 mm x 30 mm – was employed to compare SAR induced in heterogeneous and homogeneous head models at 900 MHz and 1800 MHz herein referred to as GSM (Global System for Mobile Communications) and DCS (Digital Communications System) frequencies, respectively. Values of the dielectric properties of the tissue equivalent liquid consistent with those recommended by the standard were thus deduced. Furthermore, the influence of the morphology of the head on the SAR was also studied at these two frequencies [3].
The numerical investigation is herein extended to the 3rd generation mobile communications system or UMTS (Universal Mobile Telecommunication System) in the framework of the French national project RNRT/ADONIS [4]. Numerical simulations are undertaken using the same generic mobile phone model as well as a half-wave dipole antenna for various recommended use positions in the presence of the SAM phantom.
For a better representativity of the study and for the sake of completeness of the analysis, a commercially available mobile phone model with a planar inverted-F antenna (PIFA) is also considered. Special emphasis is laid on the modelling of the mobile phone. Indeed the accurate numerical modelling of commercial mobile phones is not an immediate task especially when considered with the head phantom. The lack of computer resources and/or adequate solver usually hinders the detailed modelling of the mobile phone. Basic components of the mobile phone such as the battery, the earpiece and the casing, for example, clearly have an impact on essential parameters of the antenna taken alone such as the return loss and the SAR. The influence of such components on the return loss of the mobile phone is herein investigated both numerically and experimentally.

NUMERICAL MODELLING

All numerical simulations are performed using time domain solvers based on the FDTD (Finite Difference Time Domain) and the FITD (Finite Integral Time Domain) methods which prove appropriate when handling highly inhomogeneous media such as the human head [5]. Due to lack of memory resources on standard computers – typically restricted to 2 Gigabyte or about 6 millions voxels – a compromise between accuracy and minimum mesh size is necessary to efficiently tackle the numerical simulations. A convenient way to overcome the memory restriction is to consider only a half-head model since the electromagnetic contribution of the remaining half-head is found to be negligible [6]. For meaningful enough results a minimum cubic voxel size of 1 mm is sufficient when modelling the dipole antenna and the generic mobile phone model. By applying a non-uniform mesh the voxel size can then be progressively relaxed to about a tenth of the wavelength near the boundaries of the simulation domain. Perfectly matched layers (PML) are imposed as boundary absorbing conditions to enclose the simulation domain.

Complex modelling of commercial mobile phones can be achieved using computer aided design (CAD) softwares. However the electromagnetic simulation of such CAD models is usually not straightforward. The presence of detailed or curved structures often induce numerical instabilities in the FDTD algorithm. These instabilities can be waved by reducing the mesh size but the numerical simulation then results in relatively long run-times. Furthermore, the number of voxels rapidly increases producing impracticable SAR calculations. Clearly only essential elements of the mobile phone can be accounted for in the numerical modelling. Typical components of a commercial mobile phone with a planar inverted-F antenna are (Fig. 1): antenna, feed, short, ground plane, electromagnetic compatibility (EMC) shielding of integrated electronic circuits, earpiece or speaker, dielectric support, vibrator, display with metallic frames and dielectric casing. The earpiece and the vibrator are metallic elements embedded in-between the antenna and the ground plane. All metallic elements are supposed grounded.

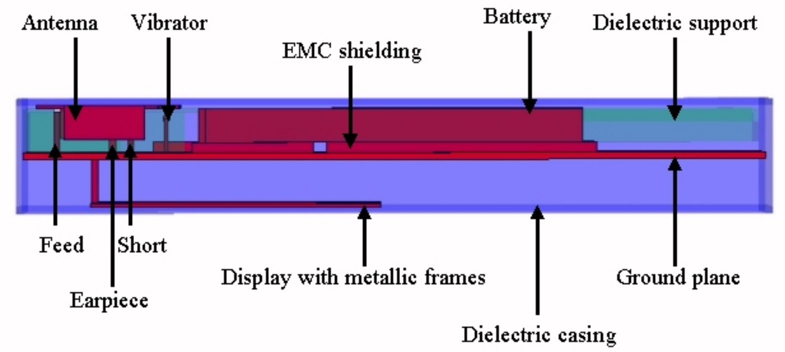

Figure 1. Typical components of a commercial mobile phone with a built-in antenna.

To investigate the influence of these components a commercial mobile phone mock-up with a coaxial cable connection to the antenna is used. The ground plane is considered with the metallic EMC shields with at least the antenna element present. Fig. 2 (a) and (b) show the measured return loss of the antenna as the different components of the mobile phone are progressively inserted. The shorting-pin is the key element which yields the dual-band characteristic of the antenna. As expected the dielectric support and casing of the mobile phone help to lower the two resonance frequencies. The speaker, the vibrator and the battery have stronger influence on the return loss of the antenna at the higher resonance frequency.

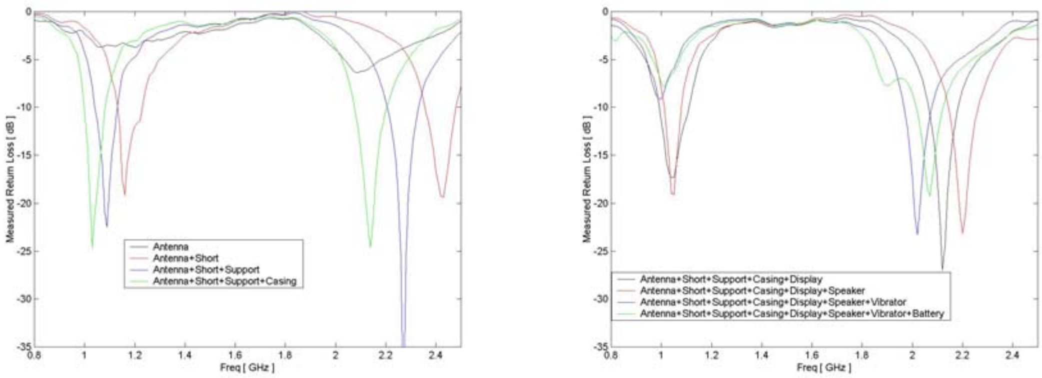

Figure 2. (a) left and (b) right . Influence of the different components of the mobile phone on the measured return loss of the antenna.

For the numerical simulations of the commercial mobile phone, a minimum mesh size of 0.25 mm is chosen near the antenna. Similar trends of the return loss are observed up to the case where the display is inserted (Fig. 3). The specific locations and relatively small dimensions of the earpiece and the vibrator require a finer mesh to properly take them into account. However in the presence of the head a smaller mesh size would produce a high mesh density incompatible with the available computer memory resource. Furthermore, a finer mesh in the FDTD algorithm would result in longer simulation run-times. The display has negligible influence on the return loss but it cannot be discarded for SAR calculations due to its proximity to the head. Indeed, the metallic frames on which the display is mounted provide paths for electric currents which impact on the local SAR distribution.

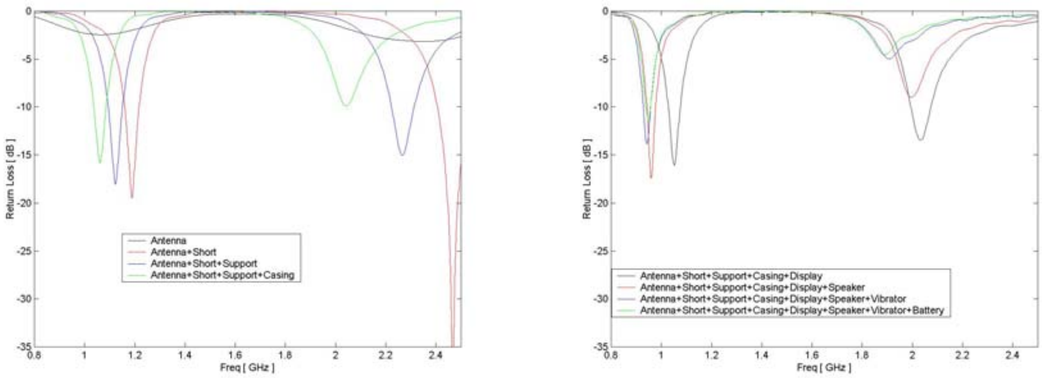

Figure 3. (a) left and (b) right. Influence of the different components of the mobile phone on the simulated return loss of the antenna.

SAR CALCULATION

From the above considerations the battery, the earpiece and the vibrator are excluded from the commercial mobile phone model for the numerical simulations in the presence of the SAM phantom. In order to maximize the impedance matching at GSM, DCS and UMTS frequencies the dimensions of the antenna are slightly modified to shift the resonances to the desired frequencies. In the absence of the phantom, the commercial mobile phone yields an omni-directional radiation pattern at 900 MHz (2.4 dBi) and a more directive radiation pattern at the other two frequencies (4.4 dBi). The phantom is filled with the tissue equivalent liquid defined by the standard i.e. conductivities and relative permittivities of 0.99 S/m and 42 at the GSM frequency, and 1.20 S/m and 40 at the DCS and UMTS frequencies. The SAR is calculated for all the four intended use positions (cheek/tilt, left/right) recommended by the standard (Fig. 4).

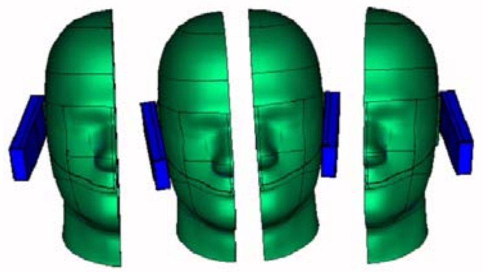

Figure 4. Recommended mobile phone intended use positions: right/tilt, right/cheek, left/cheek and left/tilt.

For the positioning of the mobile phone with respect to the phantom, staircase effects are avoided by rotating the phantom instead of the mobile phone. All input powers are normalized to 250 mW for the GSM frequency and 125 mW for the DCS and UMTS frequencies. Fig. 5(a) to (c) show the comparisons of the maximum averaged 10g SAR for the different configurations. All results are normalized with respect to the overall maximum value obtained for these configurations. As usually observed during compliance tests of mobile phones, the highest SAR values are obtained at 900 MHz. The commercial mobile phone provides SAR values comparable to those obtained with the generic mobile phone model. Fig. 6(a) to (c) show comparisons of the normalized total power dissipated in the phantom. Interestingly similar variations of the SAR and the total absorbed power are observed for a given mobile phone model, especially at 900 MHz [7].

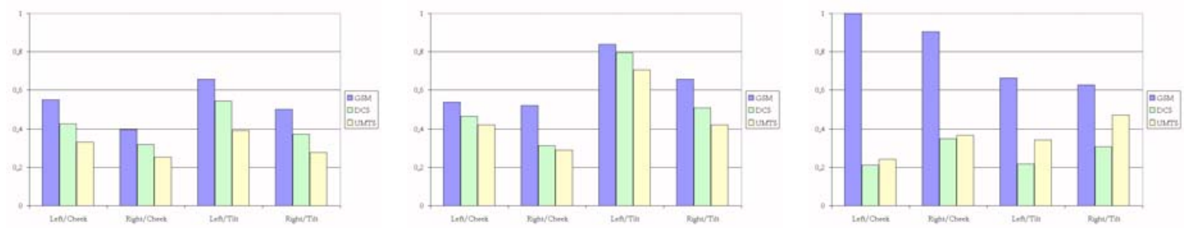

Figure 5. Normalized maximum averaged 10g SAR in the case of (a) the dipole antenna (left), (b) the generic mobile phone model (middle) and (c) the commercial mobile phone model (right) for all recommended use positions.

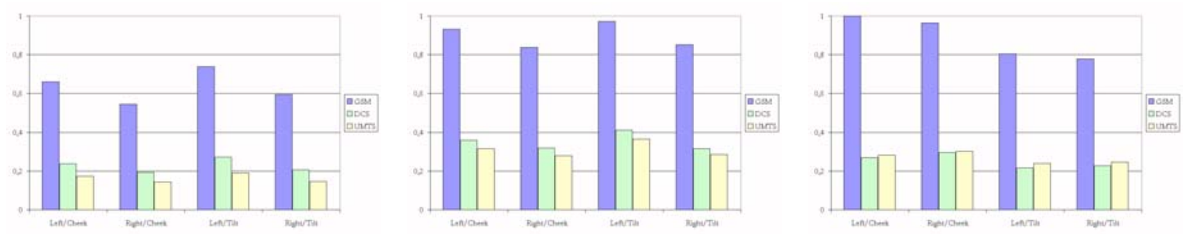

Figure 6. Normalized total absorbed power in the case of (a) the dipole antenna (left), (b) the generic mobile phone model (middle) and (c) the commercial mobile phone model (right) for all recommended use positions.

CONCLUSION

The numerical simulations of mobile phones for SAR calculations have been considered. The SAR due to a dipole antenna, a generic mobile phone and a commercial mobile phone in the presence of the SAM phantom have been calculated for all intended use positions recommended by the standard at GSM, DCS and UMTS frequencies. Special emphasis has been laid on the numerical modelling of the commercial mobile phone with a built-in antenna. The measurements and numerical simulations show that the different elements which compose the commercial mobile phone have significant influence on the return loss of the antenna. Due to lack of computer memory resources and/or long simulation run-times only some components of the commercial mobile phone can be properly modelled for efficient SAR calculations. The highest SAR values have been obtained at 900 MHz for all the configurations.

ACKNOWLEDGEMENT

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