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SPECIFIC ABSORPTION RATE REDISTRIBUTION AND AMPLIFICATION IN THE PRESENCE OF METALLIC WALLS AND ENCLOSURES

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According to the literature, in the presence of a metallic wall or enclosure the Specific Absorption Rate (SAR) inside the tissue of an exposed user of a mobile phone is enhanced and redistributed. By showing, with the help of a simulation implemented in the FTDT commercially available software SEMCAD X (www.semcad.com), that the SAR only increases by a few percent in the case of partially closed metallic structures, but is strongly affected by total metallic enclosures, I was able to confirm those findings. Additionally, the presence of a metallic implant inside the tissue further complicates the situation as it leads to an increase in SAR averaged over 1 gram of tissue (SAR1g) which is 139% higher than in the case without any implants and walls, showing a possible dangerous scenario to consider in the case of radiation protection measures

Keywords: specific absorption rate, electromagnetic radiation, anatomical modeling

1. Introduction

The importance and the need to address the Specific Absorption Rate (SAR) stems from the fact that the thermoregulation mechanisms are complicated and unreliable, being strongly dependent on a number of physiological conditions, on alcohol and drug consumption, on the temperature and humidity of the environment and a host of other factors [1, 2].

The Specific Absorption Rate is of course the measure by which the effects of electromagnetic radiation emitted by antennas are compared and standards are drafted to protect users or workers from the unwanted and possibly harmful effects of the energy transported by these fields [3-5].

This is the reason why there has been a surge of interest in recent years to determine all types of scenarios that could influence the distribution or the value of SAR in the body, from the models of the antennas used [6] to variations in the anatomical models [4] or the different types of implants [7].

There has been relatively little interest on the other hand in the presence of metallic walls or enclosures and the effects that theses might have on the power absorbed inside the tissue. On one of the earliest studies [8], an increase in the

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SAR averaged over 10 g of tissue of 60% was found in the case of a metallic wall placed as close as 30 mm to the head. On another relatively old study [9] it was found that the presence of a horizontal metallic wall placed above the head reduces the SAR value in the tissue area closest to the radiating antenna, while the same metallic wall placed parallel and on the same side as the radiating antenna leads to an increase of the SAR in the whole head.

Of the more recent studies, some deal with automotive enclosures, while others with elevator metallic enclosures. In the first case, the metallic structure leads to a strong redistribution of the SAR inside the affected tissue but without a dangerous increase [10]. In the case of elevators, a partially open enclosure leads to insignificant increases of the SAR values (a few percent) while a total enclosure leads to significant SAR increases, maximum and mediated values [11, 12].

For the present purpose, I used a model consisting of a head-simulating sphere and a dipole antenna placed in its vicinity. A number of metallic walls are placed parallel to this setting, ranging from one wall to six walls (total enclosure) in symmetrical (sphere placed in the center of the configuration) and asymmetrical configurations. And, lastly, a metallic implant in the form of a stent-simulating cylinder is placed inside the sphere to observer the further enhancement of the SAR from the electromagnetic radiation emitted by the antenna.

I conclude that there is indeed a strong increase in the value of SAR in the case of total enclosure, but a minimum increase in the case of partial enclosures. The asymmetrical position enhances the SAR values especially in the case of open enclosure, but has an opposite effect in the case of total enclosures. The SAR redistribution on the other hand is greatly affected in all scenarios, from one wall to six walls. Additionally, the presence of metallic implants inside the tissue leads to a further increase in the SAR values above the levels found in both the sphere plus implant and sphere plus metallic enclosure scenarios.

2. Materials and Methods

The model consists of a sphere with averaged electrical properties of a real human head. That is, a density of 1030 kg/m3, a relative permittivity of 43.7, a relative permeability of 1 and an electrical conductivity of 0.84 S/m. The radius of the sphere is 95 mm and is placed at 10 mm apart from a half length ($\lambda/2$) dipole antenna emitting at 835 MHz and normalized power of 1 W [14].

The metallic wall(s) is made of Iron with an electrical conductivity of 1.03·10^7 S/m and placed at a distance of 200 mm from the sphere (figure 1).

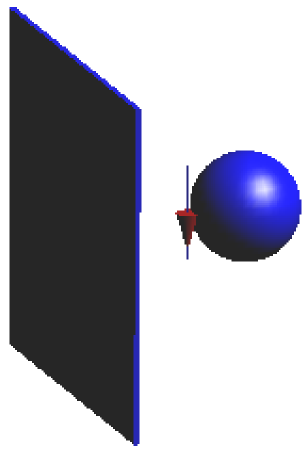
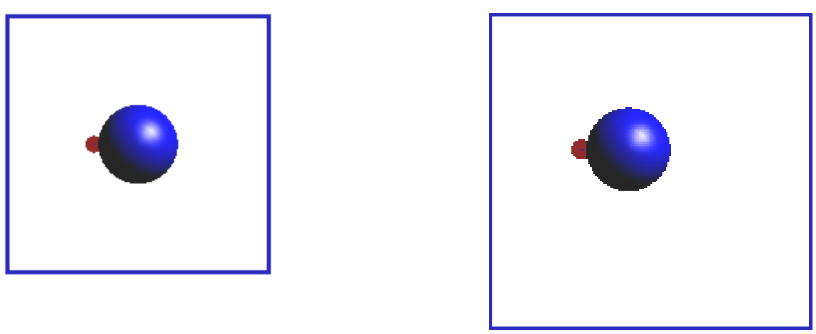


Fig. 1 One wall scenario placed in the left position (on the antenna side), 3D view

In the symmetric scenario, all walls are placed at this distance, but in the asymmetric one, the walls are extended in all three directions with an additional 100 mm (figure 2). Thus, the minimum wall-sphere distance is maintained at 200 mm while considering the asymmetric case.

The metallic implant placed parallel to the emitting antenna and inside the sphere in the case of total enclosure is a 3.6 mm diameter and 20 mm length solid cylinder with an electrical conductivity of 1·10^6 S/m.

The whole model is built and run with the commercially available SEMCAD X software (www.semcad.com). After the simulation, information about the maximum, averaged and one gram mediated SAR values, as well as the SAR distribution inside the sphere are extracted and compared.

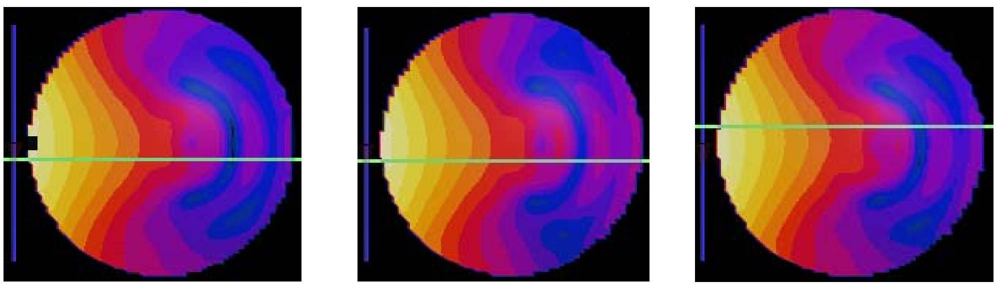


a **b**

Fig. 2 Sphere position in the four walls scenario (left, right, behind and front walls, top view): **a –** symmetric scenario, 200 mm walls; **b** – asymmetric scenario, 300 mm walls

3. Results

The presence of just a single wall is enough to cause a redistribution of the SAR inside the sphere (figure 3), without causing an increase in its values. Actually, this redistribution leads to a decrease in maximum and one gram averaged SAR (SARmax and SAR1g, respectively), except in the case where the wall is placed on the left side (antenna side). The voxel averaged SAR (SARavg) decreases in all the cases (table 1). The back-front and up-down scenarios are identical, and are not represented in the table.



a **b** **c**

Fig. 3 SAR redistribution caused by the presence of one parallel metallic wall:
a – the case without a wall; b – right wall; c – up wall

A SAR comparison along the section through the sphere (green line) confirms a slight change in SAR gradient as we go from left (antenna side) to right (figure 4). In the case of two walls present, I've considered the back-front, left-right and up-down scenarios.

Table 1

Single metallic parallel wall influence on SAR values

Wall Position	SARavg [W/kg]	SARmax [W/kg]	SAR1g [W/kg]
No wall	0.1795	19.4685	11.1286
Left	0.1723	19.9539	11.2515
Right	0.1786	17.7257	11.0084
Back	0.1769	17.5095	10.8893
Up	0.1789	17.732	10.9836

Only the left-right scenario leads to an increase in SAR1g, all other scenarios and SAR values showed a decrease. The same thing happens in the case of three walls scenario. Only the SAR1g for left-right-up scenario increases. These same things happen more or less in the following two cases, with four and five walls, respectively. Things only begin to really change in the case of a totally enclosed metallic environment.

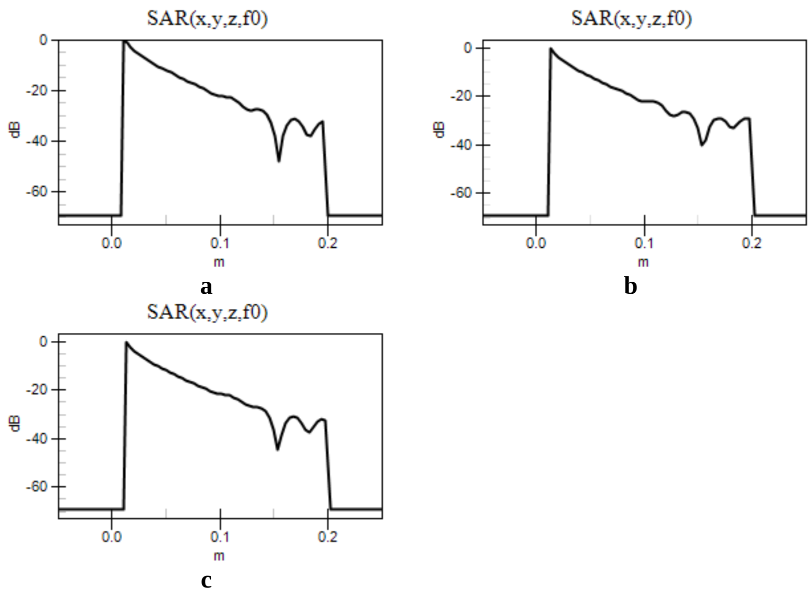


Fig. 4 SAR variation with depth:
a – without a wall; b – right wall; c – up wall

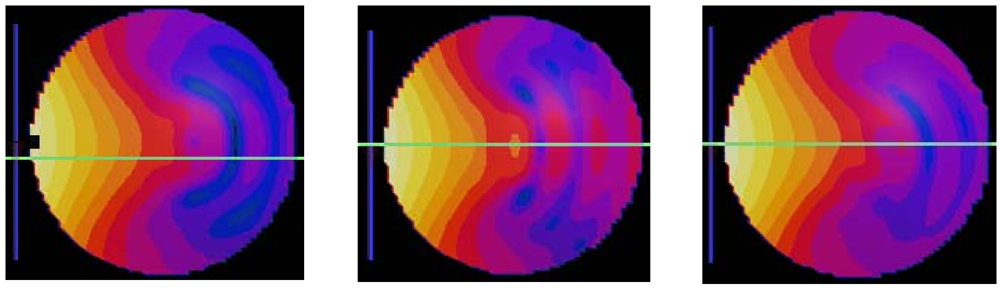
In this case, there is a totally enclosed metallic environment in the form of an Iron cube with 650x650 mm square sides and the sphere place in its center (symmetrical) at a distance of 200 mm from each of the cube sides. The SAR1g increases by 35.5 % from the case with no metallic walls present, the average SAR by 33.7 % and maximum SAR by 14.2 % (table 2).

The totally enclosed metallic cube leads to a stronger redistribution of SAR inside the sphere as well (figure 5). This result is better observed if we consider the section through the sphere (green line in figure 5) and compare the values of SAR at each point (figure 6). The maximum SAR gradient is attenuated by the presence of the metallic enclosure.

Table 2

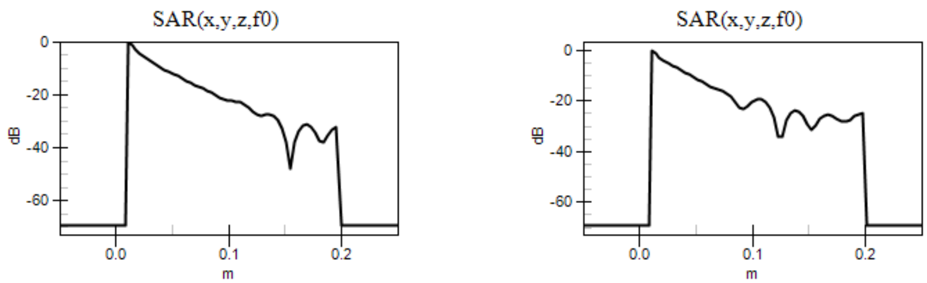
Total wall enclosure enhancement of SAR values

Wall Position	**SARavg [W/kg]**	**SARmax [W/kg]**	**SAR1g [W/kg]**
No metallic wall	0.1795	19.4685	11.1286
Totally enclosed metallic cube	0.2401	22.2343	15.081



a **b** **c**

Fig. 5 SAR redistribution in the case of totally enclosed metallic environment:
a – the case without a wall; b – with total enclosure (symmetric); c – with total enclosure (asymmetric)



a **b**

Fig. 6 SAR variation with depth: a – the case without a wall; b – with wall

An additional comparison between the strongest increase in SAR in each of the one through five metallic wall scenarios and the totally enclosed cube is given in figure 7, where the averaged SAR, due to its low values, has been multiplied by a constant equal to 80 for visualization purposes. Thus, the total enclosed environment leads to the greatest increases in SAR values overall.

The presence of a metallic implant in the form of a filled cylinder further amplifies the SAR values in the two cases considered, with and without a metallic enclosure. The SAR averaged over one gram of tissue, in the enclosure-free scenario, increases by almost 100% when the implant is present. In the case of the metallic enclosure, the presence of the implant amplifies the SAR1g value by approximately 76%.

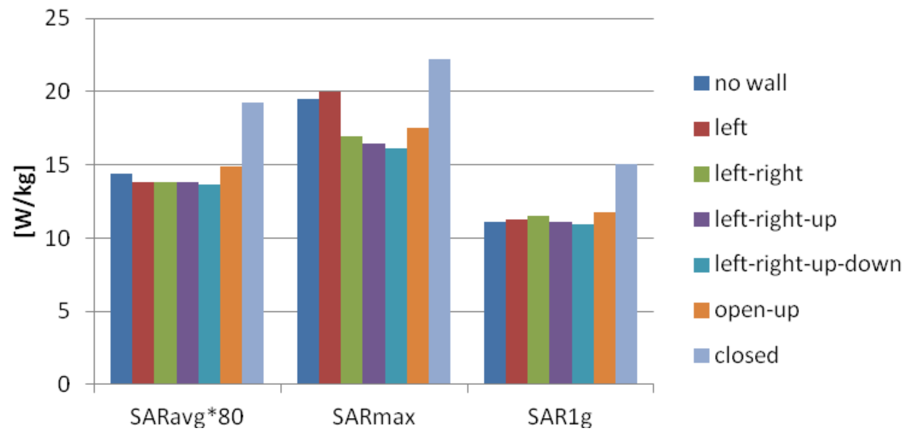


Fig. 7 SAR comparison for maximum increase in each of the scenarios from one wall to total enclosure

If we now place the sphere in an asymmetrical position like the one exemplified in figure 2, we obtain an additional increase in SAR with respect to the symmetrical case in all scenarios except the total enclosure. Nevertheless, that increase is between 3-15% (for SAR1g), while the decrease in the case of total enclosure is 27% and the value is even lower than in the case without any metallic walls present. The distribution was given in figure 4c and the actual values can be consulted from table 3.

Table 3

Comparison between SAR values in symmetric and asymmetric scenarios

Wall Position	SARavg [W/kg]	SARmax [W/kg]	SAR1g [W/kg]
Left-right	0.172293	16.9569	11.5001
Left-right-asym.	0.173692	16.715	11.3318
Left-back-right	0.167949	15.8995	10.7708
Left-back-right-asym.	0.182739	16.8713	11.4805
Left-right-back-front	0.169452	15.3217	10.2917
Left-right-back-front-asym.	0.18769	17.5507	11.8614
Open-up	0.186442	17.4894	11.7242
Open-up-asym.	0.187593	17.9397	12.0883
Totally closed	0.240144	22.2343	15.081
Totally closed asym.	0.174806	16.1282	10.9139

All in all, there is a considerable difference between a simple head-simulating sphere radiated by a dipole antenna and the same sphere and antenna but in a totally enclosed metallic environment and a metallic implant present inside the sphere and parallel to the antenna. The difference in SAR1g is approximately 139% between the two cases, with the higher value reserved for the latter case. The actual values are given in table 4.

Table 4

SAR values in cases with and without the metallic enclosure and metallic implant

Scenario with homogenous sphere	SARavg [W/kg]	SARmax [W/kg]	SAR1g [W/kg]
No enclosure, no implant	0.1795	19.4685	11.1286
No enclosure, with implant	0.1797	959.276	22.0066
With enclosure, no implant	0.2401	22.2343	15.081
With enclosure, with implant	0.2222	1160.88	26.606

4. Discussion and conclusion

The SAR increase is strongest in the case of totally enclosed metallic environments and the increase is minimum in the case of partially closed ones. This is already an interesting case, as this may occur in elevators and automotive environments, as already mentioned in the literature. The redistribution of SAR leads to an actual decrease in some cases in the SAR values.

The position of the sphere inside the metallic enclosure has been shown in the literature to have an impact on the SAR distribution and values. The redistribution of SAR is indeed taking place (figure 5), but only two positions were studied in this paper. There are some notable differences in SAR values between the two scenarios (named symmetric and asymmetric in the paper), with a difference as high as 15% in one of the cases. The relationship between SAR and position inside a metallic enclosure would certainly be an area worth investigating further, especially if we consider that in the totally closed environment, the asymmetric scenario leads to an actual decrease in SAR1g by 27%. Thus, the results seem to agree with those supported in the literature [10-12].

If a metallic implant is also present, the scenario becomes more interesting. I've only considered a simple cylindrical metallic implant in this case, that was placed parallel and close to the radiating antenna. This has lead to a substantial increase in SAR, with a difference of 139% between the scenario without a wall and implant and the metallic enclosure with implant scenario. But these values are again dependent on the type, size and position of the implant so that a final conclusion is hard to draw.

Nevertheless, considering reflections from highly conductive objects in the nearby vicinity of a mobile phone user is certainly an interesting area to study as there is at least a minimum amount of impact on the power absorbed inside the tissue, especially if a total metallic enclosure and/or a metallic implant is present.

Acknowledgment

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