SAR Dependence on Phantom Dimensions in WPT Exposure Assessment

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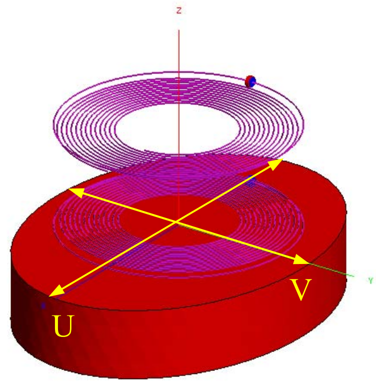
1 Introduction

The concept of wireless power transfer (WPT) for distant powering of various electronic devices has received much attention of the research community [1]. Recently, WPT technology has been actively developed for the electric vehicle charge applications [2]. According to the ICNIRP guidelines, the human exposure limits above 100 kHz using the specific absorption rate (SAR) as the assessment criteria are defined [3]. In human safety assessment of inductive coupling WPT systems, phantom of different shapes and dimensions can be used [4]. It is therefore important to consider the effect of phantom size variation on the SAR values obtained in the assessment of WPT systems. This work reports the results of EM simulation of a simple inductive coupling WPT coils operating close to the elliptical phantoms of varying dimensions.



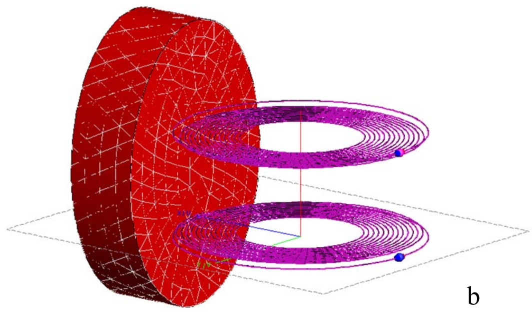


Figure 1. Layout of circular spiral oriented a) parallel and b) normal with respect to the elliptical phantom, Cases 1 and 2.

2 WPT System and Phantom Layout

In this work, the WPT systems optimized for the operation at 6-7 MHz band have been numerically analyzed by the method of moments-based EM simulation software. Two types of WPT coils are considered. The first is the relatively large circular spirals with the outer diameter of 50 cm. The second one is the small squared spirals sized 10 cm X 10 cm. The following application scenarios of WPT systems operating near the phantoms are considered: circular spirals placed parallel to the elliptical phantom – Case 1 (Fig. 1a), the same spirals oriented normal to the elliptical phantom – Case 2 (Fig. 1b), and small squared coils placed parallel to the elliptical phantom – Case 3 (Fig. 2). The following material properties of the tissue-simulating phantom liquid have been used in the analysis: $\varepsilon_r = 77.4$ and $\sigma = 0.752$ S/m.

In Cases 1 and 2 depicted in Fig. 1, the distance from the circular coil to the elliptical phantom surface has been fixed at 1 cm while the distance between the coils is 20 cm. Under these conditions, the dimension of the phantom has been changed by varying the ellipse axis U and V and keeping the phantom height fixed (15 cm). The shape of the elliptical phantom has been maintained by the unchanged ratio U/V=1.5, i.e. for each next value of U, the value of V has been changed accordingly. 10g-average SAR has been calculated for each set of U and V at two frequencies where the S-21 parameter of WPT system is at the maximum. These frequencies are 6.14 MHz and 7.18 MHz for Case 1 and 6.64 MHz and 7.54 MHz for Case 2, respectively.

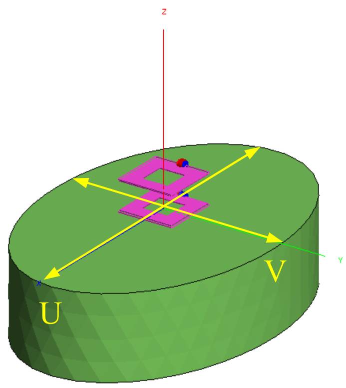


Figure 2. Layout of small squared spiral coils placed parallel to the elliptical phantom, Case 3.

In Case 3, the height of the elliptical phantom has been fixed at 15 cm. The normal orientation of the small coils has also been considered in the EM simulations.

3 EM Simulation Results

The calculated SAR values versus the smaller ellipse axis V normalized by the diameter of the circular coils D for the Case 1 are presented in Fig. 3. The EM simulations have been carried out for the 50-Ohm 1V voltage excitation ports. As can be seen, SAR remains almost unchanged for the larger dimensions of the phantom. However, there is a substantial increase of the SAR values when the phantom size decreases and becomes comparable to the coil dimension. Such an effect is not observed in Case 2 when the circular coils are oriented normal to the elliptical surface as shown in Fig. 3. Similar result has also been obtained at the lower frequency 6.64 GHz. Such a difference between Cases 1 and 2 is due to the different orientation of E-field vectors with respect to the phantom surface.

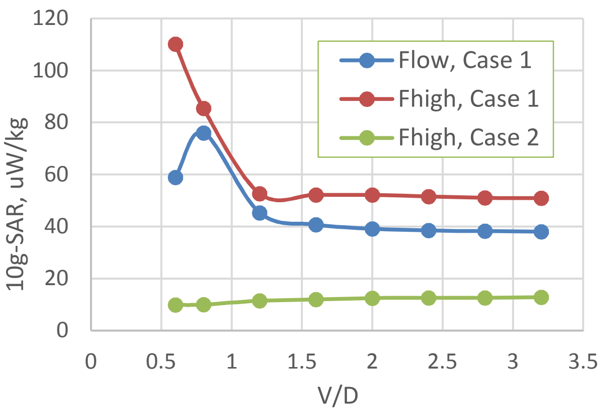


Figure 3. Calculated 10g-average SAR at versus the smaller axis of elliptical phantom V normalized by coil diameter D for the Cases 1 and 2.

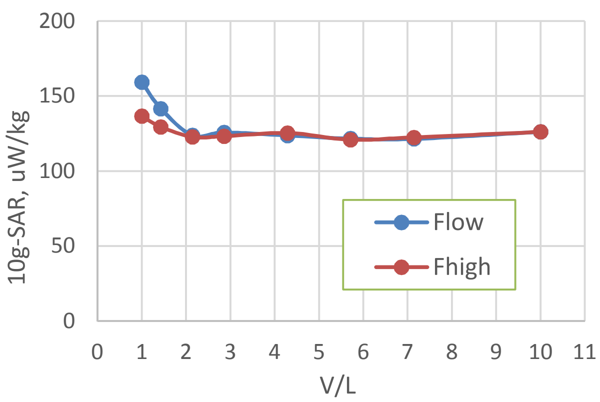


Figure 3. Calculated 10g-average SAR at 6.6 MHz and 7.64 MHz versus the smaller axis of elliptical phantom V normalized by squared coil diagonal L for the Case 3.

The calculated SAR values at frequencies 6.6 MHz and 7.64 MHz versus the smaller ellipse axis V normalized by the small squared coil diagonal L for the Case 3 are presented in Fig. 3. Similar to the Case 1, the SAR values increase when the elliptical phantom dimension decreases though the increase factor is somewhat smaller. For the larger phantoms, the SAR remains practically unchanged.

4 Conclusions

Numerical study of the effect of phantom dimension on the SAR values in WPT system applications has been presented. In case of circular spiral coils placed parallel to elliptical phantom, SAR increases substantially (with a factor of 2) with the decrease of the phantom dimensions. 10g-SAR reaches maximum when the coil diameter is comparable to the length of elliptical smaller axis. Such an effect is not observed when spiral coils are placed normal to the phantom. SAR level remains practically unchanged and much lower than in Case 1 as the phantom dimensions decrease. The difference is attributed to the different orientations of E-field vectors with respect to the phantom surface. In case of small squared coils parallel to elliptical phantom, similar effect is obtained. 10g-SAR reaches maximum when the coils size becomes comparable to the ellipse dimensions. Additional data will be presented at the Symposium.

The results obtained should be considered for selecting the phantoms with proper dimensions in the SAR measurements and human safety assessment of WPT systems.

5 Acknowledgements

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6 References

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