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Human Body Proximity to a Wireless Power Transfer System

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Introduction

Recently, there has been a great interest to wireless power transfer (WPT) systems for applications as diverse as consumer electronics, healthcare, electric vehicle charging, *etc.* [1]. In body-centric wireless applications, a human exposure has to be considered in order to ensure their compliance with existing exposure limits. Since less attention has been paid so far to study human body exposure of WPT systems, a dosimetry analysis is performed here using a detailed anatomical human body model and considering specific absorption rate (SAR) as the exposure metric. In literature, there are a few works reporting information on dosimetry related to WPT systems; *e.g.* [2]–[3]. However, in [2] only the transmitting side was considered whereas in [3] the exposure metrics were evaluated at a short range (*i.e.* 50 cm which is smaller than the considered coil largest dimension) with the anatomical body model only located between coils close to transmitter.

1. WPT system/human body coupling

1.1. Numerical methodology

A 10 MHz WPT system consisting two identical resonant coils driven by high quality factor loops was used in this study [4]. A detailed 2 mm-resolution voxel human body model from the virtual family project (*i.e.* Duke: male, 38 years old, 1.74 m height, and 70 kg weight [5]) was used for the numerical analysis. The body model dielectric properties have been taken mainly from Gabriel's data base [6]. Four different exposure scenarios have been considered as demonstrated in Fig. 1.

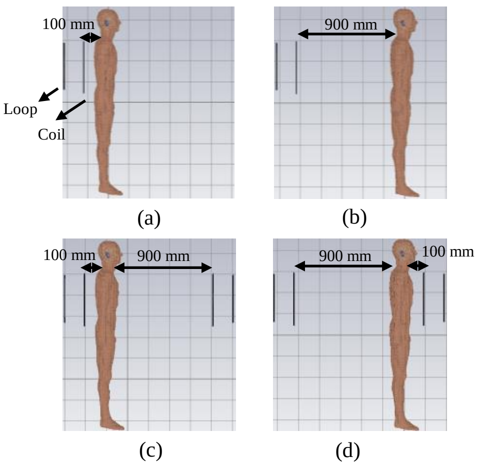

Figure 1: Schematic representation of the exposure scenarios considered in the dosimetric analysis: (a) case I; (b) case II; (c) case III; (d) case IV.

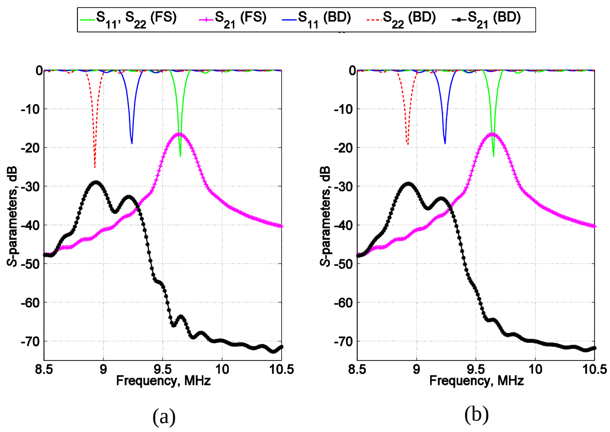

Figure 2: S-parameters of the proposed WPT system in presence of the Duke human model: (a) case III; (b) case IV. FS – free space; BD – body.

1.2. Impact of the human body on the system scattering parameters

Fig. 2 shows the impact of the human body presence on the scattering parameters of the WPT system for scenarios III and IV. For the sake of brevity, the results for cases I and II are not shown since the resonant frequencies are the same as the first resonant frequencies in scenarios III and IV. The body proximity impacts the system behavior splitting the common resonant frequency of the coils to S_{11} (Tx resonance) and S_{22} (Rx resonance). According to Fig. 2, in both scenarios, body proximity detunes the system by shifting of 4.23% and 7.44% the resonant frequencies for the Tx (1st resonance) and Rx (2nd resonance) resonances, respectively, compared to the free space case. Moreover, in presence of the body S_{21} parameter drops considerably by 16.2 and 12.6 dB in case III and 16.6 and 12.8 dB in case IV at the resonant frequencies.

1.3. SAR assessment

A dosimetry study was performed to evaluate the exposure levels with respect to the ICNIRP basic restrictions [7]. Here the considered dosimetric quantity is the local SAR averaged over 10g tissue using methodology suggested in IEEE C95.3. SAR results are computed for an input power of 1 W and are given in Table I. As observed, in the studied exposure scenarios, the values are identical in scenario I and III (at Tx resonance for scenario III), which is due to the insignificant influence of the Rx coil when critical coupling condition has been reached. Similar trend is noticed for cases II and IV (at Rx resonance for scenario IV) with a small difference though due to the presence of the Rx coil in scenario IV. This suggests that, for the considered exposure scenarios where both Tx and Rx are present, with the body closer to the Tx or Rx sides exposure metrics must be obtained at the Tx or Rx resonance frequencies, respectively. Moreover, in exposure scenario III the values are higher at the Tx than the Rx resonance, which is related to the stronger *H*-fields near the Tx coil. In scenario IV, an inverse behaviour is noticed; the dosimetric values are higher at the Rx compared to the Tx resonance as the body is more exposed to the generated fields by the Rx coil.
The compliance with the ICNIRP guidelines was also checked by evaluating the maximum allowable input power (MAP); results are summarized in Table II. Note that the ICNIRP limit for SAR is 2 for head and trunk. As observed, the MAP that satisfy SAR are identical in scenario I and III (at Tx resonance for scenario III), which is due to the minor impact of the Rx coil when critical coupling condition has been reached. However, the influence of Rx presence leads to slightly different results in cases II and IV (at Rx resonance for scenario IV). Moreover, in exposure scenario III (and inversely in IV), it is observed that the MAP that satisfies SAR limit is much lower at the Tx resonance (28.6 W) than the Rx one (1 kW), which is due to the body location that is closer to the power source. Complete SAR results will be presented during the conference.

Table I. SAR results for an input power of 1 W

Study case	$f_{res.}$ (MHz)		SAR_{10g} (W/kg)	
	1st (Tx)	2nd (Rx)	1st (Tx)	2nd (Rx)
I	9.24	–	0.07	–
II	9.25	–	6.8×10^{-5}	–
III	9.24	8.93	0.07	0.002
IV	9.25	8.93	4.4×10^{-5}	6.7×10^{-5}

Table II. MAP to satisfy ICNIRP basic restrictions

Metrics / Study case	SAR_{10g} (W/kg)	
	1st (Tx)	2nd (Rx)
I	28.6 W	–
II	29.4×10^3 W	–
III	28.6 W	1.0×10^3 W
IV	45.4×10^3 W	29.8×10^3 W

2. Conclusion

A study of interactions between a human body and a wireless power transfer system has been presented. It is demonstrated that the body presence splits the coils common resonant frequency in two (Tx and Rx). It has also been observed that SAR values should be evaluated depending on the body location, *i.e.* calculated at the Tx and Rx resonance in exposure scenarios where the body is close to Tx and Rx, respectively.

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