Exposure Assessment of a High-Resonance Wireless Power Transfer System under the Misaligned Condition

SangWook Park¹, ByeongWoo Kim², BeomJin Choi¹

¹ EMI/EMC R&D Center, Reliability & Safety R&D Division, Korea Automotive Technology Institute, Korea
² Department of Electrical Engineering, University of Ulsan, Korea

{parksw, bjchoi}@katech.re.kr
bywokim@ulsan.ac.kr

Abstract. This paper presents the dosimetry of a wireless power transfer (WPT) system using magnetically coupled high-resonance phenomenon under the misalignment condition. The power transfer efficiency is investigated in the misalignment between the transmitter and receiver, as well as in the alignment. Additionally, the power transfer efficiency at various misaligned distances is also investigated under matching and mismatching conditions. The numerical dosimetry for the alignment and misalignment cases under the matching condition is conducted with the simplified cylindrical human model. The results show that the specific absorption rates in the misalignment case are stronger than those in the alignment case.

Keywords: dosimetry, misalignment, specific absorption rate, wireless power transfer.

1 Introduction

The wireless power transfer (WPT) technique has been gradually receiving greater attention since the Massachusetts Institute of Technology (MIT) research team proposed the WPT technique using a magnetically coupled high-resonance phenomenon [1]. This technique is expected to be useful for various applications such as cellular phones, laptop computers, home electrical appliances, and electric vehicles. The WPT technique will bring convenience in daily life like wireless communications. However, the electromagnetic energies for the WPT are much stronger than those for wireless communications. Therefore, it is necessary to investigate electromagnetic compatibility (EMC) and safety for electromagnetic human exposure. Electric vehicle (EV) applications are expected to need significant power, which produces strong electric and magnetic fields. Thus, EMC and electromagnetic field (EMF) safety problems become more critical in EV applications.

The EMF safety of the WPT system is the focus of this work, and compliance of such a system to international EMF safety guidelines should be investigated [2]-[5]. Fundamental studies on the dosimetry of the WPT system were reported in references [6]-[8]. However, these studies did not take into account the misalignment between...
the transmitter and receiver and the matching condition. Misalignment often occurs in charging, and thus it should be investigated from the perspective of EMF safety. This paper reports the design of a WPT system using high-resonance phenomenon. Numerical dosimetry with the simplified cylindrical human model was conducted for the system under alignment and misalignment conditions between the transmitter and the receiver. The results for the alignment case are compared to those for the misalignment case.

2 WPT system and misalignment feature

![Fig. 1. WPT system: (a) alignment case and (b) misalignment case.](image)

A WPT system using electromagnetic resonance phenomenon, shown in Fig. 1 (a), was designed for charging electric vehicles. The WPT system consisted of two resonant coils and two loops. Spiral-type coils having five turns and a pitch of 5 mm were the resonators. The electromagnetic energies are efficiently transferred through these resonant coils. The loops acted as matching circuits. Both the coil radius and the power transfer distance of the WPT system were 150 mm. Copper wire with a radius of 2 mm was used for the system. A capacitance of 5 pF was added to the coil to achieve resonance at a 13.56 MHz frequency. The power transfer efficiency ($|S_{21}|^2$) was 98% in the alignment case. The misalignment case between transmitter and receiver, shown in Fig. 1 (b), was also investigated because misalignment often occurs when a car is parked for WPT charging. The power transfer efficiency in the misalignment case generally decreases without matching. However, a practical WPT system should be matched for power transfer efficiency. In this work, the power transfer efficiency was investigated with various misaligned distances ($m$) in the matching and mismatching conditions. The results are shown in Fig. 2. The efficiency
improvements were 83.6% at \( m = 250 \) mm. In the next section, the dosimetry for the WPT system in this misalignment case \( (m = 250 \) mm) will be conducted and compared to the alignment case.

![Image of power transfer efficiency comparison](image1)

**Fig. 2.** Power transfer efficiency comparison of WPT system with matching and without matching.

3 Dosimetry

![Image of cylindrical simplified human model position](image2)

**Fig. 3.** Cylindrical simplified human model position with respect to WPT system: (a) alignment and (b) misalignment.

Fig. 3 shows the cylindrical model position with respect to the WPT system. The SARs were calculated in the five different cases. The cylinder was 1700 mm high and had a diameter of 280 mm, similar to the size of an average human. The dielectric properties of the cylindrical model were set to be two-thirds that of muscle tissue, which represents the average dielectric properties of the human body. The electrical properties of muscle tissue were taken from Gabriel’s Cole–Cole models [9]. The localized SAR (SAR10g) and whole-body SAR (SARwb) for the five cases are shown in Fig. 4. The results show that the SARs of the misalignment cases are larger than the
SAR of the alignment case. This is because the electric and magnetic fields are strongly distributed over a large area in the misalignment case to achieve the best power transfer efficiency. The maximum allowable powers (MAPs) to comply with the ICNIRP guideline are shown in Fig. 5 for the five cases. The results show that the MAPs for the misalignment cases are lower than the MAP for the alignment case. These results suggest that we should consider the misalignment condition of the WPT system when conducting exposure assessment.

Fig. 4. Localized SAR and whole-body SAR for alignment (case1) and misalignment cases (case2-5).

Fig. 5. Maximum allowable powers to comply with the ICNIRP guideline for five different cases.
4 Conclusion

Dosimetry was conducted for WPT under conditions of alignment and misalignment between transmitter and receiver. The SARs in the misalignment condition were higher than that in the alignment condition. The dosimetric results of the WPT system indicated that the worst case for exposure generally occurred in the misalignment case. Therefore, dosimetry for the WPT system should be conducted in the misalignment case, as well as the alignment case. In future works, dosimetry will be conducted with a precise whole-body voxel human model based on anatomical structures.

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References