Effect of Nearby Human Body on WPT System

Qiaowei Yuan*, Qiang Chen†, and Kunio Sawaya†
*Sendai National College of Technology, Japan
†Tohoku University, Japan

***Abstract*—Based on the transmitting efficiency of WPT system calculated by using s-parameters when the WPT system is equivalent to a 2-ports lossy network [1], the effects of human body on the transmitting efficiency of WPT system with three different transmitting/receiving elements are further investigated in this paper. It is found that the WPT system using the element consisting of loop and a parasitic helical, resonant element in other words, can prevent the reduction in the transmitting efficiency from the human body, thus it is an efficient and safe choice to us a loop with a parasitic helical as the transmitting/receiving element.**

I. Introduction

Wireless power transmitting (WPT) is interested again because of its potential application to charge laptops, cellphones, household robots, MP3 players and other portable electronics without cords [1]-[6]. The optimum load for maximum transmitting efficiency of WPT system was presented when the WPT system was equivalent to a 2-ports lossy network in [5] by present authors. The maximum transmitting efficiency of WPT system with resonant transmitting/receiving elements and non-resonant transmitting/receiving elements have been analyzed and compared in [1]. It has been observed that the resonant characteristic of transmitting/receiving elements gives little impact on the maximum transmitting efficiency when the receiving element is close to the transmitting element, but affects the maximum transmitting efficiency greatly when the receiving element is far from the transmitting element. In this report, the effects of human body on WPT system with three different transmitting/receiving elements will be further investigated, and then to discuss the safety for human bodies when WPT is near to the human bodies.

II. Three WPT systems

Three WPT systems used in this report are shown in Fig. 1. In type-A, a square loop D with a side length of 30 cm is used as the transmitting element and receiving element; In type-B, the same square loop D as type-A loaded with a 210 nF inductor is used as the transmitting element and receiving element; In type-C, the same square loop D with a parasitic square helical coil C is used as the transmitting element and receiving element; All transmitting or receiving elements are made of copper wire with the conductivity of $\sigma = 5.8 \times 10^7$ [S/m]. The radius of all wires are 2 mm. The input impedances of three types of elements which are used in the above three WPT systems are compared in Fig. 2. It is found that element in type-A system does not resonate at the concerned frequency range, while the element used in type-B gets antiresonance and that used in type-C gets resonance at a frequency of 19.2MHz, respectively. Frequency of 19.2MHz will be regarded as the operating frequency in this paper.

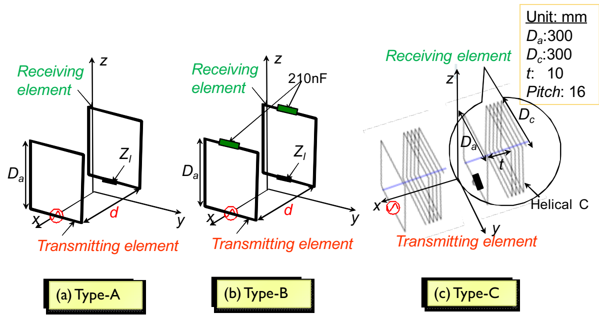

Fig. 1. Three types of WPT systems.

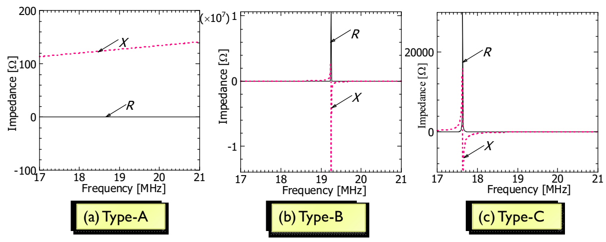

Fig. 2. Input impedances of three types of transmitting elements.

III. Efficiencies of WPT Systems calculated by using S parameters

The transmitting efficiencies of three WPT systems when the loads are satisfied with their matching condition respectively are shown in Figs. 3, 4,,where all s-parameters are calculated by FEKO soft and the transmitting efficiency is calculated by using

$$\eta = \frac{|s_{21}|\left(1 - |\Gamma_l|^2\right)}{|1 - s_{22}\Gamma_l|^2\left(1 - |\Gamma_{in}|^2\right)}. \tag{1}$$

where, Γ_l is the reflection coefficient related with the load impedance Z_l and defined as

$$\Gamma_l = \frac{Z_l - Z_0}{Z_l + Z_0}, \tag{2}$$

and Γ_{in} is the reflection coefficient at the input port, calculated by

$$\Gamma_{in} = s_{11} + \frac{s_{12}s_{21}\Gamma_l}{1 - s_{22}\Gamma_l}. \tag{3}$$

From Figs. 3, 4, it can be found that, no matter how the resonance situation the transmitting/receiving element of the WPT system is, all of the maximum transmitting efficiencies of three WPT systems are greater than 90% when the distance d between transmitting element and receiving element is equivalent to 10 cm. However, when the distance d is increased to 30 cm, the transmitting efficiency of type-A and type-B drop to about 25%, 18%, respectively. It was explained in **??** that the WPT system using the type-C as transmitting/receiving elements has less reflected power at the transmitting port.

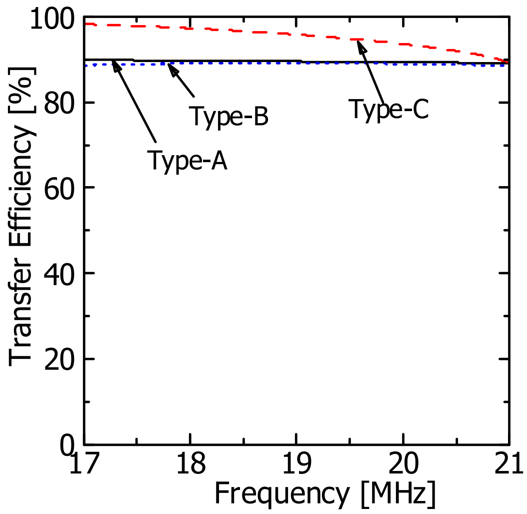

Fig. 3. Transmitting efficiency of three WPT systems (d=0.1cm).

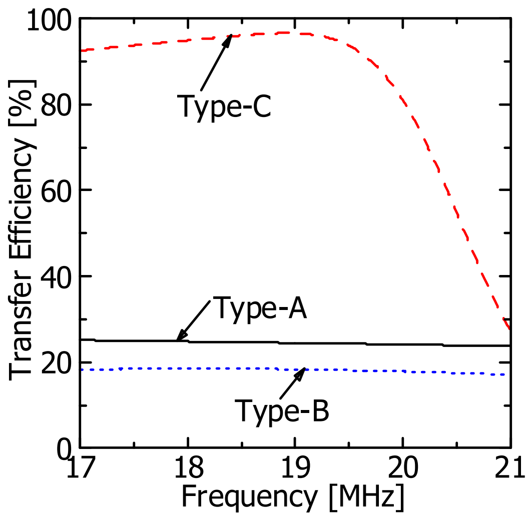

Fig. 4. Transmitting efficiency of three WPT systems (d=0.3cm).

IV. Effect o f human body on Efficiencies of WPT Systems calculated by using S parameters

As shown in Fig. 5, the human body has, for simplicity, been modeled as a rectangular dielectric box with a size of 0.5 m × 0.2 m × 1.7 m. The distance between the center of the human body and the center of the receiving element in the y direction is denoted by s. Muscle-type dielectric material with a relative dielectric constant of 107.2 and conductivity of 0.67 [S/m] which are based on the body tissue dielectric parameters published by FCC is used to represent the human body approximately. Moreover, a perfect conducting box with the same size of the human body is used for comparison.

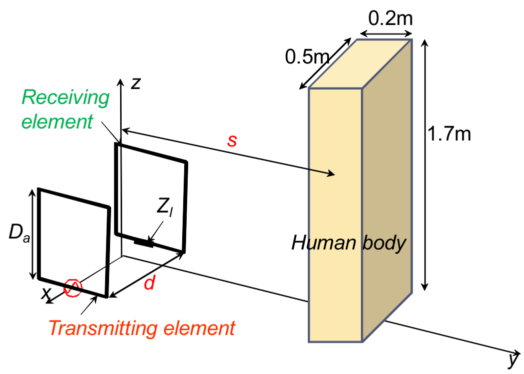

Fig. 5. WPT system near to human body.

The power transmission efficiencies of the WPT systems near to different kinds of human bodies are compared in Figs.6-9. In Figs. 6, 8, the distance d between transmitting element and receiving element is 0.1 m, while the distance d in Figs.7, 9 is 0.3m. Figs. 6, 7 are the transmitting efficiencies when a perfect conducting human body model is used, Figs. 8, 9 are the transmitting efficiencies when a muscle-type human body box is used. From the Figs. 6- 9, it is observed that power transmitting efficiency is reduced when a human body is near to the WPT system, particularly when the WPT system using type-A or type-B transmitting/receiving element. The reduction caused by the existence of the conducting box is more serious than that caused by the existence of the muscle-type human body. However, it is also observed that the reduction caused by the conducting box or the muscle type human body is very small in the WPT system using type-C transmitting/receiving element. It can be explained that the near magnetic field surrounding the type-C transmitting/receiving element is much stronger than that of type-B or type-C as shown in Figs. 10-12.

V. Conclusions

The effects of human body on the transmitting efficiency of WPT system with three different transmitting/receiving elements have been investigated in this paper. It has been found that the WPT system using the element consisting of loop and a parasitic helical can prevent the reduction in the transmitting efficiency from the human body, thus it is more efficient and safe choice to us a loop with a parasitic helical as the transmitting/receiving element.

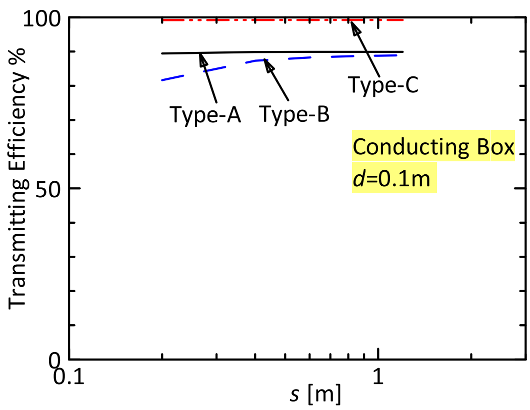

Fig. 6. Transmitting efficiency of WPT with a conducting box (*d*=0.1m).

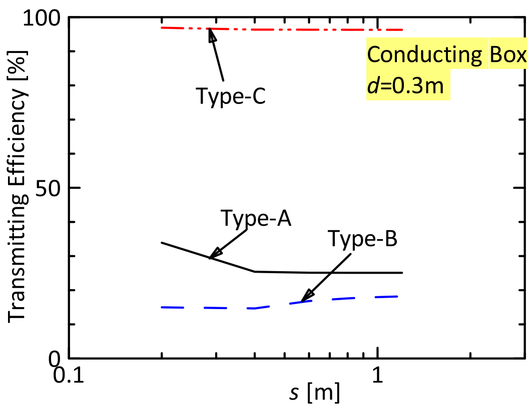

Fig. 7. Transmitting efficiency of WPT with a conducting box (*d*=0.3m).

REFERENCES

[1] Q. Yuan, Q. Chen, and K. Sawaya, "Maximum transmitting efficiency of wireless power transfer system with resonant/non-resonant transmitting/receiving elements," *Proc. 2010 IEEE Antennas and Propagation Society International Symposium*, p. 521.6, Toronto, Canada, July 2010.

[2] Kurs, Aristeidis Karakis, Robert Moffatt, J. D. Joannopoulos, Peter Fisher, Marin Soljacic,"Wireless Power transmission via Strongly Coupled Magnetic Resonances," *SCIENCE*, Vol.317, pp. 83-86, July 2007.

[3] Y. Noguchi, S. Nakano, Y. Kato, T. Sakurai and T. Someya, "A large-area wireless power-transmission sheet using printed organic transistors and plastic MEMS switches," *Nature materials*, Vol. 6, pp. 413-417, June 2007.

[4] Aristeidis Karalis, J.D. Joannopoulos, and Marin Soljacic, "Efficient wireless non-radiative mid-range energy transfer," *Annels Physics*, 323(2008), pp.34-48.

[5] Q. Yuan, Q. Chen, and K. Sawaya, "Numerical Analysis on Transmission Efficiency of Evanescent Resonant Coupling Wireless Power Transfer System," *IEEE Transactions on Antennas and Propagation*, vol. 58, no. 5, pp. 1751 - 1758, May 2010.

[6] Qiaowei Yuan, Qiang Chen and Kunio Sawaya, "Effect of Human Body on Near-Field Resonant Coupling Wireless Power Transmission System," *Proceedings Of the 2009 International Symposium on EMC*, Kyoto, 21Q1-1, pp.25 -28, Japan, July, 2009.

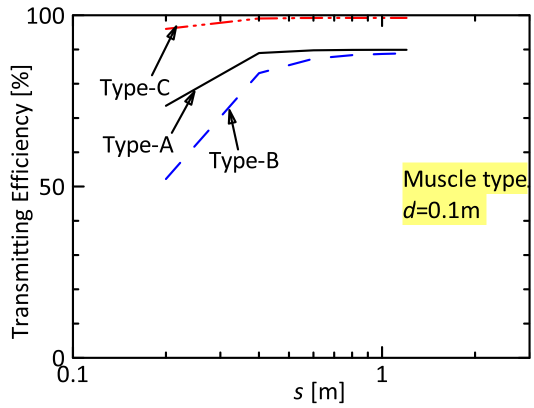

Fig. 8. Transmitting efficiency of WPT with a muscle body (*d*=0.1cm).

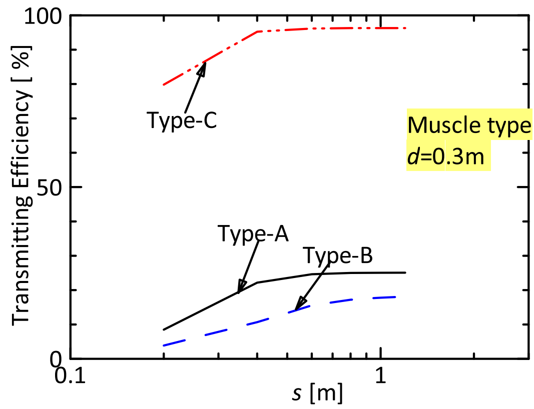

Fig. 9. Transmitting efficiency of WPT with a muscle body (*d*=0.3m).

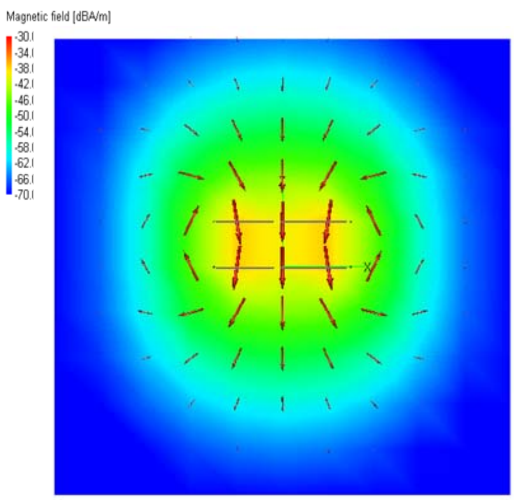

Fig. 10. Near field of type-A.

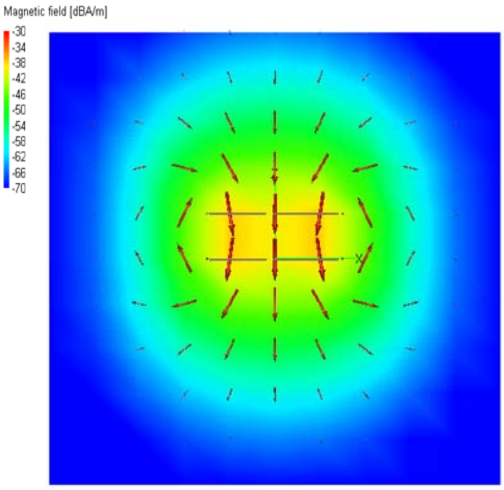

Fig. 11. Near field of type-B.

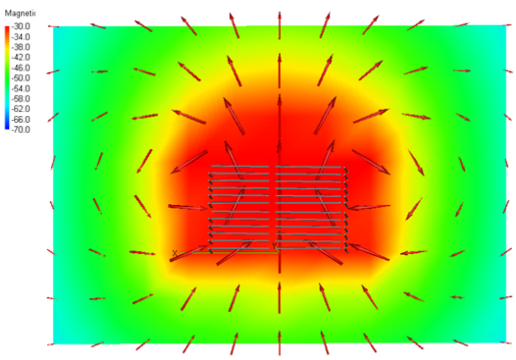

Fig. 12. Near field of type-C.