Improvement of Transmission Efficiency using Shielded-Loop Antenna for Wireless Power Transfer

Naoya Kajiura, Hiroshi Hirayama
Nagoya Institute of Technology, Gokiso-cho, Showa-ku, Nagoya, 466-8555 Japan
E-mail: hirayama@m.ieice.org

***Abstract* – Coupled-resonant wireless power transfer (WPT) using shielded loop antenna for high-efficiency transmission is proposed. Transmission efficiency is determined by the coupling coefficient *k* and the Q factor. Coupling coefficient *k* is determined by the difference between the magnetic- and the electric- field coupling coefficient. By using the shielded-loop structure, electric field coupling is suppressed to improve transmission efficiency. Numerical simulation verified that transmission distance over 80% efficiency is extend 2.8 times by using the shielded-loop antenna.**

***Index Terms* — Wireless power transfer, Shielded-loop antenna, Coupling coefficient.**

1. Introduction

Coupled-resonant wireless power transfer is required higher transmission efficiency for practical use [1]. Transmission efficiency is determined by the coupling coefficient *k* and the Q factor [2]. Coupling coefficient between the resonators is determined by the difference between the magnetic field coupling coefficient and the electric field coupling coefficient [3]. Therefore, for the magnetic coupling WPT system, transmission efficiency is able to be improved by suppressing electric field coupling.

Shielded-loop antenna is widely used as a magnetic field sensor because of its electric field suppression effect [4]. In this report, we propose wireless power transfer using shielded loop antenna. Transmission efficiency is improved by this structure.

2. Simulation Model

A structure of a conventional loop antenna is shown in Fig. 1. Since this loop structure acts as an inductor, a resonant capacitor is loaded.

A structure of a shielded-loop antenna is shown in Fig. 2. This structure is made from a coaxial cable. Both the inner and the outer conductors are grounded at the end of the coaxial cable. There is a gap in a part of the outer conductor so that the current does not flow on the outer conductor. Sensitivity to electric field components is suppressed by the outer conductor.

A simulation model is shown in Fig. 3. The conventional loop antenna or the shielded loop antenna is used in this model. Transmitting (Tx) loop has the port 1. Receiving (Rx) loop has the port 2.

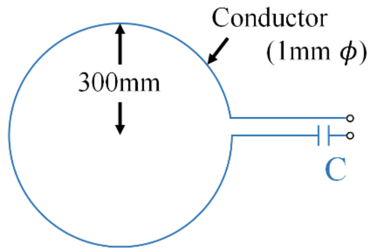


Fig.1. Conventional loop antenna

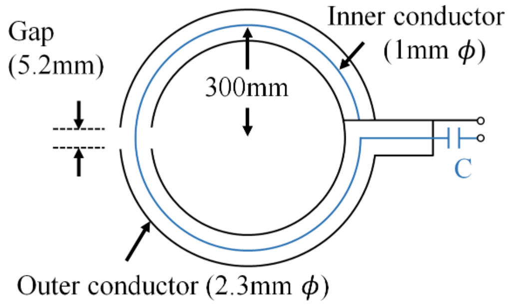


Fig.2. Shielded-loop antenna

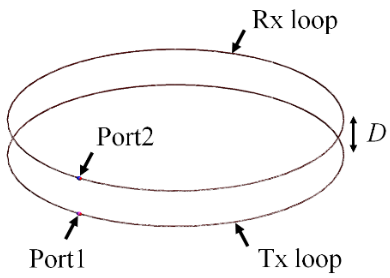
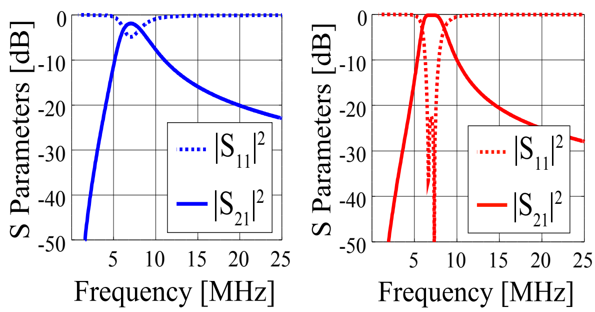


Fig.3. Simulation model



(a) Conventional loop (b) Shielded loop

Fig.4. S paramaters

Capacitance of the resonant capacitor is determined so that the resonant frequency becomes 6.78 MHz. Conductivity of copper is assumed.

3. S Parameters

The S parameters of the conventional loop antenna and the shielded-loop antenna are shown in Fig. 4(a) and (b), respectively. In this calculation, transmission distance D is set to 7 cm.

Value of S_{21} at the resonant frequency is improved from –1.88 dB to –0.132dB by using shielded loop. Additionally, frequency split in S_{11} is observed only in the shielded loop antenna. From these result, it is considered that coupling between the antennas become stronger by the shield loop structure.

4. Transfer Distance Characteristics of S_{21}

The distance characteristics of S_{21} at the resonant frequency are shown in Fig. 5. In the conventional loop antenna, transmission efficiency falls at the transmission distance of 2.1cm. In contrast, the shielded-loop antenna maintains transmission efficiency until the transmission distance of 8.9cm. Distance over 80% transmission efficiency extends 2.8 times by using the shielded structure.

5. Near Field Distribution

The electric field distribution and the magnetic field distribution are shown in Fig. 6 and 7, respectively. The transmission distance D is set to 7 cm.

Electric field distribution is considerably suppressed by the shield loop antenna. Whereas magnetic field distribution is not affected by the shield loop antenna.

In order to investigate the electric field suppression effect, spatial impedance is calculated. The spatial impedance ζ is obtained as

$$\zeta = 20\log_{10}\left(\frac{|\mathbf{E}|}{\eta_0|\mathbf{H}|}\right). \qquad (1)$$

The spatial impedance ζ is shown in Fig. 8. It can be seen that the shielded loop antenna has smaller spatial impedance than the conventional loop antenna, which means that the electric field component was suppressed by the shielded structure.

6. Conclusion

The shielded loop antenna in order to suppress electric field coupling to improve transmission efficiency was discussed. Numerical simulation verified that the transmission distance over 80% efficiency becomes 2.8 times.

Experimental variation is further study.

Acknowledgment

This work was supported by JSPS KAKENHI Grant-in-Aid for Scientific Research(c) Number 15K06061.

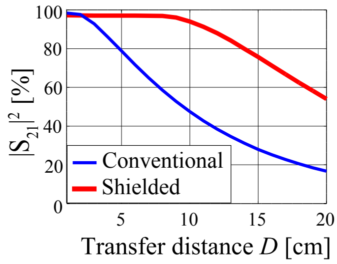
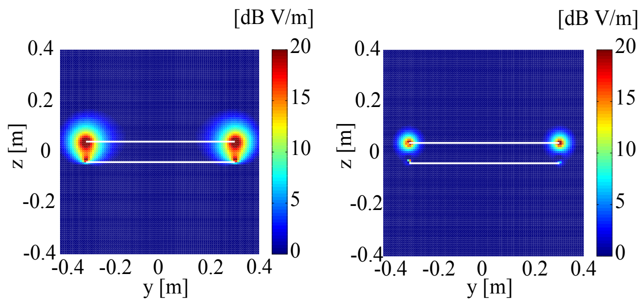
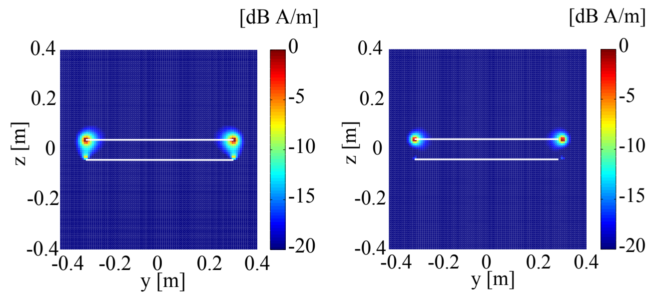


Fig.5. $|S_{21}|^2$ vs transfer distance



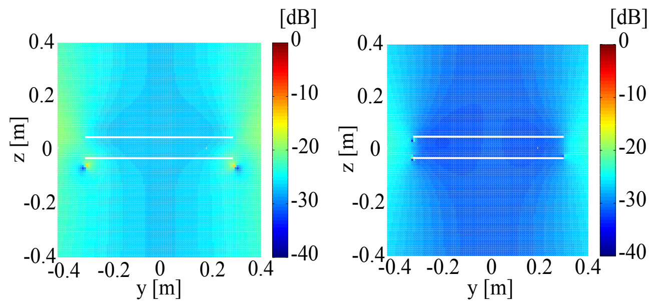
(a) Conventional loop (b) Shielded loop

Fig.6. Electric field distribution



(a) Conventional loop (b) Shielded loop

Fig.7. Magnetic field distribution



(a) Conventional loop (b) Shielded loop

Fig.8. Spatial impedance distribution

References

[1] A. Kurs, A. Karalis, R. Moffatt, J. joannpoulos, P. Fisher, M. Soljacic, "Wireless Power Transfer via Strongly Coupled Magnetic Resonances," Science Express, Vol. 317, No. 5834, pp. 83-86, July 2007.

[2] T. Ohira, "Extended k-Q product formulas for capacitive- and inductive-coupling wireless power transfer schemes," IEICE Electronics Express, Vol. 11, No.9, pp. 1-7, May 2014.

[3] I. Awai, "New Expressions for Coupling Coefficient between Resonators," IEICE Trans. Elec., Vol.E88-C, No.12, pp. 2295-2301, Dec. 2005.

[4] H. Hirayama, N. Kikuma, K. Sakakibara, "An Estimation Method of Poynting Vector with Near-Magnetic-Field Measurement," IEICE Trans. on Elec. Vol.E93-C, No. 1, pp.66-73, Jan. 2010.