Effectiveness of Transmitting Cross Coil Stacked with Arrayed Coils in Wireless Power Transfer with Magnetically Coupled Resonance

Kazunari Mase†, Nobuyoshi Kikuma‡, and Kunio Sakakibara‡
†Dept. of Computer Science and Engineering
‡Dept. of Electrical and Mechanical Engineering
Nagoya Institute of Technology, Nagoya 466-8555, Japan
Email: kikuma@m.ieice.org

***Abstract* – This paper proposes a novel antenna configuration for wireless power transfer system with magnetically coupled resonance. The computer analysis shows high transmitting efficiency with wider receiving area of the proposed antenna.**

***Index Terms* — Wireless power transfer, Magnetically coupled resonance, Cross coil, Stacked coil array**

1. Introduction

One of the problems in the wireless power transfer (WPT) with magnetically coupled resonance is a decrease in transmitting efficiency due to misalignment of the receiving coil to the transmitting coil. In this paper, we attempt to obtain high transmitting efficiency which does not depend on the position of the receiving coil in the transmitting coil area.

For the purpose, we propose here the use of the cross coil [1] stacked with square coils arrayed on a plane (CSA) [2], [3], and the transmitting efficiency is analyzed with the electromagnetic field simulator based on the Method of Moments (MoM). Specifically, we examine the transmitting efficiency corresponding to the position of the receiving coil in order to show the effectiveness of using the proposed transmitting coils.

2. Analytical Model

First, the conventional cross model and the proposed CSA model for the WPT system with magnetically coupled resonance are shown in Figs. 1 and 2, respectively. Both models have the transmitting coil which is composed of a cross-shaped loop coil [1] of one turn as depicted in Figs. 1 and 2, and also the transmitting coil of CSA model is stacked with 4 square coils arrayed on a plane as shown in Fig. 2. Each receiving coil (Rx) is a square-shaped loop coil of two turns and of 500 mm length on a side. The wire of coil is made of copper, and has a thickness of 40 mm and a section radius of 1 mm.

In Fig. 1, the transmitting coil (Tx) of cross model is 1000 mm long on a side and has cross width of 3.5 mm, and has the tuning capacitor. At the terminal Port 1 of the transmitting coil (Tx), the voltage generator (1 V, 50 Ω) and the tuning capacitor are loaded in series. At the terminal Port 6 of the receiving coil (Rx), the resistance of 50 Ω and the tuning capacitor are loaded in series. Those capacitances of the tuning capacitors are determined to resonate at 10 MHz.

The transmitting coil Tx1 of CSA model in Fig. 2 has the same form as the transmitting coil (Tx) of cross model in Fig. 1. The arrayed 4 transmitting coils Tx2, Tx3, Tx4, and Tx5 of CSA model have the same form as the receiving coil (Rx), which are 470 mm long on a side. Transmitting coils Tx2 to Tx5 are placed at the position of 40 mm above Tx1, and the gap between the adjacent transmitting coils Tx2 to Tx5 is 60 mm. At the terminal Port 1 of the transmitting coil Tx1, the voltage generator (1 V, 50 Ω) and the tuning capacitor are loaded in series. At the terminals Port 2 to Port 5 of the transmitting coils Tx2 to Tx5, only the tuning capacitors are loaded. It means that the transmitting coils Tx2 to Tx5 operate as parasitic elements. Those capacitances of the tuning capacitors are determined to resonate at 10 MHz in each of the transmitting coil. At the terminal Port 6 of the receiving coil (Rx), the load of 50 Ω and the tuning capacitor is loaded in series. In this paper, the capacitance of the tuning capacitor of Port 6 (Rx) in CSA model is determined to resonate at 9.04 MHz in the receiving coil.

3. Analysis Results

First, we analyze the distance characteristics of the transmitting efficiency in the *z*-axis direction in Figs. 1 and 2 when the receiving coil (Rx) is placed at center of point A in Fig. 3. The distance characteristics obtained are shown in Fig. 3, where the horizontal axis is the distance D between transmitting coil and receiving coil and the vertical axis is the transmitting efficiency (S_{61}). The distance D is varied from 50 mm to 1050 mm. From Fig. 3, it is found that the maximum transmitting distance of CSA model is longer than that of cross model by 20 % when the value of the transmitting efficiency is 80 % .

Next, we analyze the position characteristics of the transmitting efficiency in the *xy*-plane designated in Figs. 1 and 2. The position characteristics obtained are shown in Figs. 4 and 5, where the horizontal and vertical axes are the position x and y and the color bar represents the transmitting efficiency. The distance D is 300 mm and the position x and y are varied from −500 mm to 500 mm, where the black circle shows the area of 80 % or more in the transmitting efficiency in Figs. 4 and 5. Comparing the cross model in Fig. 4 with the CSA model in Fig. 5, we can see that the receiving area of CSA model is wider than that of cross model by 30 % when the value of the transmitting efficiency is 80 % or more.

4. Conclusions

In this paper, we have examined the transmitting efficiency of the transmitting cross coil which is stacked with 4 square coils arrayed on a plane in the WPT system with magnetically coupled resonance. From the results of computer analysis, it is confirmed that the CSA magnifies significantly the effective receiving area where the transmitting efficiency is 80 % or more compared to the conventional cross coil which has the same size as the CSA. In future works, we will verify the performance of the CSA with the actual model.

References

[1] Masafumi Kadoi, Nobuyoshi Kikuma, Hiroshi Hirayama, and Kunio Sakakibara,“A consider of antenna shape for enhancing transfer efficiency in wireless power transfer with magnetically coupled resonance,” *IEICE General Conference*, B-1-7, Mar. 2011.

[2] Bingnan Wang, Koon Hoo Teo, Satoshi Yamaguchi, Toru Takahashi, Yoshihiko Konishi,“Flexible and mobile near-field wireless power transfer using an array of resonators,” *IEICE General Conference*, WPT2011-16, Oct. 2011.

[3] Keishi Miwa, Nobuyoshi Kikuma, Hiroshi Hirayama, and Kunio Sakakibara,“A consideration of efficiency improvement of transmitting coil array in wireless power transfer with magnetically coupled resonance,” *IEICE General Conference*, BCS-1-14, Mar. 2013.

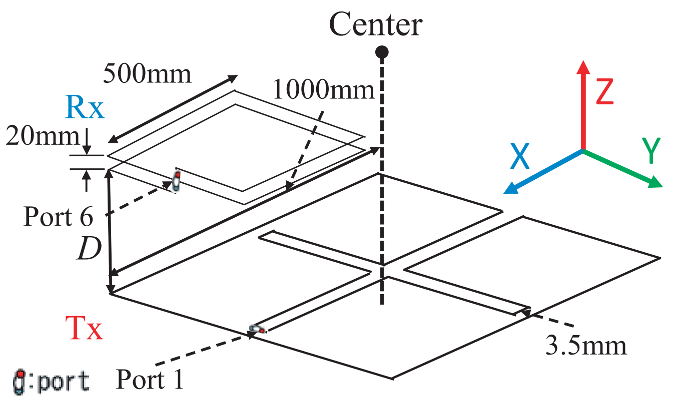

Fig. 1. Cross model (conventional)

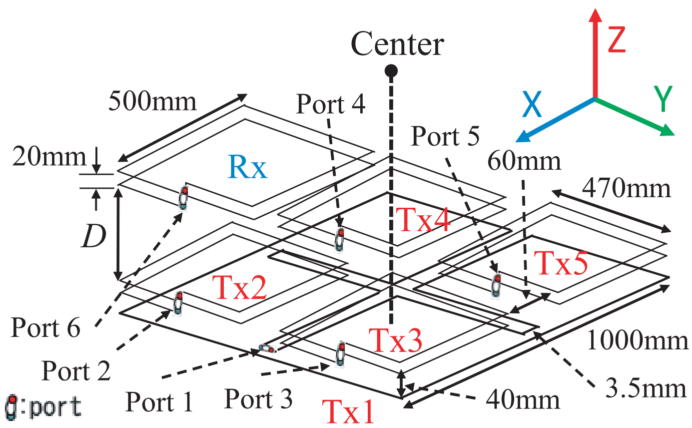

Fig. 2. CSA model (proposed)

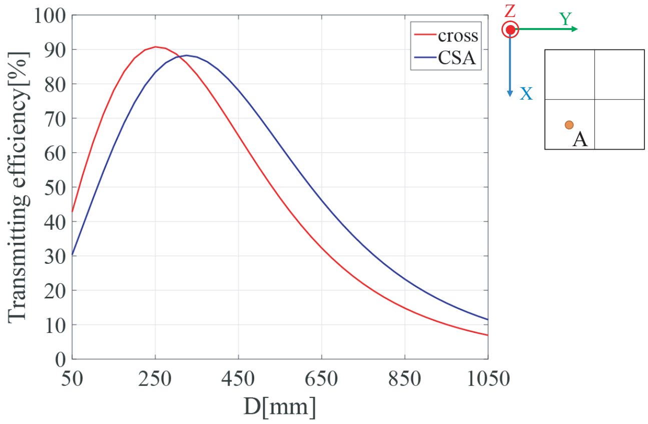

Fig. 3. Transmitting efficiency vs. distance D between Tx and Rx

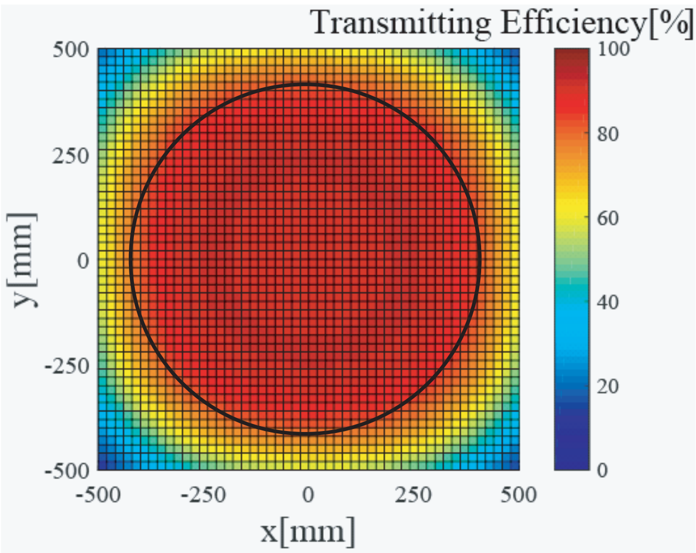

Fig. 4. Transmitting efficiency according to receiving position in cross model

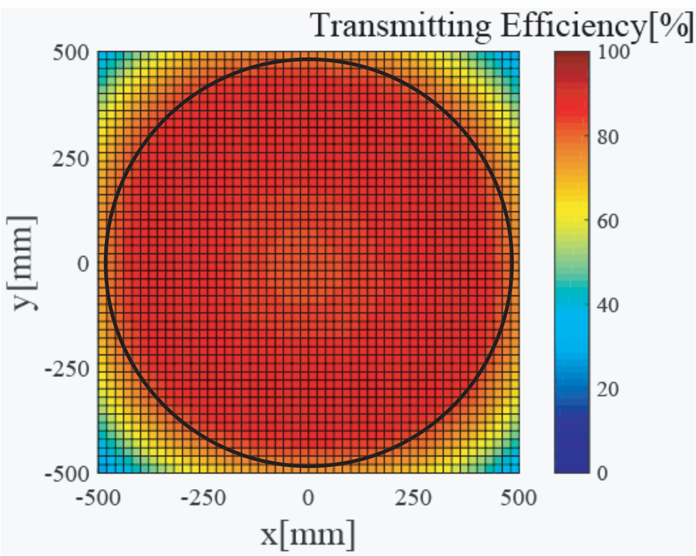

Fig. 5. Transmitting efficiency according to receiving position in CSA model