A Consideration of Antenna Configuration for Its Size Reduction in Wireless Power Transfer with Magnetically Coupled Resonance

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Abstract

This paper proposes a novel antenna configuration for wireless power transfer system. The computer analysis shows high transmission efficiency and effective size reduction of proposed antennas.

Keywords: wireless power transfer, magnetically coupled resonance, size reduction of antenna

1. Introduction

Recently, the technology of supplying the electric power by the wireless attracts our attention for use in household electric appliances and the electric vehicles. Moreover, the size reduction of the electric equipment is in great demand. Therefore, it is also necessary to downsize the wireless power transmission system for the practical use in the electric equipment.

In this paper, we attempt to reduce the size of the antennas used for the wireless power transmission system with magnetically coupled resonance, and for the purpose we propose here a novel configuration of antenna. In addition, the transmission efficiency when using the proposed antenna is analyzed with an electromagnetic field simulator (MoM), and we show through the evaluation the effectiveness of using the proposed antenna for the size reduction of the wireless power transmission system.

2. Reference Model and Proposed Model

First, as a reference, the conventional model of the wireless power transmission system (operating frequency: 10MHz) is shown in Fig.1. The reference model has the same form of antennas in both transmitting and receiving, each of which is a square wire loop of one square meter. Next, the proposed model is shown in Fig.2. The proposed model also has the same form in both transmitting and receiving, and each antenna is a folded wire loop which is placed within the square of one square meter. The size of the folded wire antenna is investigated in this paper.

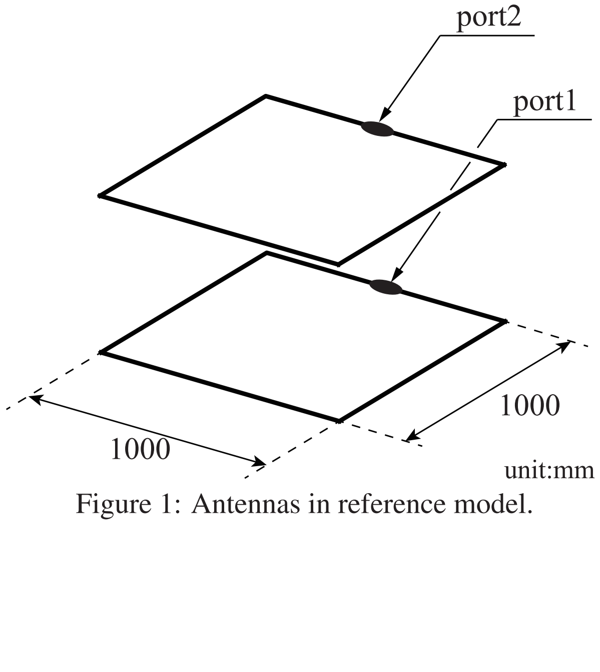

Figure 1: Antennas in reference model.

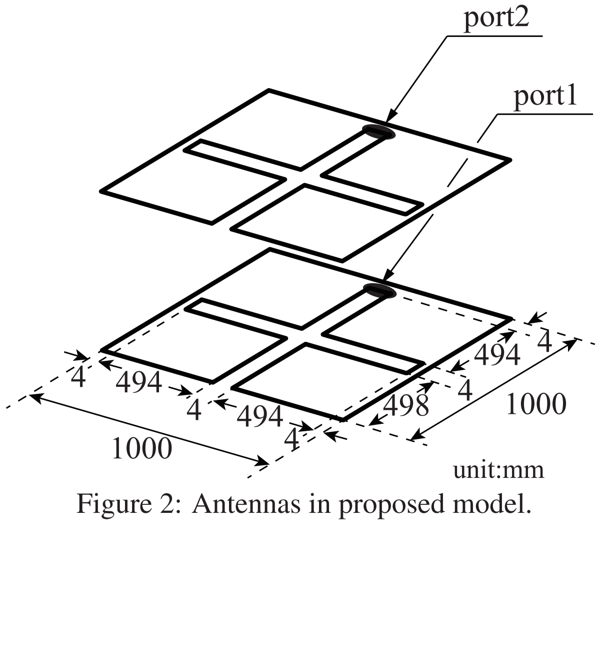

Figure 2: Antennas in proposed model.

It is noted that the total wire length of each antenna in both models is very small compared with a wavelength of operating frequency (30m). In the situation, Figure 3 shows the current flow on the wire antenna in the proposed model. As shown in Fig.3, we can see the antenna is composed of four small loops whose current flow directions are the same. It is an important characteristic of the proposed model, and as a whole the current flow direction of the proposed antenna is almost the same as the reference one.

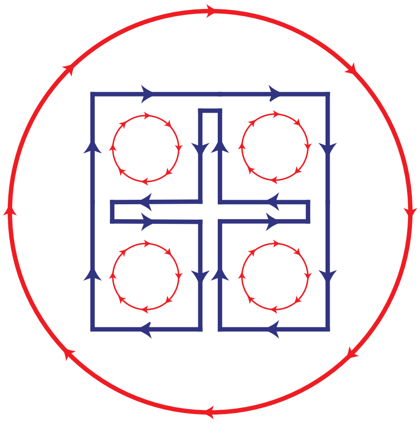

Figure 3: Current flow on the wire loop in the proposed model.

In the magnetically coupled resonance, each of transmitting and receiving antennas works as a resonator of the same frequency. At the terminal (port1) of the transmitting antenna, the voltage generator (1V) and the tuning capacitor are connected in series through the transmission line of characteristic impedance Z_0=50Ω. At the terminal (port2) of the receiving antenna, on the other hand, the load Z_l=50Ω and the tuning capacitor are connected in series through the transmission line of characteristic impedance Z_0=50Ω. The capacitances of the tuning capacitors are determined to resonate at 10MHz in each of the transmitting and receiving antennas [1]. The parameters in the reference and proposed models are described in Tables 1 and 2, respectively.

Table 1: Parameters in reference model.

Size of antenna	1 m^2
Radius of wire	0.5 mm
Tuning capacitor	48.48 pF

Table 2: Parameters in proposed model.

Size of antenna	1 m^2
Radius of wire	0.5 mm
Tuning capacitor	20.94 pF

3. Performance Analysis by Computer Simulation

For the analysis, we used the Method of Moment (FEKO). The simulation conditions are shown in Table 1.

Table 3: Computer simulation conditions.

Characteristic Impedance	50 Ω
Wire Material	
Relative permeability	0.999991
Magnetic loss tangent	0
Conductivity	5.96×10^8
Voltage Source	
Voltage	1 V
Frequency	10 MHz

The positions of the transmitting and receiving antennas are depicted in Fig.4. The displacement of the transmission antenna to the receiving antenna is assumed to be (dx, dy, dz) in (x, y, z) coordinates.

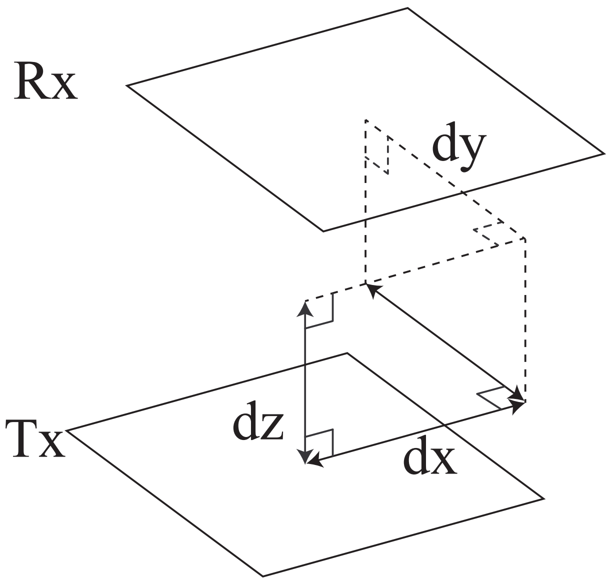

Figure 4: Positions of transmitting and receiving antennas.

First, we examined dx-dz characteristics of the transmission efficiency to know the transmission distance and the displacement between the transmitting and receiving antennas. It is assumed dy=0. The transmission efficiency of the reference model is shown in Fig.5, and that of proposed model is shown in Fig.6. From comparison between Figs.5 and 6, it can be confirmed that the transmission distance of the proposed model is about four times longer than that of the reference model.

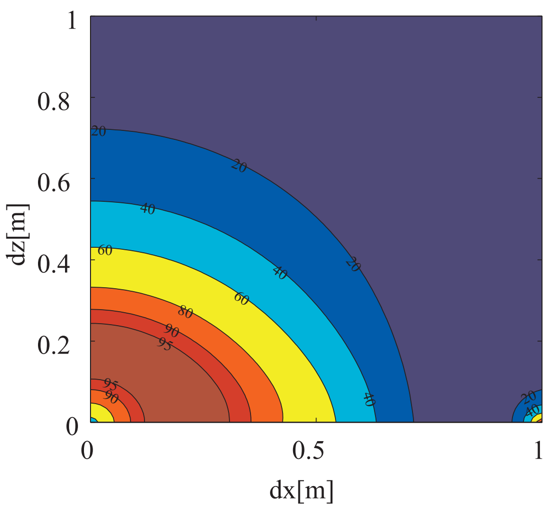

Figure 5: Transmission efficiency in dx-dz plane of reference model.

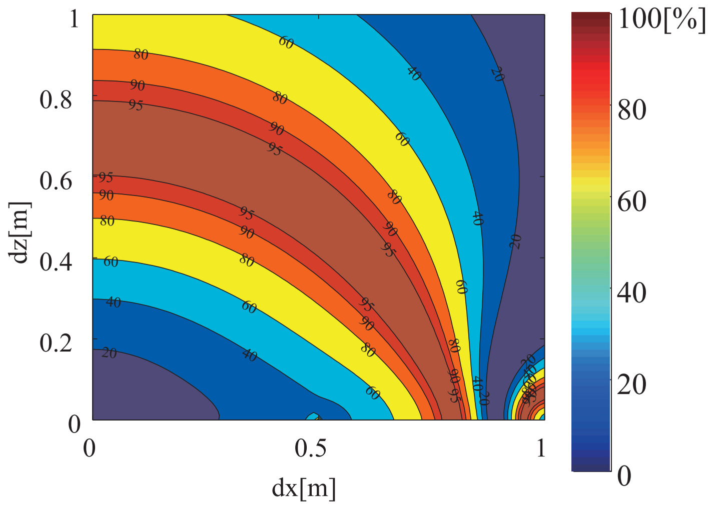

Figure 6: Transmission efficiency in dx-dz plane of proposed model (same size).

Next, we examined how much the size of the antenna in proposed model is reduced when the transmission distance of the proposed model is equal to that of the reference model. The transmission efficiency in *dx*-*dz* plane of the reference model is shown in Fig.7, while that of proposed model is shown in Fig.8. In this conditions, the size of reference model is 1m^2, and that of proposed model is 0.49m^2. From the results, it is found that the proposed model can achieve the size reduction of about 51%.

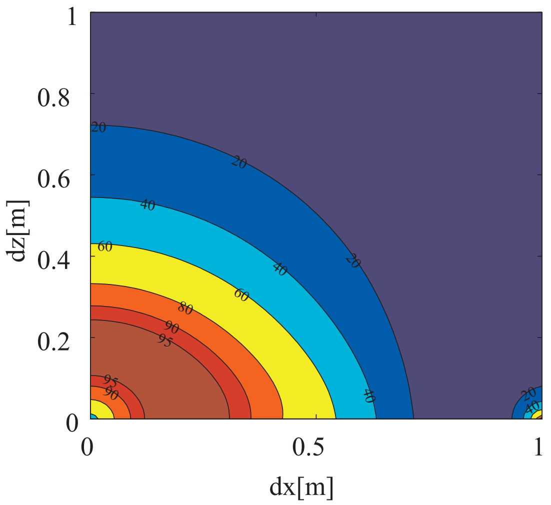

Figure 7: Transmission efficiency in *dx*-*dz* plane of reference model.

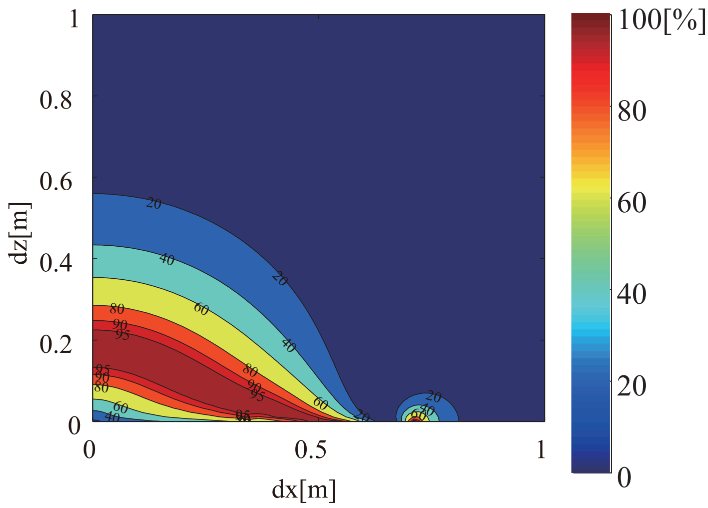

Figure 8: Transmission efficiency in *dx*-*dz* plane of proposed model (same distance).

4. Conclusions

In this paper, we have proposed a novel configuration of antenna to downsize the antennas used for the wireless electric power transmission system. From the results of computer analysis, it can be confirmed that the transmitting distance of the proposed model is about four times longer than that of reference model when the proposed and reference antennas have the same size. In addition, we can see that the area of the antenna of the proposed model is about 51% smaller than that of reference model when the proposed and reference antennas have the same transmission distance. Thus, it has been shown that we can accomplish significantly the size reduction of antennas.

References

[1] Yosuke Hiraiwa, Nobuyoshi Kikuma, Hiroshi Hirayama, and Kunio Sakakibara, "A Consideration on Transmission Efficiency Characteristics of Wireless Power Transmission Using Proximity Coils," IEICE Technical Report, AP2009-86, pp.41-46, Sep. 2009.

[2] Masafumi Kadoi, Nobuyoshi Kikuma, Hiroshi Hirayama, and Kunio Sakakibara, "A Study on Antenna Shape for Electro-Magnetic Resonant Type Wireless Power Transmission System," 2010 IEICE Society Conference, B-1-11, Sept. 2010.

[3] Masafumi Kadoi, Nobuyoshi Kikuma, Hiroshi Hirayama, and Kunio Sakakibara, "A Consideration of Antenna Shape for Enhancing Transfer Efficiency in Wireless Power Transfer with Magnetically Coupled Resonance," 2011 IEICE General Conference, B-1-7, Mar. 2011.

[4] Ikuo Awai and Zhang Yangjun, "Coupling Coefficient of Resonators: An Intuitive Way of Its Understanding," Trans. of IEICE, Vol.J89-C, No.12, pp.962–968, Dec. 2006.