Impedance Matching using Folded Spiral Antenna for Coupled-resonant Wireless Power Transfer

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Abstract **– Folded spiral antenna for wireless power transfer (WPT) is prosed. In order to realize maximum available efficiency, impedance matching should be achieved. It is known that the folded dipole antennas has a capability of adjusting input impedance by using two conductors with different diameters. The folded spiral antenna proposed in this report is based on self-resonant spiral antenna, that has folded structure with different diameter conductors. By using the proposed structure, maximum available efficiency is achieved without using a matching circuit. Numerical simulation demonstrates that by using the proposed structure, transfer distance over 80% efficiency extends 3.3 times.**

Index Terms **— Wireless power transfer, Coupled resonance, Impedance matching, Folded antenna.**

1. Introduction

Coupled-resonant WPT technology [1] is getting large interests for charge of mobile devices and electric cars. Impedance matching is necessary to realize maximum available efficiency [2].

A folded dipole antenna [3] is widely used in far field communication systems because of its capability of adjusting an input impedance. We have been studied a spiral antenna for WPT system [4]. In this report, we propose a folded spiral antenna for near field WPT system. Numerical simulation shows that the folded spiral antenna has capability of achieving maximum available efficiency without using a matching circuit.

2. Operating principle

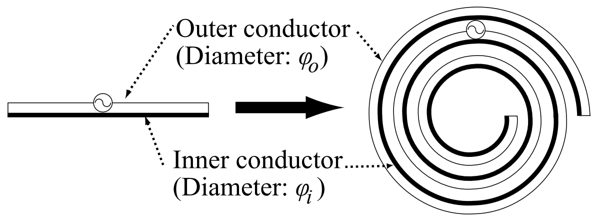
Basic principle of the proposed structure is shown in Fig. 1. Fig. 1(a) is a folded dipole antenna with different diameter conductor. By adjusting a diameter of the outer conductor and the inner conductor, input impedance is able to set an optimum value.

Fig. 1(b) shows the proposed structure. The folded structure is applied to the self-resonant spiral antenna.

3. Simulation model

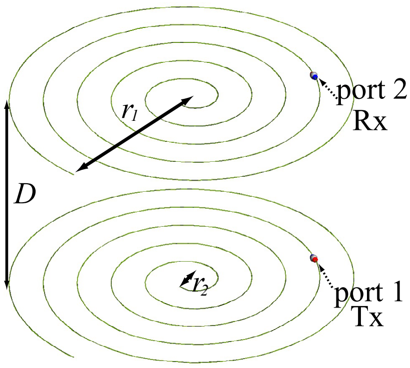
Consideration model of a conventional spiral antenna is shown in Fig 2(a). Mechanical parameters of the antenna is described in Table 1. Transmitting (Tx) antenna and receiving (Rx) antenna have port 1 and port 2, respectively. A voltage source with output impedance of 50Ω is connected to the Port 1. A 50-Ω load is connected to the Port 2. The conductivity of copper ($\sigma = 57.8 \times 10^6$ S/m) is assumed for the antenna.

Consideration model of a folded spiral antenna is shown in Fig. 2(b). A pitch between the two conductors is defined as p. Diameter of the inner conductor and the outer conductor is φ_i and φ_i , respectively.

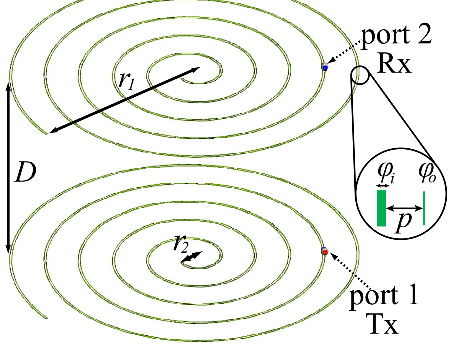


(a) Folded dipole antenna (b) Folded spiral antenna

Fig. 1. Folded spiral antenna with conductors of different diameter



(a) Conventional model (Spiral antenna)



(b) Proposed model (Folded spiral antenna)

Fig. 2. Consideration model

TABLE I
Mechanical parameters of the antenna

	r_1	r_2	D	p	φ_o
[mm]	600	50	2000	5	2

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4. Results

(1) Effect of the Diameter of Inner Conductor φ_i on the Transmission Efficiency

At first, maximum available efficiency η_{max} [2] is calculated by following equation:

$$\eta_{max} = 1 + \frac{2}{|Z_{21}|^2}\left\{|\mathbf{R}| - \sqrt{(|\mathbf{R}| + |z_{21}|^2)|\mathbf{R}|}\right\} \qquad (1)$$

where **R** is the real part of the Z parameter, which is calculated from S parameter.

Figure 3 shows inner diameter characteristics of $|S_{21}|^2$ and η_{max}. When $\varphi_i = 10$ mm, $|S_{21}|^2$ realize η_{max} without using a matching circuit.

Figure 4 shows effect of φ_i on frequency characteristic of S parameter. $|S_{11}|$ takes the smallest value at φ_i =10 mm. S_{21} takes the maximum value at the same frequency which S_{11} takes the smallest value.

Figure 5 shows a frequency locus of the input impedance on smith chart. The marker on the locus shows the frequency at which $|S_{11}|$ became minimum. Fig. 5 shows that the folded spiral antenna has a capability of adjusting input impedance by changing the diameter of the conductor.

(2) Distance Characteristic of the Transmission Efficiency

A distance characteristics of η_{max} and $|S_{21}|^2$ at resonant frequency are shown in Fig 6. By using the folded spiral antenna with the same outer- and inner- conductor diameter, transfer distance over 80% efficiency of $|S_{21}|^2$ extends 2.0 times compared to the spiral antenna.

By optimizing the inner conductor diameter to φ_i=10 mm, transfer distance over 80% efficiency of $|S_{21}|^2$ extends 3.3 times compared to the spiral antenna.

5. Conclusion

We proposed a folded spiral antenna for near field WPT system. A folded spiral antenna realized maximum available efficiency by changing the diameter of the inner conductor. Numerical simulation demonstrates that transfer distance over 80% efficiency of $|S_{21}|^2$ extends 3.3 times compared to the spiral antenna without using matching circuit.

An experimental validation is further study.

Acknowledgment

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References

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

[2] T. Ohira, "Maximum available efficiency formulation based on a black-box model of linear two-port power transfer systems," IEICE Electron. Express, Vol.11, No.13, pp.1-6, Apr. 2014.

[3] H. Miyagoshi, K. Noguchi, K. Itoh, and J. Ida "High-Impedance Wideband Folded Dipole Antenna for Energy Harvesting Applications," Proc. of ISAP 2014, pp. 601- 602, Dec. 2014.

[4] K. Komatu, T. Amano, H. Hirayama, N. Kikuma, and K. Sakakibara "A consideration of electric and magnetic coupling coefficient of spiral antenna for wireless power transfer," Proc. of ISAP 2012, pp. 170-173, Oct. 2012.

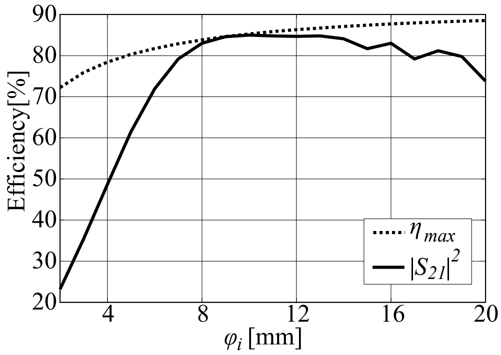

Fig. 3. Inner diameter characteristic of $|S_{21}|^2$ and η_{max} (D=2m)

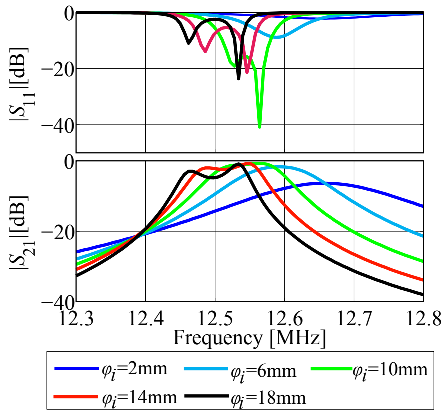

Fig. 4. Frequency characteristic of S parameter (D=2m)

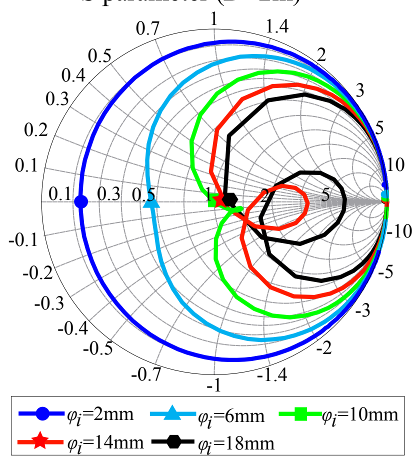

Fig. 5. Impute impedance (D=2m)

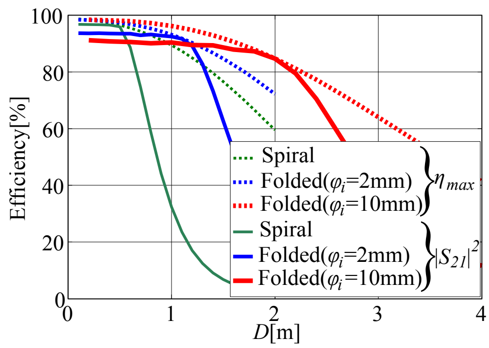

Fig. 6. Distance characteristic of transmission efficiency