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Implementation of Effective Wireless Power Transmission Circuit for Low Power System

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Abstract

Wireless power transfer (WPT) is the technology that enables the power to transmit electromagnetic field to an electrical load without the use of wires. There are two kinds of magnetic resonant coupling and inductive coupling ways transmitting from the source to the output load. Compared with microwave method for energy transfer over a long distance, the magnetic resonance method has the advantages of reducing the barrier of electromagnetic wave and enhancing the efficiency of power transmission. In this paper, the wireless power transfer circuit having a resonant frequency of 13.45 MHz for the low power system is studied, and the hardware implementation is accomplished to measure the power transmission efficiency for the distance between the transmitter and the receiver.

Key words : wireless power transfer, wireless resonant frequency, power efficiency, magnetic resonance, coupling coefficient

Ⅰ. Introduction

Wireless power transfer (WPT) [1] is a technology that can be used for transmitting the power to an electrical device without the use of wires. There are two kinds of inductive coupling and magnetic resonant coupling methods. In 1899, Nikola Tesla started to study a wireless transfer device. In 1946, William C. Brown invented wireless power transmission by using a rectenna, a rectifying antenna, converting microwave energy into direct current electricity.

Compared with the induction coupling method [2], Magnetic resonance, which uses the principle of strong magnetic coupling, has a long transmission distance.

Ⅱ. Design of Wireless Power Transfer Circuit

The equivalent magnetic resonant coupling circuit is shown in Fig. 1. Compared with the original inductive circuit [3], the magnetic resonant coil is added to the circuit.

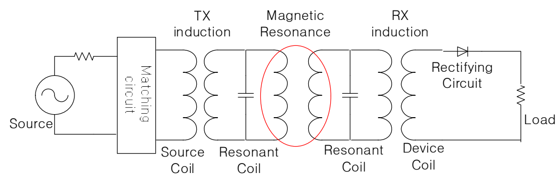

Fig. 1. A scheme for wireless power transmission using resonant coil.

The simulation circuit using LT SPICE for transmitting/receiving part of the magnetic

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induction method is shown in Fig. 2. The source frequency ranges from 1 Mhz to 20 Mhz. The coupling coefficient [3] of *kxy* is ranged from 0 to 1.

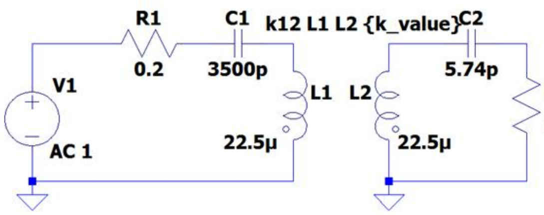

Fig. 2. The transmitting/receiving part of the magnetic induction circuit.

The power transmission efficiency of S_{21} is defined by eq. (1).

$$S_{21} = 2\frac{V_L}{V_S}\left(\frac{R_S}{R_L}\right)^{\frac{1}{2}} \qquad (1)$$

where *VL* indicates the load voltage, *VS* the source voltage, *RS* the source resistance, and *RL* the load resistance.

The magnitude of S_{21} is affected by the frequency and the coupling coefficient of k_{23} depending on the distance between the sending and receiving coils. The mutual inductance increases as the distance decreases and vice versa. The increased distance enables the transmission efficiency to be reduced and result in mismatching two coils. As shown in Fig. 3, the magnitude of transmission efficiency increases as the coupling coefficient increases, having the centered resonant frequency of 13.45 Mhz.

In order to obtain the corresponding inductance for transmitting/ receiving coils of the magnetic induction method, the structure of coils is shown in Fig. 4. The turns of transmitting and receiving coils are 10 and 5.

The mutual inductance is obtained from the distance ranging 2 mm to 10 mm. The maximum inductance of transmitter is 886 nH and the one of receiver is 135.7 nH, and then the mutual inductance is 122.996 nH. The minimum mutual

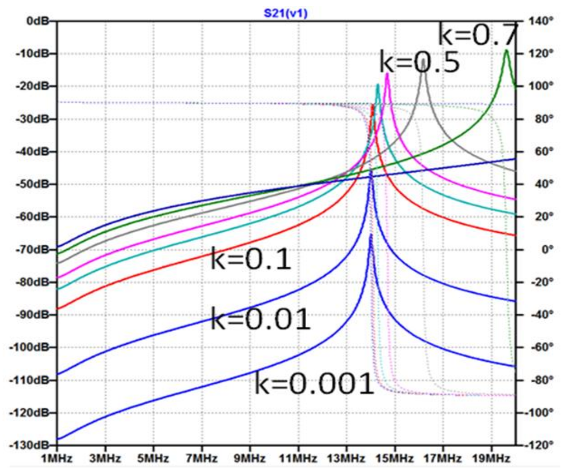

Fig. 3. The magnitude and phase of S21 vs. k (coupling coefficient).

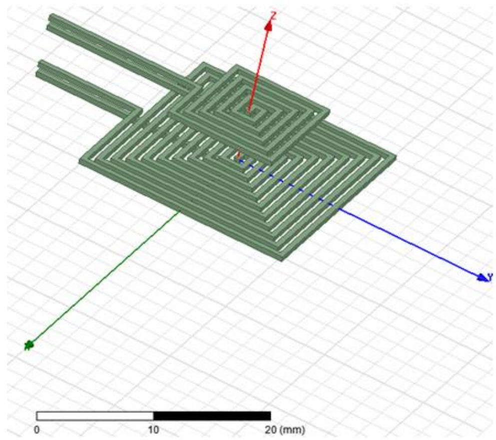

Fig. 4. The structure of transmitter and receiver for the inductive method.

inductance is obtained for the distance of 10 mm.

As shown in Fig. 5, the mutual inductance decreases as the mutual distance between transmitter and receiver increases.

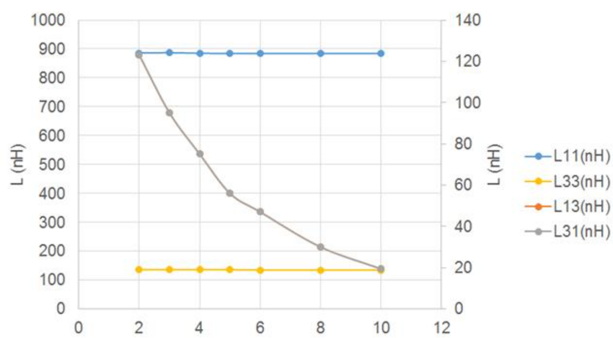

Fig. 5. The inductances vs. distance.

III. Simulation and Implementation

The simulation circuit shown in Fig. 6 is to represent the relationship between the degree of coupling coefficient and the shape of frequency. The frequency is split from the coupling coefficient of greater than 0.01. At the centered frequency of 13.45 Mhz, the resonant phenomenon occurs for less than 0.01 as shown in Fig. 7.

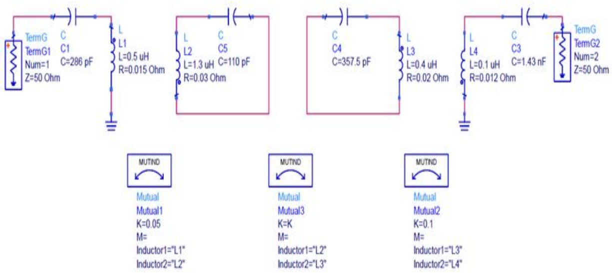

Fig. 6. The simulation circuit for magnetic resonant method.

As shown in Fig. 8, the enamel copper wire is wounded 6 turns with diameter of 37~46 mm for the inductance of 2.8 μH and 3 turns for the inductance of 17.5 μH. The corresponding capacitance of 50 pF and 8 pF are set to make the resonant frequency of 13.45 Mhz.

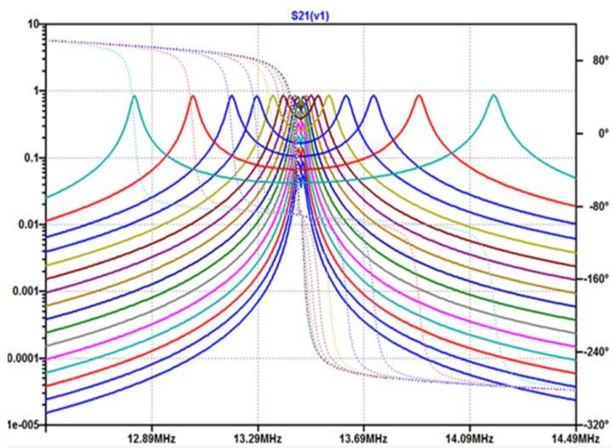

Fig. 7. Power transmission efficiency of S21.

The power transmission efficiency [4]using the S-parameters is represented by eq. (2).

$$\eta = \frac{|S_{21}|^2}{(1-|S_{11}|^2)} \times 100(\%) \quad (2)$$

Fig. 8. 6 turns and 3 turns with the diameter of 37~46mm.

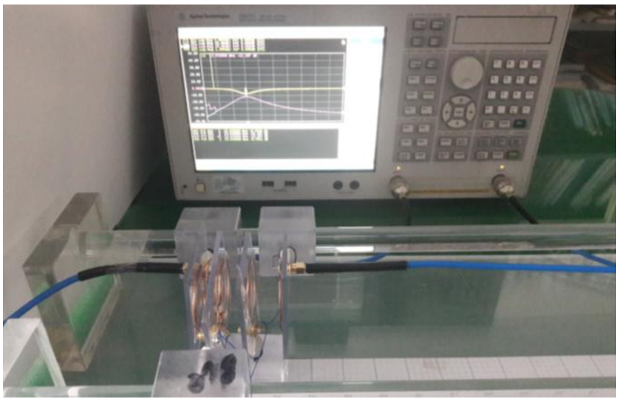

Fig. 9. S-parameter measurement circuit for transmission distance.

The power transmission efficiency shows the maximum value of 93.3% at the mutual distance of 10 mm, while the split occurs at the short distance of 5 mm. As the distance increases, the efficiency measured in Fig. 9 decreases as shown in Fig. 10.

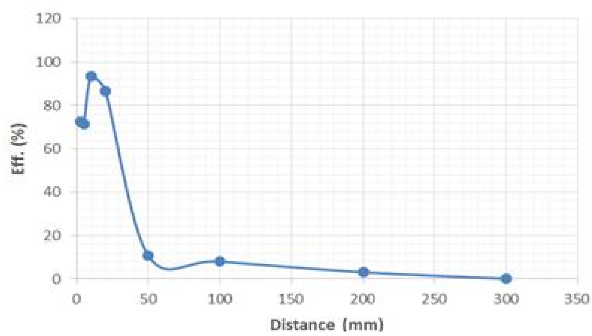

Fig. 10. Efficiency by magnetic resonant way vs. transmission distance.

IV. Conclusions

The WPT circuit is successfully designed, and the relationship between the coupling coefficient and the power transmission efficiency is analyzed. It is proved that the power transmission efficiency using magnetic resonant method decreases as the transmission distance increases except the distance that the split frequency occurs. The hardware implementation for applying WPT system in real time is accomplished for analyzing the power transmission efficiency.

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