The Efficiency Comparisons of Resonators for Wireless Power Transfer Using Various Litz Wires

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Abstract

In this paper, the efficiency of resonators for WPT using various litz wires is analyzed. By adjusting the value of distance between source coil and resonance coil (D_SR) and pitch of resonance coil (P_RC), the impedance bandwidth and efficiency of resonators can be optimized. It is observed that the thickness of wire forming resonator is the most critical parameter to determine the performance of a wireless power transfer system.

Keywords : WPT, Coupled magnetic resonance, Litz wire, Resonator

1. Introduction

In 2007, researchers in Massachusetts Institute of Technology (MIT) proposed a Wireless Power Transfer (WPT) system utilizing coupled magnetic resonance [1]. Unlike a previous wireless power transfer technique using inductive coupling, a WPT using coupled magnetic resonance has a longer transmission distance and better directionality. Thus, the WPT system using coupled magnetic resonance is highly regarded as the bright technology of our future. However, the efficiency of this technique sharply decreases as the distance between resonators increases. As a result, the incident power cannot be transferred well at low efficiency. Several techniques have been proposed to improve the efficiency of WPT systems recently [2-3]. In this paper, the efficiency comparisons of resonators for WPT system using various litz wires are investigated.

2. Resonator structures and performances

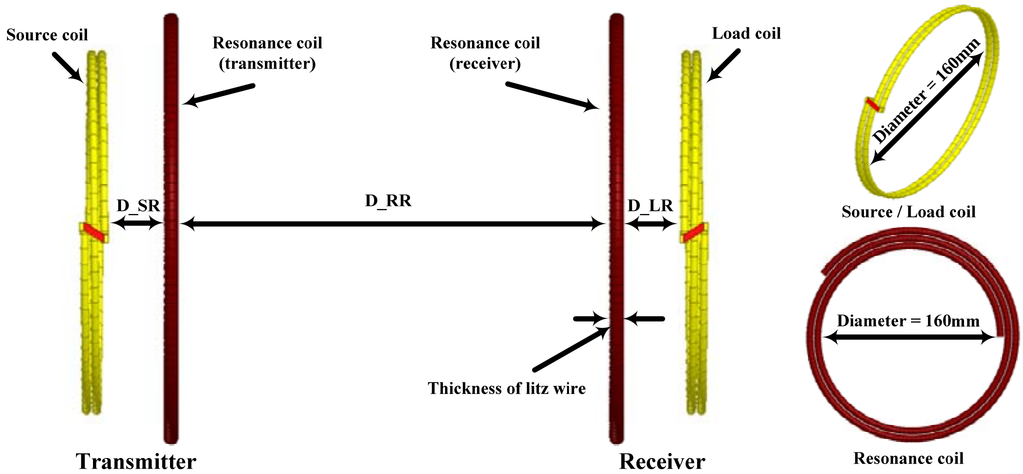
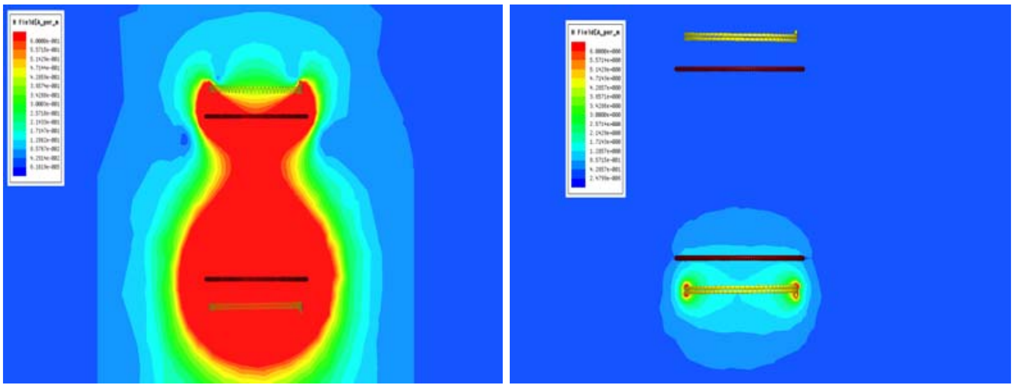


Fig. 1 The geometry of the proposed resonators

The geometry of the proposed resonators using coupled magnetic resonances is shown in Fig 1. The proposed resonators consist of source-coil, resonance-coil (transmitter), resonance-coil (receiver) and load-coil. The resonance-coils of transmitter and receiver (copper, σ = 5.8 x 10^7 S/m) using litz wire have the same diameter of 160 mm and source- and load-coils of helical type also have the size with the thickness of 3.6 mm. Resonance coils used to investigate the efficiency have the dimensions of 0.1 mm x 500, 0.1 mm x 1000 and 0.1 mm x 1500 (diameter *of one strand* x number of strand). The thicknesses of 0.1 mm x 500, 0.1 mm x 1000 and 0.1 mm x 1500 litz wires are 3 mm, 4.8 mm and 6.3 mm, respectively. Litz wire is a type of cable used in electronic devices to carry alternating current. This wire is designed to reduce the skin effect and proximity effect losses in conductors [4]. It consists of many thin wires strands. The resonator structures are designed using a commercial simulation tool (HFSS, ver.13). In simulation, the lits wire is modeled as a single strand which has the same hickness as that of an actual litz wire. The measured inductance of an actual litz wire using LCR meter is 5.64 μ H and the inductance of a simulated litz wire using Q3D extractor is 5.3 μ H.



(a) (b)

Fig. 2 H-field characteristics of the proposed resonators (a) when the resonators have the same resonant frequency (13.83 MHz) (b) when the resonators have the different resonant frequency

The H-field characteristics of the proposed resonators are shown in Fig. 2. The magnitude of H-field in Fig. 2 shows the power intensity of resonators. As shown in Fig. 2(a), a power transfer is possible when the resonant frequencies of transmitting and receiving of resonators are the same. If the resonant frequencies are not the same, the incident power is not transferred well to receiver as shown in Fig. 2(b). For good impedance bandwidth and efficiency of resonators, a choice of proper distance between source-coil and resonance-coil (D_SR), pitch of resonance-coil (P_RC) and thickness of litz wire is important.

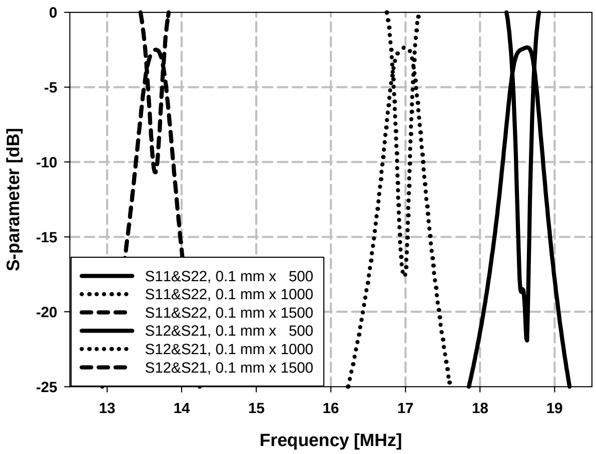
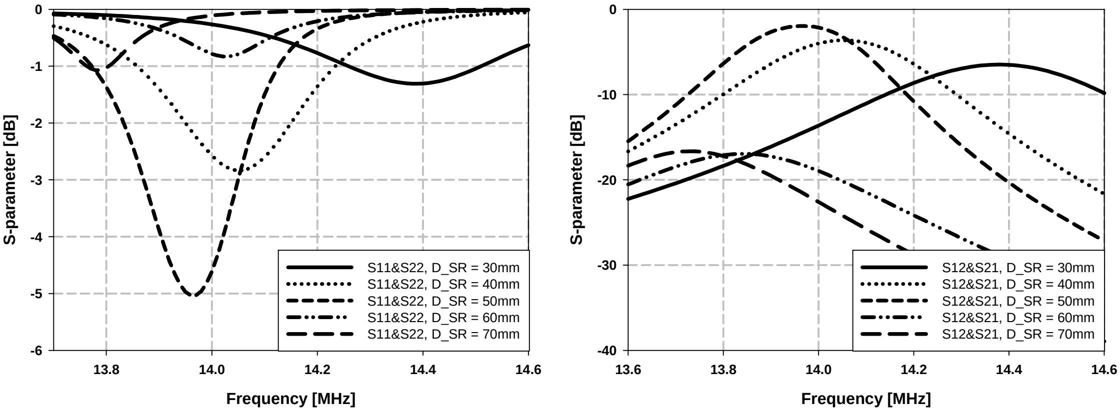


Fig. 3 The variation of resonant frequency of resonators for various thicknesses of litz wire

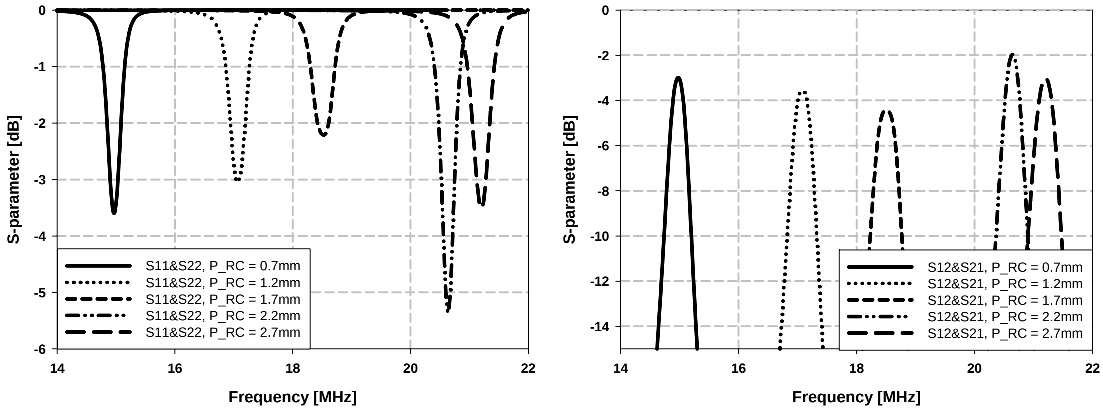
The variation of resonant frequency of resonators for various thicknesses of litz wire is shown in Fig. 3. As the thickness of resonators is increased, the resonant frequency becomes lower.



(a) (b)

Fig. 4 S-parameter characteristics of the 0.1mm x 1500 litz wire
for various D_SR (30mm, 40mm, 50mm, 60mm, 70mm)

The S-parameter characteristics for various D_SR values are shown in Fig. 4. As the distance D_SR is increased, the resonant frequency becomes lower. As shown in Fig. 4, the impedance bandwidth and efficiency of resonators are the best when D_SR is 50mm and the bandwidth and efficiency is the worst when D_SR is 60mm.



(a) (b)

Fig. 5 The S-parameter characteristics of the 0.1mm x 1500 litz wire
for P_RC values (0.7mm, 1.2mm, 1.7mm, 2.2mm, 2.7mm)

The S-parameter characteristics for different P_RC values are shown in Fig. 5. As P_RC is increased, the resonant frequency becomes high. As shown in Fig. 4 and 5, the effect of P_RC on the resonant frequency of resonance-coil is higher than D_RC. By adjusting the value of D_SR, P_RC and thickness of litz wire, the impedance bandwidth and efficiency of resonators can be improved as shown in Fig. 4 and 5.

3. Results

Table 1: Parameters for resonators using various litz wires

	0.1 mm x 500	0.1 mm x 1000	0.1 mm x 1500
Coil thickness	3 mm	4.8 mm	6.3 mm
D_SR	54 mm	45 mm	50 mm
D_RR	160 mm	160 mm	160 mm
RC_turn	7.5	6.8	6.5
P_RC	0.3 mm	0.3 mm	0.3 mm

The geometrical parameters for resonators using various litz wires are shown in Table 1. D_RR represents the distance between resonance coils. RC_turn stands for the number of turns of resonance coil. The resonator structures were designed and analyzed using a High Frequency Structure Simulator (HFSS Ver.13) [5].

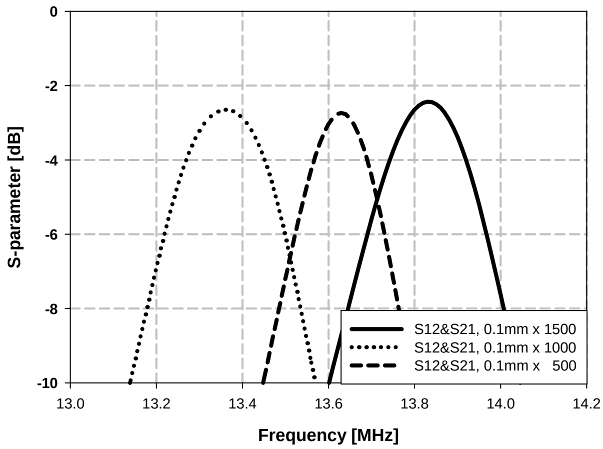


Fig. 6 The efficiency comparison of the proposed resonators

The efficiency comparison of the proposed resonators is shown in Fig 6. The maximum efficiency of the resonator was obtained when 0.1 mm x 1500 litz wires were used for resonators. The efficiencies of resonators using three different litz wires listed in Table 1 were 53.70 % (S_{21} = -2.70 dB, 0.1mm x 500), 54.95 % (S_{21} = -2.6 dB, 0.1mm x 1000), 57.10 % (S_{21} = -2.43 dB, 0.1mm x 1500), respectively.

4. Conclusion

In this paper, the efficiency of resonators using various litz wires is analyzed. The efficiencies of resonators and impedance bandwidth are dependent upon D_SR, P_RC and the thickness of litz wire. The maximum efficiency is obtained 0.1mm x 1500 litz wire is used as resonator.

References

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