Design and Implementation of Near-Field Spatial Wireless Power Transfer Using Orthogonal Multiple Coils

Seong-Hyeop Ahn, Ho-Seong Jeong, and Wang-Sang Lee

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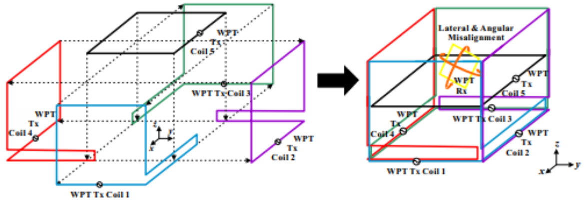
Introduction

The near-field spatial freedom wireless power transfer (WPT) system is proposed in this paper. The proposed WPT system consists of orthogonal multiple coils for high isolation and spatial wireless power transfer. Each proposed coil is designed and manufactured using copper wire. For high isolation, each coil was designed to overlap a certain area of an adjacent coil through structural deformation. Measurement results show the system is impedance-matched at 6.78 MHz, and it is possible to secure a spatial charging environment. The proposed WPT system can be applied to a variety of electronic mobile device charging environments.

Concept of the proposed WPT system

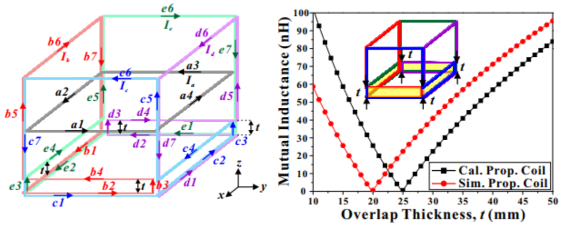


Concept of the proposed 3D WPT system using highly isolated multi-coils

Concept of the near-field spatial WPT system

- ✓ Highly isolation transmitting coils
  - ➢ High isolation coil through the structural design
- ✓ Spatial freedom wireless power transfer system
  - ➢ Insensitive to misalignment wireless power transfer system
  - ➢ Increased charging freedom of the receiving coil

Analysis of the Mutual Inductance



Configuration of the 3D coil for the mutual inductance calculation and mutual inductance depending on the overlap thickness

Calculation of the mutual inductance between the 3D coils depending on the overlap.

- ✓ Using Neumann formula
  - ➢ $M = \frac{\mu_0}{4\pi} \oint_{C_1} \oint_{C_2} \frac{dl_1 dl_2}{r}$

$\boldsymbol{C_1, C_2}$: integral path of the conductor element of each coil, $\boldsymbol{dl_1, dl_2}$: lines of C_1 & C_2, $\boldsymbol{r}$: distance between dl_1 & dl_2.

- ➢ $M_{Prop,b_1c} = M_{b_1c_1} + M_{b_1c_2} + M_{b_1c_3} - M_{b_1c_4} + M_{b_1c_5} + M_{b_1c_6} + M_{b_1c_7} = M_{b_1c_2} - M_{b_1c_4}$

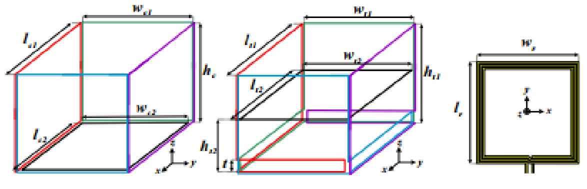
Using this equation calculates the total mutual inductance of each proposed coil.

- ➢ $M_{Prop,bc} = \sum_{n=1}^{7} M_{Prop,b_nc} = M_{Prop,b_1c} + M_{Prop,b_2c} + M_{Prop,b_3c} + M_{Prop,b_4c} + M_{Prop,b_5c} + M_{Prop,b_6c} + M_{Prop,b_7c}$
- ➢ $M_{Prop,bc} = (M_{b_1c_2} - M_{b_1c_4}) + (-M_{b_2c_1} + M_{b_2c_6}) + (M_{b_3c_3} + M_{b_3c_5} - M_{b_3c_7}) + (M_{b_4c_1} - M_{b_4c_6}) + (M_{b_5c_3} + M_{b_5c_5} - M_{b_5c_7}) + (-M_{b_6c_2} + M_{b_6c_4}) + (-M_{b_7c_3} + M_{b_7c_5} + M_{b_7c_7})$

Each coil has same configuration, so other mutual inductances are as follows:

- ➢ $M_{Prop,bc} = M_{Prop,cd} = M_{Prop,de} = M_{Prop,ea}$

Proposed Spatial Freedom WPT System



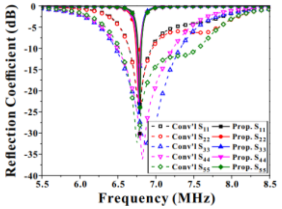
Configuration of the 3D coil for the mutual inductance calculation and mutual inductance depending on the overlap thickness

Parameters and characteristics of the conventional and proposed WPT systems

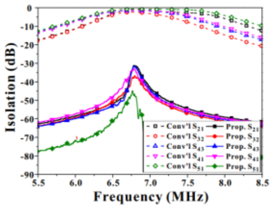
- ✓ Parameters of the conventional and proposed coils

Para.	l_{c1}	w_{c1}	l_{c2}	w_{c2}	h_c	l_r	w_r
mm	300	300	298	298	300	180	180
Para.	l_{t1}	w_{t1}	l_{t2}	w_{t2}	h_{t1}	h_{t2}	t
mm	300	300	298	298	300	160	20

- ✓ Characteristics of the conventional and proposed WPT coils
  - ➢ Operation frequency: 6.78 MHz
  - ➢ Reflection coefficient: ≤ -15 dB (conv'l, prop.)
  - ➢ Isolation: -4 dB (conv'l), -30 dB (prop.)

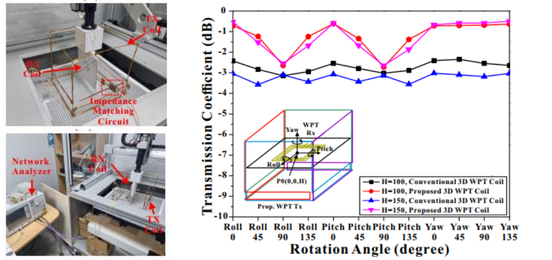


Reflection coefficient of the conventional and proposed coils



Isolation between each coil of the conventional and proposed coils

Results and Discussion



Measurement setup and Measured transmission coefficient with respect to the state of the receiving coil

Transmission coefficient of the proposed WPT multiple coils according to the rotation angle

- ✓ Measurement setup and method
  - ➢ Measure the transmission efficiency by rotating the roll, pitch, and yaw at 45° intervals in the center of the conventional and proposed coil
- ✓ Results and discussion of the measurement
  - ➢ Transfer efficiency is improved by more than 30% over conventional WPT coil
  - ➢ Phase shift circuits need to be applied to improve some areas of transfer efficiency reduction

Conclusions

- ✓ The near-field spatial freedom wireless power transfer (WPT) system is proposed in this paper. The multiple coils have high isolation characteristics.
- ✓ The proposed WPT system has improved power transmission efficiency in the charging area. It can solve the misalignment problem.