3D Electromagnetic Simulation for Wide Band Wireless Power Transfer Via Resonance Inductive Coupling

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Abstract

Introduction:
Wireless power transfer (WPT) is an emerging technology for charging implantable devices, industrial devices, and consumer electronics. It can be categorized as short-distance, mid-range, and long-distance WPT based on the distance between the transmitter (Tx) and the receiver (Rx). The most promising method for mid-range WPT is resonant inductive coupling. A mid-range WPT system using resonant inductive coupling consists of four coils, a Tx coil for power input, a Tx and a Rx resonating coil for power transfer through resonant coupling, a Rx coil for power reception through inductive coupling (Kurs A, et al, Science, 2007, 317(5834):83-86). This paper demonstrates how to conduct simulations for designing a new wideband four-coil WPT system using COMSOL Multiphysics®.

Use of COMSOL Multiphysics®:
Fig. 1(a) shows the model of the new design for simulations. The two resonators are ellipsoidal helices which are the conventional cylindrical helices tapering off from the middle towards the ends along the axial direction. The axial length, the diameter of helix, the pitch, and the wire diameter are denoted as H, D, p, and d, respectively. Moreover, the Tx and Rx resonating coils are aligned along their axial direction 20cm apart. The Tx and Rx coil are placed at the centre of the corresponding resonators. The simulation was completed using 3D-RF-Module, Electromagnetic-Waves, Frequency-Domain-interference of COMSOL Multiphysics®. The traditional four coil system with cylindrical helix resonators was also simulated for comparison.
The study takes two steps. First, the Eigenfrequency-Study was used to compute the fundamental resonant frequency of the WPT model. The geometry was imported from a .STL file. The material of coils is PEC. The coil was surrounded by the sufficiently large spherical air domain. Further, the air domain was enclosed by a PML to absorb the reflected waves.
Secondly, a frequency domain simulation was used to compute the response of the model subjected to a time-harmonic excitation driving-port at the frequency obtained from step-1. The excitation port is assigned to the Tx and Rx coil with 50-ohm external cable impedance. A 1-V driving voltage was applied at the input port. The WPT system is a two-port network . In the simulation model, impedance matching is done at both the Tx and Rx coils using lumped capacitors at the fundamental resonant frequency. It is to minimize the reflection at the input and maximize the WPT efficiency.
Further, the model is run through a wide range of frequencies around the resonant

frequency, and the efficiency of the WPT system (η) is calculated based on η=|S_21 |^2/(1-|S_11 |^2) (O. Jonah et al, IEEE-Trans.-Antennas-Propag., vol-61, no-3, pp.1378-1384, 2013), where S21 and S11 are the transmission and reflection coefficient of a two-port network, respectively. As shown in Fig. 1(b), the ellipsoidal and cylindrical helix system has a 90%-efficiency-bandwidth of 15.0 % at 53.45 MHz and one of 2.3% at 47.10 MHz, respectively. It can be seen, the ellipsoidal helix system shows a much wider bandwidth with a high efficiency compared to the conventional cylindrical helix system . The results are validated experimentally.

Figures used in the abstract

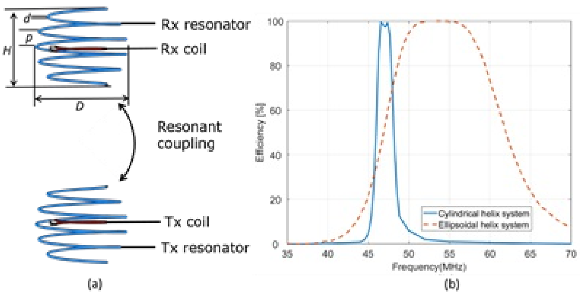

Figure 1: Fig. 1. 3D View of (a) Geometry used for simulation with ellipsoidal helix resonator; (b) Simulated efficiency of the proposed ellipsoidal helix system and the cylindrical helix system