Designing A Wireless Charging System With COMSOL Multiphysics

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Abstract

Wireless power transfer (WPT) systems enable the transfer of electrical energy wirelessly without any physical contact by using magnetic fields generated by time-varying currents. Among several WPT techniques, inductive power transfer (IPT) is the most widely used due to its simplicity and safety, as well as short range convenience. In this work, we present a COMSOL Multiphysics® model of a WPT system based on IPT techniques. We assess system electromagnetic performance by analyzing magnetic field distribution, mutual inductance, and power transfer efficiency. The WPT-IPT design is optimized to fulfill the Qi standard, making it compatible with common wireless charging standards.

The WPT-IPT system considered contains two magnetically coupled coils—transmitter and receiver—each with magnetic cores for enhanced flux linkage and coupling efficiency (Figure 1). The coils are separated by an air gap to simulate typical alignment conditions in consumer electronic devices. The design objective is to transfer 15 W of power with over 95% power transfer efficiency at an operating frequency of 110 kHz (±10 %) and maintain this performance for vertical offsets up to 2 mm and lateral offsets up to 10 mm.
The WPT-IPT model setup is as follows. We use Magnetic Fields physics from COMSOL's AC/DC Module to model the system in the frequency domain. Both primary and secondary coils are modeled using homogenized multiturn coils with Litz wire features. The electromagnetic loss in the magnetic shields is included as a complex magnetic permeability. The primary coil is connected to the AC voltage source and a compensating capacitor, while the secondary coil is connected to a compensating network of capacitors. The lumped circuit components are fully coupled with the 3D electromagnetic model of the WPT using the Electric Circuits interface.

We employ a suite of COMSOL simulations to ensure the WPT design meets the performance objectives. Frequency domain simulations were performed over a range of 80 kHz to 130 kHz, and capacitor values were tuned to maximize power transfer. At an operating frequency of 110 kHz (±10 %), the system can transmit over 16 W (Figure 2) and maintains this performance for vertical offsets up to 2 mm and lateral offsets up to 10 mm, exceeding the design requirements. When the vertical offset is increased to 10 mm, the system can transfer up to 10 W. Within the operating frequency range, the system achieves a power transfer efficiency greater than 97%, exceeding design requirements (Figure 3). The magnetic flux density is 0.2 mT outside the shield region, which satisfies the leakage flux requirement for the Qi standard (Figure 4).

In summary, we developed a COMSOL Multiphysics electromagnetics model of a wireless charging system to assess, tune, and optimize its performance. Such simulations help expedite the design process, reducing the burden of prototyping and time to market.

Figures used in the abstract

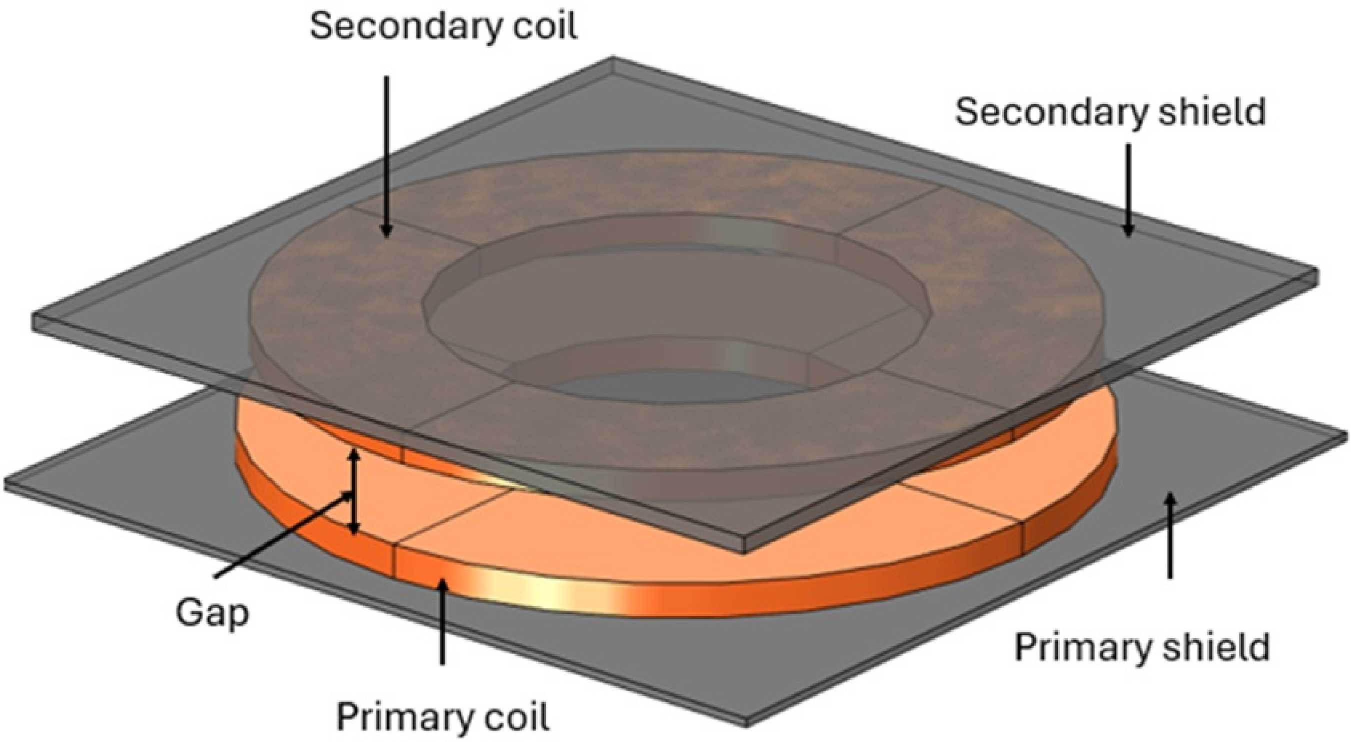

Figure 1 : Geometric configuration of a wireless charging system.

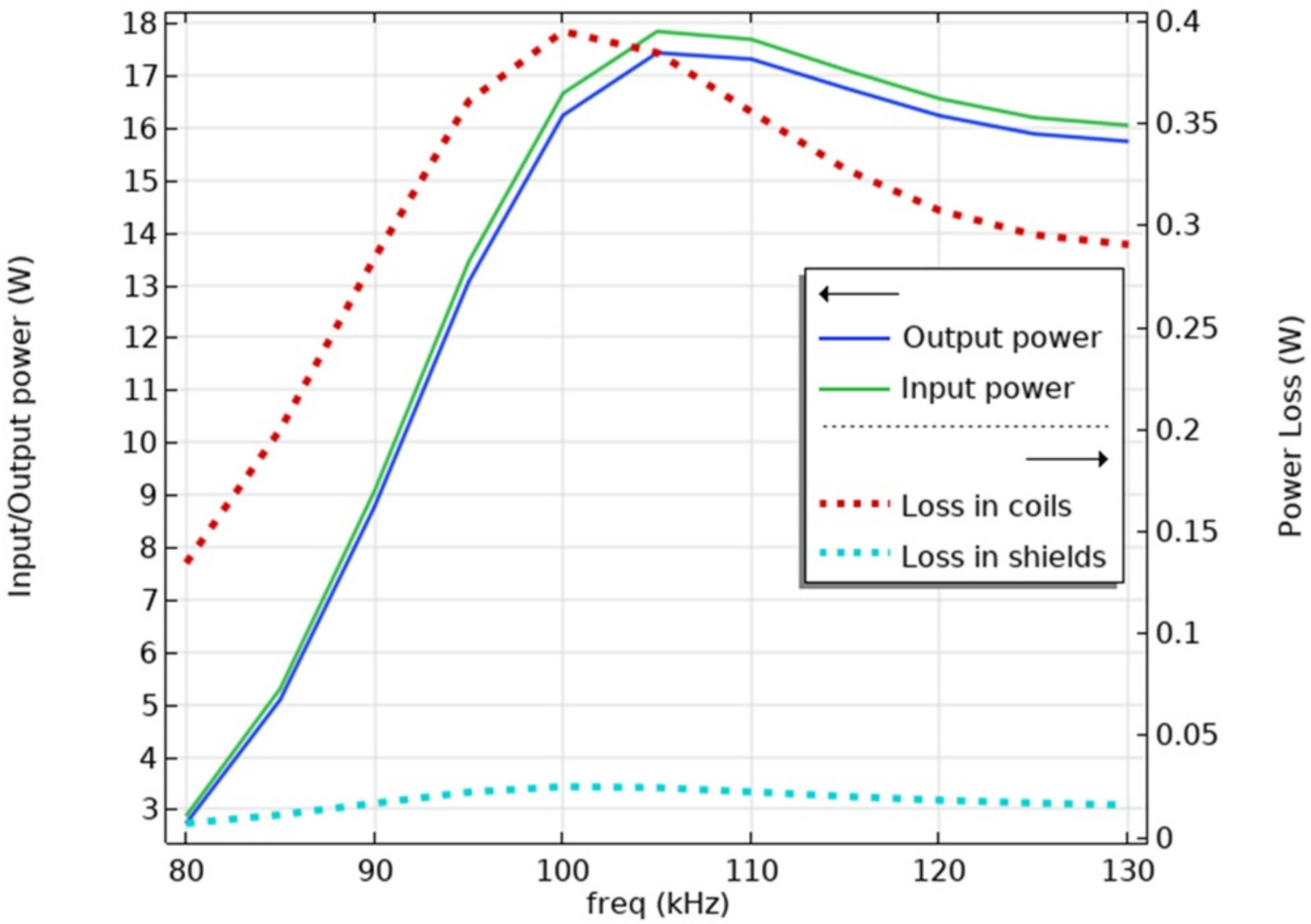

Figure 2 : Input power, output power, and losses as a function of frequency.

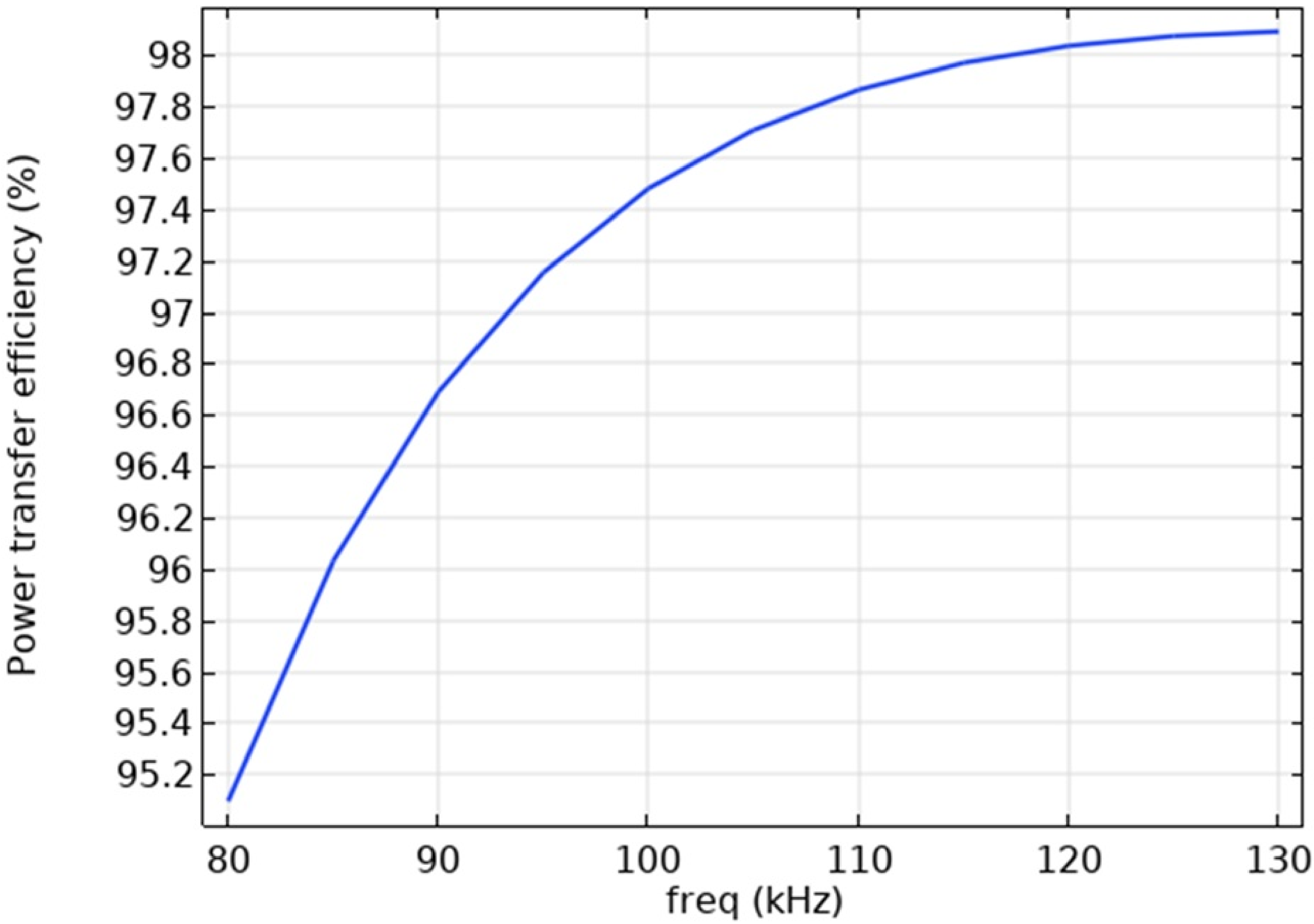

Figure 3 : Power transfer efficiency as a function of frequency is greater than the target 95% across the frequency range of interest.

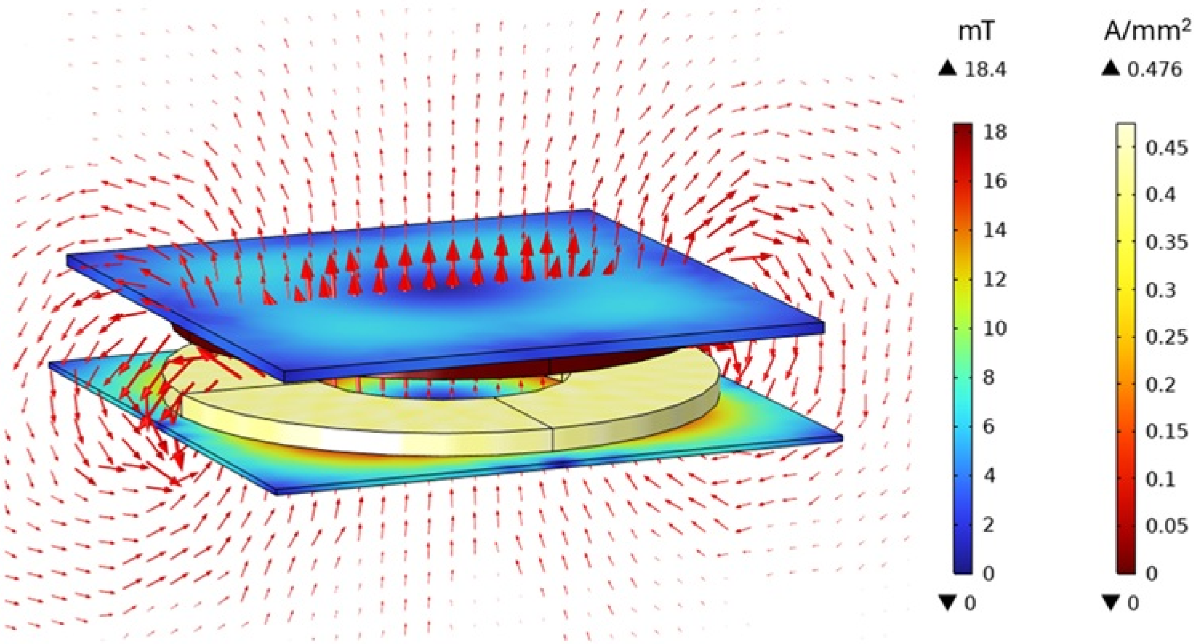

Figure 4 : Distribution of magnetic flux density in the shields and current density in the coils.