Modeling, Simulation and Verification of Contactless Power Transfer Systems

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Abstract

Contactless energy transfer applications are gaining importance due to their user convenience and reliability [1]. Moreover, as a general trend in consumer electronics, reduced-sized devices are strongly preferred, which implies operating at high power density levels. Therefore, a correct optimization of the winding is important to be able to dissipate the losses.
As shown in Figure 1, a contactless energy transfer system is mainly composed of two coupled coils. The transmitter is fed with a high frequency current which generates an alternating magnetic field. This field causes a varying flux through the receiver, in which an electromotive force is induced due to Faraday's Law. The efficiency is the ratio between the output power and the supplied power. The difference between them is the power loss in the windings.
Losses in the winding are usually grouped into two depending on their origin [2]: Conduction losses are those caused by the conduction of the current as a consequence of the applied external voltage. Proximity losses are caused by the induced currents generated by the magnetic field. In both cases, power losses are usually modeled by resistances [3]. In order to reduce these losses, the use of Litz wire is widely extended [4].

In this work, the AC/DC Module in COMSOL Multiphysics® software is used to model and simulate a wireless energy transfer system composed of two coils made of Litz wire. The main objective of the simulations is to estimate the coupling between transmitter and receiver and be able to calculate the losses.
While the coupling inductance can be obtained directly on the simulation model, the losses in Litz wire require the simulation of a very complex geometry with an extremely fine mesh. This results in an unrealistic burden in terms of computing cost. The chosen approach to avoid such simulations is to calculate the conduction and proximity losses in a single conductor by their analytical expressions [5] and then integrate them in the model considering the number of turns and strands. However, proximity losses depend on the magnetic field level, and as a consequence, the simulated magnetic field is needed in order to calculate the losses.
In this work, the COMSOL LiveLink™ for MATLAB® has been used to handle both problems: Firstly, the simplified model of the system (Figure 2) is launched and the main variables are evaluated. Then, the simulation results are used to calculate the losses in the winding. The frequency was swept to obtain the frequency-dependent impedance. Additionally, the case of misaligned coils was studied.

The model was verified with experimental results. Figure 3 shows the measuring setup. The obtained results for the losses resistance (R) when sweeping frequency (f) and misalignment (Δr) are shown in Figure 4.

In this work, a model for contactless energy transfer systems is presented. The method combines COMSOL simulations with analytical developments to calculate the interest variables in the system. The simulation results are consistent with the measurements.

Reference

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Figures used in the abstract

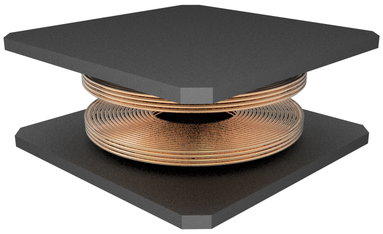

Figure 1: Representation of a typical contactless power transfer system.

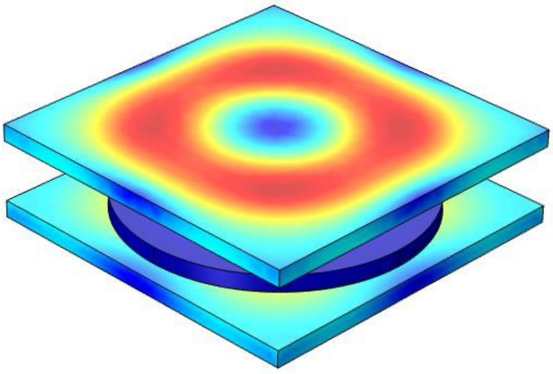

Figure 2: Simplified model of the system.

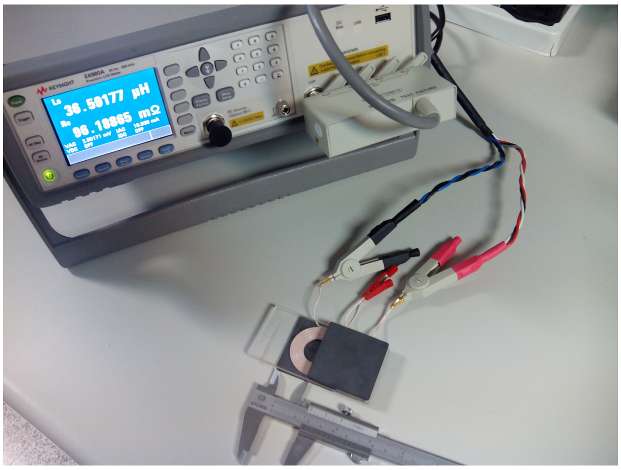

Figure 3: Small signal measuring setup.

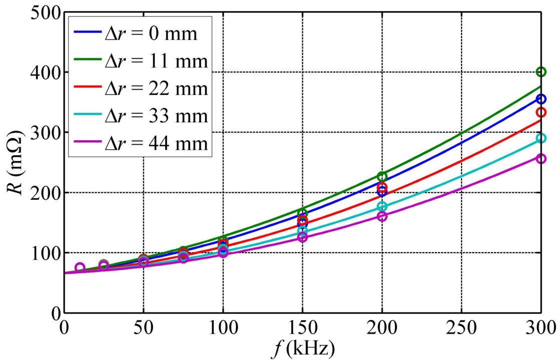

Figure 4: Simulated and measured loss resistance as a function of frequency for different missalignment values.