

Nonlinear optimization of magnetic resonant wireless power transfer systems

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The efficiency of near field magnetic resonant wireless power transfer (WPT) systems depends on the distance and misalignment between the transmit and receive coils. As the distance between the two coils is reduced, the coupling between them and the power transfer efficiency increases. When the coupling between the coils increases above a critical point, frequency splitting occurs, and the power transfer efficiency has two peaks at two frequencies different from the original resonant frequency of the system. Consequently a lot of research efforts have been directed towards optimizing the power transfer efficiency of such systems and eliminating the frequency splitting effect. Such methods include changing the operating frequency of the WPT system to a new frequency which corresponds to the peak power transfer efficiency or tuning the resonance frequency of the WPT systems in order to restore the peak power transfer efficiency to the original system frequency. All these methods improve the system efficiency at the expense of increasing the system complexity. In this work we apply harmonic balance optimization in order to optimize the efficiency of the WPT system simultaneously under multiple distance or misalignment conditions without increasing the system complexity. A fixed transmitted power is assumed and the two port s-parameters of the transmit and receive coil system are simulated using a commercial finite-element simulator for a number of desired distances and misalignment conditions. The RF-DC conversion efficiency of the rectifier used in the receiver coil is then optimized, with optimization parameters the rectifier matching network components and the rectifier load resistance. Multiple distance or misalignment conditions can be simultaneously optimized by introducing multiple copies of the system in a harmonic balance optimization schematic. The results of the optimization are shown in the following example (Fig. 1a). First the system is optimized for a single transmit-receive coil distance of $d = 70$ mm and transmit power of 0 dBm, and the RF-DC conversion efficiency is evaluated for three distances of $d = 40$ mm, 50 mm and 70 mm. While a peak efficiency of 60.8 % is obtained at $d = 70$ mm, the efficiency drops to 45.1 % at 40 mm distance. Second the system is optimized simultaneously at $d = 40$ mm and $d = 70$ mm. In this case, while a slightly reduced efficiency of 57.4 % is obtained at $d = 70$ mm, a significantly higher efficiency of 68.6 % at $d = 40$ mm is provided. Examples of different optimization conditions will be presented along with measurements on a fabricated prototype (Fig. 1b).

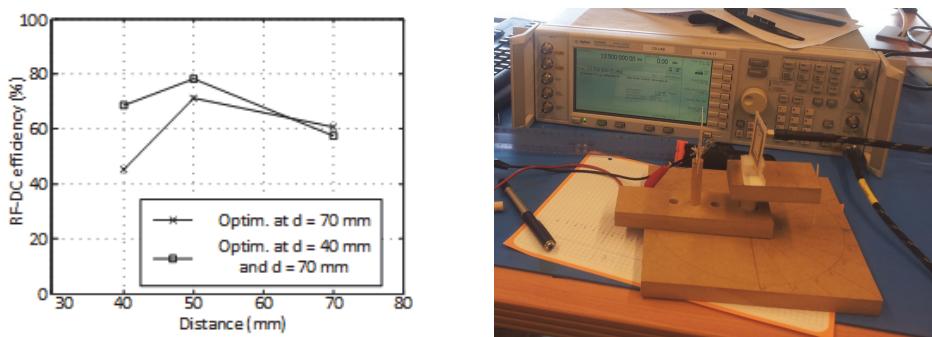


Fig. 1. a) Simulated RF-DC conversion efficiency under different optimization conditions, b) fabricated prototype and laboratory test setup.

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