Keysight Technologies
NCK University Uses ADS to Create an Impedance Matching Method for Wireless Battery Charging

Case Study

Challenge

- Recharging a Li-ion battery in 5 hours or less
- Impedance matching is difficult due to the dynamic load caused by the varying state-of-charge

Solution

- Simulated a dual-diode rectifier model for input impedance calculations using ADS harmonic balance simulation
- Used a sweeping method to match impedance between the Li-ion battery and rectenna
- Designed a rectenna using ADS EM-circuit co-simulation

Results

- Achieved 76% battery charging efficiency, compared to only 50%

Implantable medical biosensors are commonly used to treat health problems, via the unobtrusive collection of medical data, such as neural activity or cardiac pacemaker status. Because they are required to operate continuously, sufficient electrical power is essential. Rechargeable lithium-ion (Li-ion) batteries are a good power source for implants due to their small size, high energy density, low self-discharge rate, and long lifespan. Wireless battery charging allows the implantable medical devices to harvest RF energy. Typically, this can be accomplished though inductive coupling or far-field waves, but both have limitations.

National Cheng Kung University (NCKU) in Taiwan used Keysight Technologies' Advanced Design System (ADS) software to investigate an approach to overcome such limitations. They created a DC driving impedance matching method for wireless charging using the medical implant communication service (MICS) band. ADS simplified the development and implementation of both the matching network and the rectifier-antenna ("rectenna") subsystem. The team performed EM and circuit co-simulation, and thus explored the design space.

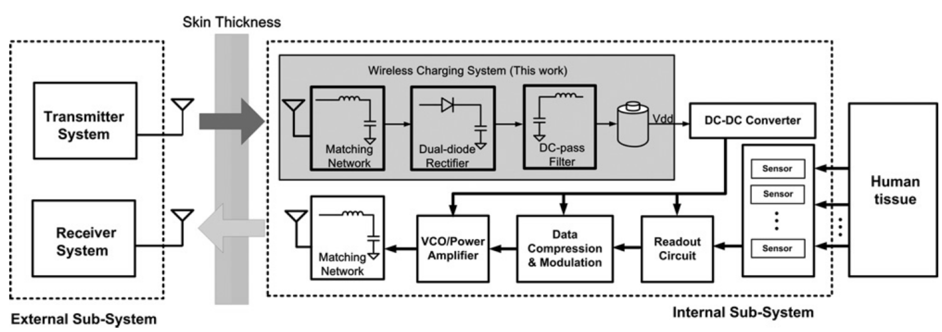

Figure 1. Far-field wireless charging system for implanted devices. The work from NCK University addresses the subsystems in the gray box.

KEYSIGHT TECHNOLOGIES

Challenge

Wirelessly charging Li-ion rechargeable batteries in implantable medical biosensors is tricky as RF power must be transmitted through skin tissue from an external transmitting device. For NCKU, the wireless battery charger had to fit within a 14-mm diameter disk and include a printed circuit antenna that could operate over the MICS band, a matching network, two rectifier diodes, and an LC low-pass filter. The challenge was to recharge the Li-ion cell with its 10-mAh capacity, in 5 hours (a so-called 0.2-C rate). Complicating matters was the battery's resistance, reactance, and cell voltage, which varied dramatically with its state-of-charge, making it difficult to determine what load to optimize the matching network for the dynamics of the load. Furthermore, the traditional method of impedance matching uses a DC resistive load to decide the rectifier's impedance, which introduces loss because of the mismatch between the rectenna and Li-ion battery.

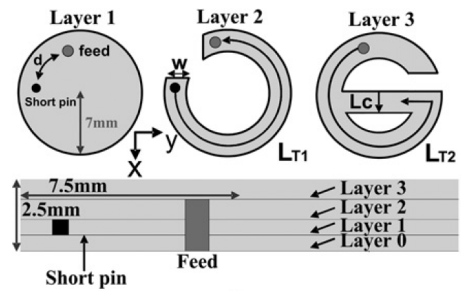

Figure 2. Layout and stackup of implanted planar inverted-F antenna.

Solution

To overcome these challenges, a new impedance matching method was required—one that adopted the output DC current of the dual-diode rectifiers to establish a simple equivalent model for wireless battery charging. To do that, researchers from NCKU turned to ADS, with its ability to perform EM and circuit co-simulation.

To create the impedance matching model, researchers used ADS harmonic balance to simulate the dual-diode rectifier circuit and explore the design space. A sweeping method, whereby the resistance values and custom Li-ion battery potentials are swept and corresponding output voltage, current and impedance recorded, was then used to match impedance between the Li-ion battery and rectenna. Next, the model was used to come up with an optimized rectenna circuit consisting of just three capacitors, one inductor, two diodes, and the PCB itself (with both the interconnect and MICS band implantable antenna). Finally, the implantable rectenna was designed using ADS EM-circuit co-simulation. Using this feature, researchers ensured the rectenna experienced reduced EM loss on human tissue and in turn, improved radiation characteristics.

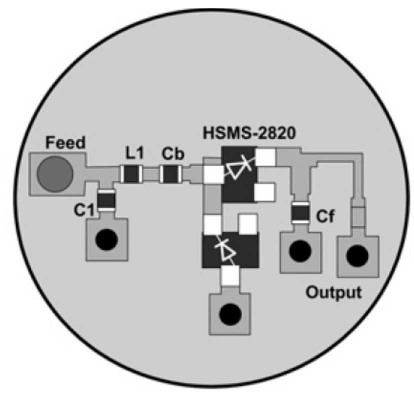

Figure 3. Rectifying circuit on the backside of the antenna.

Results

With this approach, NCKU researchers developed a simple, yet effective DC driving impedance matching method for rectennas and wirelessly charging implantable Li-ion rechargeable batteries. The paper contains detailed results — an example of these results is duplicated in Figure 4. For 10-dBm input RF power, researchers achieved a 76% RF-to-DC conversion efficiency of incident power to battery charging power averaged over a five-hour charge cycle. In contrast, comparable prior work achieved only a 50% conversion efficiency.

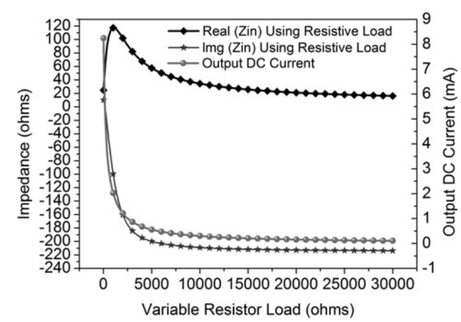

Figure 4. Load resistance against impedance of the dual-diode.

More Information

To learn more about how NCKU created an impedance matching method for wireless battery charging using Keysight ADS, go to:

Direct current driving impedance matching method for rectenna using medical implant communication service band for wireless battery charging.

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Published in USA, October 7, 2017
5992-2544EN
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