Designing Wireless Power Supply Systems

Simulating the entire power supply system helps to develop the latest technology for charging mobile electronic devices.

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Our mobile, wireless, connected world depends on batteries. The power for phones, laptops, cameras, MP3 players and other modern electronic devices is drawn from small rechargeable batteries. All too often, recharging the battery for each device requires digging through a large and jumbled collection of cables and chargers to find the right one. New technology is changing how we recharge by eliminating the need for these cables and multiple chargers. A number of promising new wireless power supply technologies will allow consumers to quickly, easily and efficiently charge their battery-powered devices without cables.

Most common types of wireless power supply systems utilize microwaves, electric field coupling, inductive coupling (transfer) or magnetic resonance methods. Each type has its strengths and weaknesses, but all show promise as alternatives to chargers and cables.

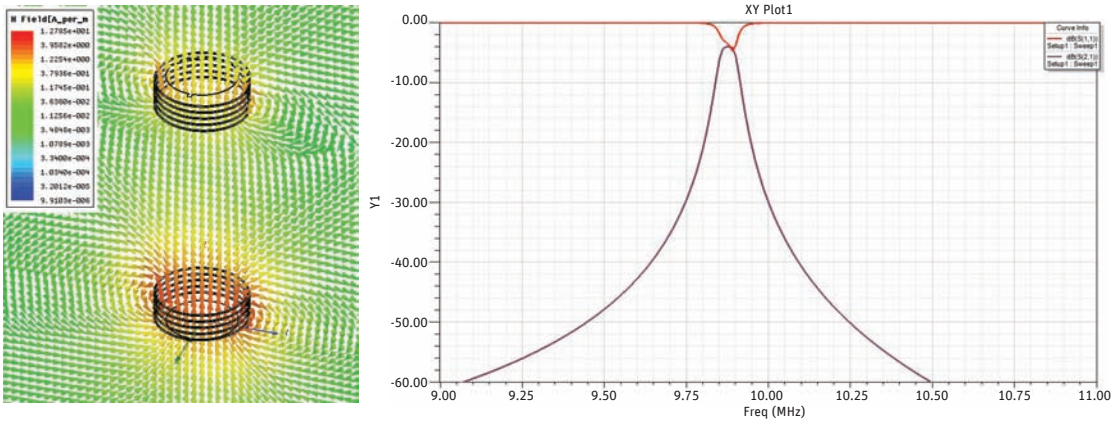
The most familiar technology — and one that is already in use in a number of household devices, such as electric toothbrushes and cordless phones — utilizes the inductive transfer, or coupling, method. However, inductive coupling is not very suitable for applications that involve significant power transfer over a distance.

Another method for charging small portable devices uses magnetic resonance. This technique enables the transmission of more power to far greater distances than the popular inductive coupling method. Magnetic resonance allows for greater flexibility in positioning the antennas used as part of this system. Due to the flexibility and efficiency that inductive coupling offers, a number of companies are now actively developing designs and beginning to use this technology in their products.

In yet another wireless power supply application, Takenaka Corporation is using software from ANSYS to develop systems based on the electric field coupling method. (See sidebar.)

Electromagnetic Analysis

Developing a design for a reliable wireless power supply system of any kind depends on being able to model the electromagnetic performance of the microwave antennas. The circuitry that drives and controls system operation should be modeled and, preferably, be linked to the 3-D electromagnetic design — a key to obtaining the best possible range and power transfer characteristics. ANSYS software provides a full range of simulation capabilities that can be used to efficiently design a wireless power supply system. For example, ANSYS HFSS technology allows engineers to quickly and easily determine the transmitted,



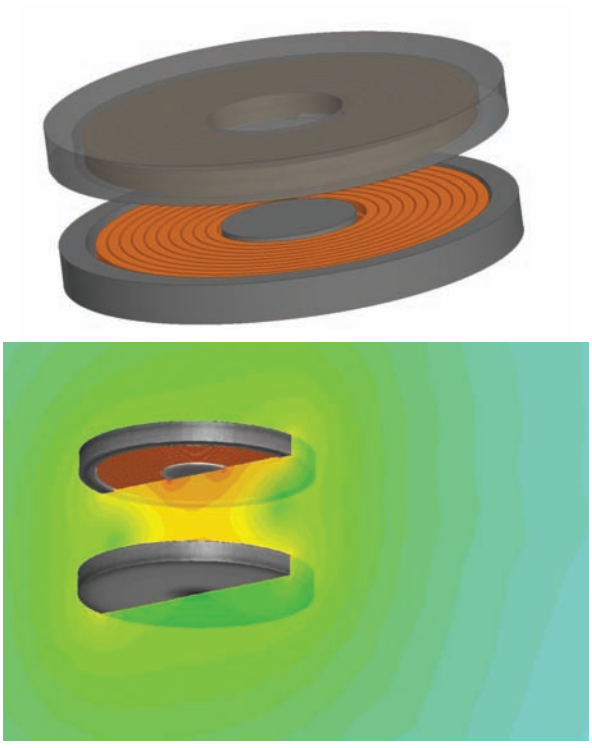
Coil antenna model (left) and results (right) using ANSYS HFSS

reflected and total electromagnetic field of a transmit-and-receive coil antenna; the tool also optimizes the coil design to fully take advantage of the magnetic resonance phenomena.

Capabilities for Complete Power System Simulation

When designing a high-frequency wireless power supply system such as those based on magnetic resonance, Ansoft Designer software can be used as both system and circuit simulators. A bidirectional dynamic link can be established between Ansoft Designer and HFSS, enabling a system simulation that includes IGBT inverters, coil antennas and the rectifier circuit. Using the dynamic link capability, an engineer can obtain all the electromagnetic field characteristics of the full system. This data can be used to simulate EMI and EMC behavior as well, so the engineer can determine if the system meets regulatory limits.

ANSYS Maxwell software can easily be applied to analyze low-frequency inductive coils used in inductive coupling method power supplies. A low-frequency system typically uses Litz wire in the construction of the coil antennas, which can be easily simulated with Maxwell. This tool also can extract the equivalent R, L and C characteristics of the coils, so the engineer can construct an equivalent circuit model of an inductive coil antenna.



Coil antenna model (top) and magnetic field simulation using ANSYS Maxwell (bottom)

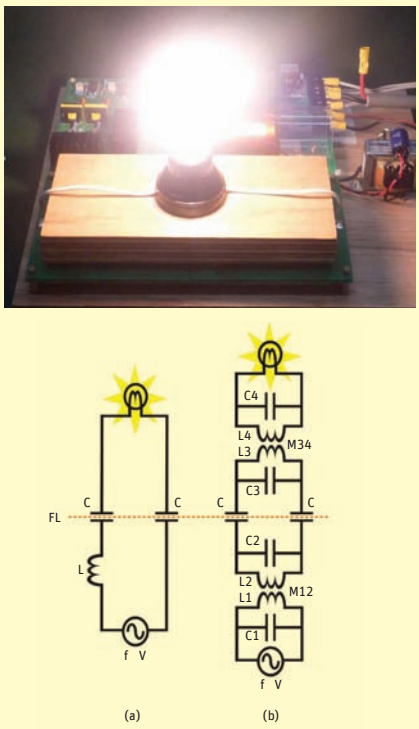
Electric Field Coupling Method

Takenaka Corporation, a major general contractor in Japan, is developing wireless power supply systems that are embedded in the walls and floors of buildings. These power systems use the electric field coupling method, designed with the assistance of ANSYS electromagnetic simulation tools.

Dr. Kenichi Harakawa of the technical research center at Takenaka Corporation is studying the technology of wireless transmission of electric power — including both serial and parallel circuit topologies. While these topologies can be used to transmit electric power, the system that utilizes the series resonance phenomena has a significant drawback. In this circuit, the junction capacitance — the capacitive coupling that occurs between transmitter and receiver — determines the resonant frequency of the system. As the junction capacitance varies, the system resonant peak varies and, therefore, affects the power transmission efficiency.

The alternative topology is one of a loosely coupled system, or a parallel resonant circuit. In this topology, the parallel resonant circuit delivers robust performance even with a change in junction capacitance, as junction capacity is a small contributor to overall system capacitance. As a result, the resonant peak is much more stable, and the system will have better performance.

In designing the circuit for this system, Takenaka Corporation used ANSYS Q3D Extractor software to determine the capacitance between electrodes, Maxwell for the inductor design, and HFSS to analyze the electromagnetic radiation characteristic. Using engineering simulation contributed greatly to the development of this system, and it functions as the software predicted.



Electric power is transmitted by a series resonant system (top). The circuit for the serial system is on the left and for the parallel system is on the right (bottom).

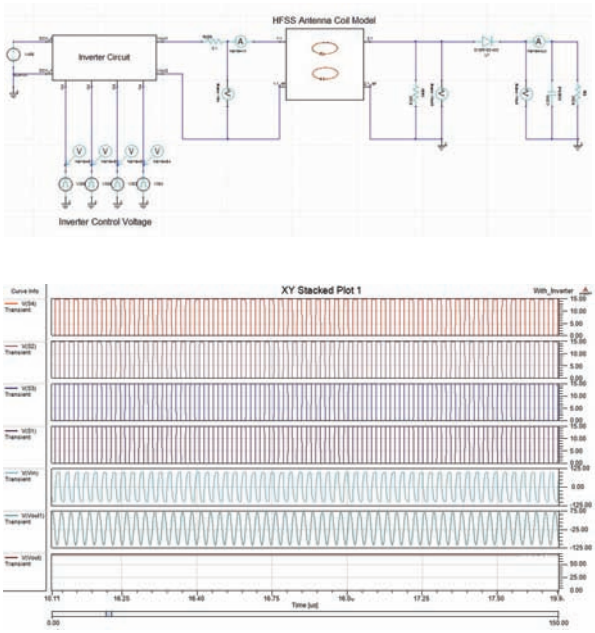
The ANSYS engineering simulation suite allows engineers to use the appropriate tool for a given design challenge.

Simulation of low-frequency wireless systems can be conducted in the same manner as high-frequency systems by using the dynamic link capabilities between Maxwell and ANSYS Simplorer — a circuit and system simulator with specific emphasis on power electronic design.

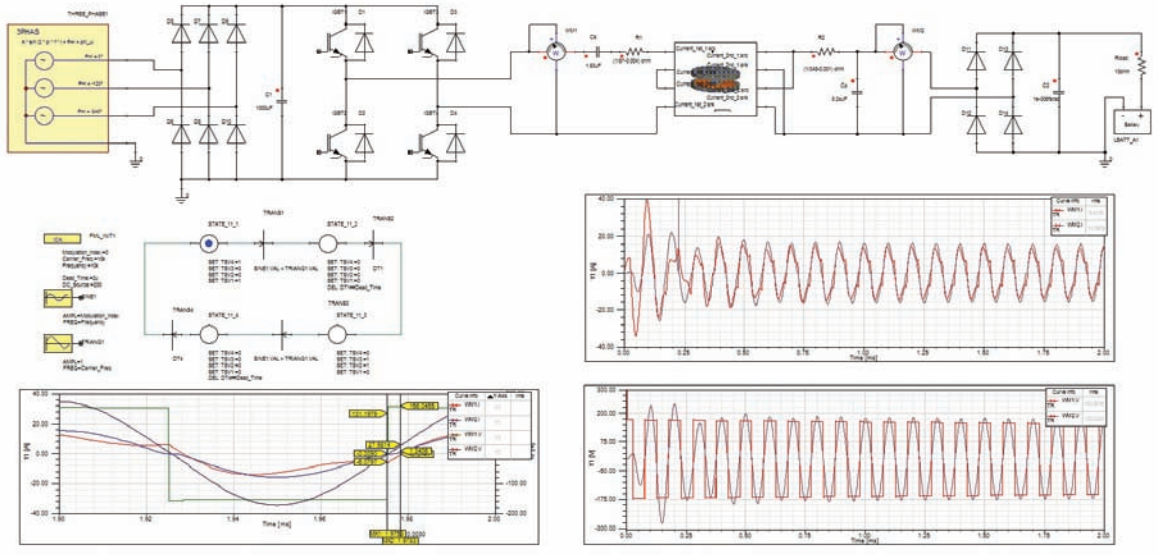
Employing the entire ANSYS suite of electromagnetic simulation tools enables engineers to analyze the full end-to-end wireless power supply system by using the unique cosimulation and dynamic link capabilities between these ANSYS tools.

End-to-End System Models

A wireless power supply system is an emerging technology that relies on dependable electromagnetic as well as circuit simulation. The ANSYS engineering simulation suite allows engineers to use the appropriate tool for a given design challenge: for example, 3-D coil design or a power rectifier circuit. The dynamic link capability between field solver tools (HFSS or Maxwell) and circuit simulation tools (Designer or Simplorer) enables efficient and easy creation of a full end-to-end simulation of an entire wireless power supply system. End-to-end system models allow the engineer to tune system performance and to predict system metrics as well as EMI/EMC compatibility. ■



Wireless power supply system (top) and transient analysis results modeled using ANSYS Nexxim circuit technology in Ansoft Designer (bottom)



Wireless power supply system modeled in ANSYS Simplorer