Wireless Power Transmission for Geophysical Applications

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Wireless power transmission can be beneficial whenever a direct connection between a power source and a receiver is prohibited. Applications arise in the geophysical area, where it is desired to transfer power from one point to another along an underground pipe in a well, or between pipes in a well, in order to power a sensor. In one application there is a physical obstruction in the well (called a "packer") that prevents a direct wired transmission of power along the well. In another application power must be sent between a vertical well and a lateral well, and it is desired to transmit wirelessly across the break.

This investigation will focus on optimizing the achievable range and power transfer efficiency when transmitting wirelessly between two coils that are wrapped around a pipe in the presence of a lossy environment. Many of the conclusions apply to other applications, however, including wireless transmission between coils in free space or in other lossy environments.

A CAD model for the transmit and receive coils is used, in which each coil is modeled as an inductor in series with a resistor, along with a shunt capacitance placed in parallel across the circuit to model the stray capacitance of the coil. A shunt resistor is also placed in parallel across the inductor to model the eddy current losses in the pipe and the lossy surrounding environment, which may include a lossy earth and/or water having various amount of salinity. The coil interaction is accounted for by the mutual inductance between the two coils. Tuning capacitors are placed in series with the coils in order to compensate the coil inductances. To enhance the power transmission efficiency, the coils are wound on ferrite cores that surround the pipe.

Based on the simple CAD model, a power transfer efficiency is calculated, which is defined as the power that can be delivered to a match load on the receive coil to the power supplied by an ideal source connected to the transmit coil. Simple approximate formulas are also derived (in the weak-coupling limit) that directly show in a simple way the effects of the various coil parameters on the power transfer efficiency, including the effects of the eddy current losses. Experimental methods and data are shown to validate the theoretical formula in the low-frequency range. The effect of encapsulating the coils with an insulating casing is also discussed. This increases the power transfer efficiency by reducing the eddy currents in the surrounding lossy environment, and it also makes the system less sensitive to the surrounding environment.