Maximization of the Efficiency in a Multi-Coil Wireless Power Transfer Systems for Biomedical Applications

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Biomedical implants are increasingly employed for therapeutic use and prosthetics. Implantable devices must avoid repeated surgeries to replace/recharge the power source of the implanted circuitry and, therefore, should incorporate a wireless power transfer (WPT) system to obviate the need for bulky implantable batteries. Furthermore, the same WPT system can be engineered to transfer data to and from the implant, thus making biomedical implants more practical. An effective WPT system design, conforming with all requirements typical of biomedical implants, is crucial for reliable operation and the safety of the patient.

One of the simplest forms of WPT system is a two-coil, inductively coupled system transmitting power from a transmitter coil to a receiver coil. The performance of simple two-coil systems can be improved by using multiple coils. In the literature, multi-coil WPT systems have demonstrated superior performance through either 1) magnetic resonance (employing two self-resonant intermediate coils), or 2) impedance transformation (which requires additional compensating capacitors and typically inverts and scales the reflected impedance).

Ideally, improvements in power transfer efficiency (PTE) – one of the important metrics in biomedical implants – should be independent of the load. This is important in real-life applications, as any power delivery system sees a range of load values in its operation cycle. Further, any load-dependent PTE enhancement would be better classified as an impedance-matching technique. To achieve an improvement in the system performance independent of the load used for multi coil system, the coupling coefficient, K, or the quality factor, Q, must be improved, which is typically accomplished through geometrical improvements of the coils since the K and Q are intrinsic properties.

In this work, a conventional multi-coil system is studied for its performance from a magnetic-energy-efficiency perspective, and a load-independent technique to improve the PTE is presented. A new multi-coil system (containing four transmitter coils), with load-independent PTE improvement is accomplished by incorporating appropriate circuitry along with a new PTE-aware resonance condition. The efficiency of the system is increased by maximizing the magnetic energy in the mutual impedance of the transmitter and receiver. In particular, the proposed multi-coil system is designed to be efficient for low-coupling conditions, as is typical in biomedical applications. We will demonstrate the performance of the proposed transmitter by comparing it with other commonly-used transmitter solutions, such as series/parallel coils and coils terminated with a resonant capacitor.