Resonant Inductive Coupling for Long Range Wireless Power Transfer

Cole A. Nieslen
niels538@umn.edu
EE 4161W

***Abstract*—Wireless power transfer (WPT) has the potential to revolutionize how electronics are powered by removing the need for cable-based power solutions. This will be made possible by the availability of long range WPT technology that will allow for power transmitters to be built into spaces (houses, buildings, cars) to power electronics with receiving coils. There is great challenge in the design of long range WPT systems, however, due to issues arising mostly from insufficient coil coupling and efficiency. A solution to this problem is resonant WPT, where transmit and receive coils are designed to resonate with high Q at one frequency, which means high efficiency (low loss) and enhanced coupling. This technology has promise in allowing for power transfer in the range of meters, which is ideal for powering portable electronics in a building and similar environments. The availability of low frequency (1-100 MHz) ISM bands that allow for unrestricted radiation of RF energy are a key factor that suggests the development of this technology is wholly feasible from a regulatory stance. The usage of these RF bands also allows for miniaturization of receiving coils, making it feasible to place receiving coils in portable electronics. All together the future of wireless power transfer featuring resonant technology looks promising in simplifying access to energy demanded by modern societies.**

I. Introduction

The explosive rise of mobile electronics in the recent history has introduced many new technological issues yet to be resolved. One stalled issue is how to power these devices. Traditionally, portable devices have been powered with secondary battery cells that are recharged via cable based methodologies. Consumer demand for increased battery life as well as greater device mobility however has been at odds with these traditional methods have done little to improve battery life since the advent of lithium battery technology. These issues have spurred interest in alternative technologies such as wireless power transfer (WPT). Generally wireless power transfer refers to cableless and contactless methods for power transfer. Some common approaches involve acoustic waves, light and RF and electromagnetic induction. Practically WPT is limited to RF and low frequency electromagnetic methods due to their high achievable efficiencies (90% +) compared to essentially all other methods. Currently most deployed WPT technologies are what is referred to as *inductive*, meaning they rely on the coupling of magnetic field between inductors (coils). Current standards such as QI, unfortunately, are designed to be near field only and limit power transfer to within a few centimeters of tethered transmitters, providing no resolution to the battery life issue. This limitation is because of a fundamental physical limitations for how well two coils can couple at a distance, which correlates to effectively power can be transfered. Coupling can be thought as closely related to the amount of flux leaving a transmitting coil compared to a receiving coil. Given EM field typically follow inverse distance laws for field strength, it is easy to understand how coupling greatly drops with distance. A newer technology called *resonant inductive coupling* [1] however has promise for long range wireless transfer and the coupling issue. While still relying on magnetically coupled coils, this solution differs in that it uses resonant high Q (low loss) coils that are all tuned to the same frequency for both the transmitter and receiver. In effect, the method works by storing energy not transmitted in a given cycle in the resonant transmitter coil. This results in a stronger field emitted by the transmitting coil and thus more flux coupling with the receiving coil, therefore greater power transfered than regular inductive methods. This is important as it can allow for devices at a distance, such as the height of a phone in hand or a computer on a table to be powered wirelessly by a remote transmitter. This transmitter could be built into the floor, wall or ceiling of a room, the interior of a car, or perhaps the floor of a garage to power electric cars. The effective integration of these transmitters into commonly inhabited environments stands as the solution to the mobile device power problem, as it would allow for the devices to be constantly powered and charged without the need for cables. Many issues stand with the realization of this technology, such as system cost, coupling and load matching to a spatially mobile device, efficacy of coupling to small receivers such as cell phones and efficiency issues due to coupling to unintended metallic objects. There are also many enabling factors as of recent, such as the availability of cost effective, high speed GaN power transistors that allow for this technology to be implemented in previously difficult to utilize but open for use ISM bands. To be a viable solution to the powering of mobile devices, resonant inductive coupling based WPT must address all of these issues and show viability to power consumer devices at full load at commonly used distances. Therefore, this paper seeks to explore the vulnerabilities and feasibility of this technology to power electronic devices as a future option to power the needs of modern electronics.

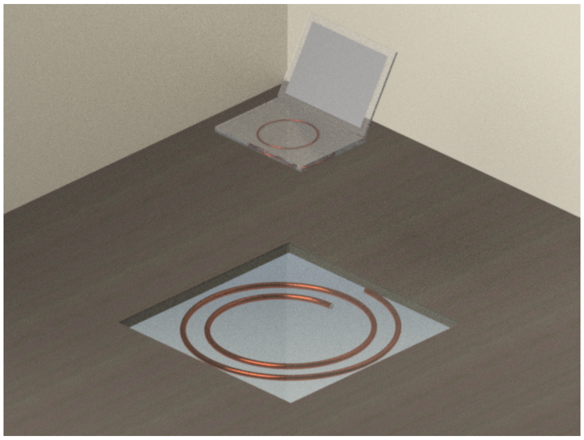

Fig. 1. Visualization of a hypothetical resonant inductively coupled WPT system. The picture shows a large transmitter coil built into the floor of a room that would emit power via a oscillating magnetic field. A computer, shown hovering above the transmitter would also contain a coil as shown that would couple to the transmitted magnetic flux and absorb transmitted power. Note the receiving coil is much smaller than the transmitter. A large transmitter coil is needed in order to allow for reasonable coupling to the receiving device over a large number of positions. A challenge associated with this is a small portion of the transmitters flux passes through a given receiver. Therefore the transmitter requires a very high Q to ensure energy of the flux not coupled to the receiver is not lost, but stored to be later absorbed by the receiver.

REFERENCES

[1] 1. A. Massa, G. Oliveri, F. Viani and P. Rocca, "Array Designs for Long-Distance Wireless Power Transmission: State-of-the-Art and Innovative Solutions," in Proceedings of the IEEE, vol. 101, no. 6, pp. 1464-1481, June 2013.