Electrical Energy Transmitted Without Wire through the Magnetic Resonance

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Abstract: **We briefly review the methods behind mid-range wireless power transfer using Strongly Coupled Magnetic Resonance (SCMR) to power embedded systems applications. From these reviewed methods, we then develop a mathematical model for SCMR to calculate resonant frequencies and other electrical characteristics for a given coil in MATLAB. The results from the model are verified experimentally through the implementation of several design iterations. The MATLAB model is accurate to within 10% of the experimental values. We also discuss the optimal design for maximum wireless power transfer and the constraints associated. We present a significantly scaled down design with wireless power transfer via SCMR over 10cm using 8.25cm diameter coils, roughly 7.5 times smaller. The smaller design makes it an excellent choice for powering small scale embedded systems applications.**

Index Terms: **SCMR, WPT, Strongly Coupled Magnetic Resonance, Wireless Power Transfer, Power, Mid-Range.**

I. INTRODUCTION

The transmission of power wirelessly has long been dream of pioneers in the field that would eventually become Electrical Engineering, namely Nikola Tesla. While Tesla was indeed able to demonstrate mid-to-long-range wireless power transfer over a century ago, safe and practical methods for achieving similar results have only been discovered recently in 2007. This method which exploits electromagnetic resonance, or rather, an object's tendency to oscillate at large amplitudes at specific frequencies was deemed Strongly Coupled Magnetic Resonance (SCMR) bits discoverers. Although there are many electromagnetic phenomena capable of wireless energy transfer from one point to another (for example, transformers, which demonstrate a high efficiency at very close distances), SCMR is the only method capable of efficiently transferring energy in the mid-range (that does not require an uninterrupted line-of-sight) where the transfer distance is several times greater than the radius of the transmitting device. Previous work done and a basic understanding of SCMR systems is presented in section 2. Mathematical modelling and MATLAB implementation of resonating coils and their associated geometric and electrical characteristics are discussed in section 3. We also analyze the effects of varying geometric parameters of a coil on electrical characteristics. Experiments using multiple coil designs and respective results are presented.

II. BACKGROUND

Over the past 20 years there has been an inordinate increase in the amount of mobile electronics (smart phones, tablets, laptops) being manufactured and purchased across the globe. While these devices have produced endless conveniences for the end-user they still present the inconvenience of statically tethering the user to an outlet when the battery runs low. Thus, a recent interest in midrange wireless power transfer has led to the discovery and development of SCMR systems. The idea behind wireless power transfer via SCMR is quite simple from an intuitive standpoint objects that share the same resonant frequency will efficiently exchange energy, and lose only a relatively small amount of that energy to any off-resonant objects encountered by the resonating field. Thus, SCMR system consists of a 2 or more identically tuned (usually identically sized) resonating coils – a transmitter and a receiver. In order to excite the resonant frequency in the transmitting resonator however, a single turn loop, which is connected to a source outputting power at the resonant frequency of the dual-coil system, is inductively coupled to the transmitting coil. In order to use the power obtained at the receiving end resonator, one or several loops will be inductively coupled to the receiver. This is so that the receiving resonator has no direct contact with the electrical load, as it would ultimately alter the resonant frequency otherwise, preventing the coupled magnetic resonance from occurring. A simple illustration of an SCMR system is shown below in Figure 1

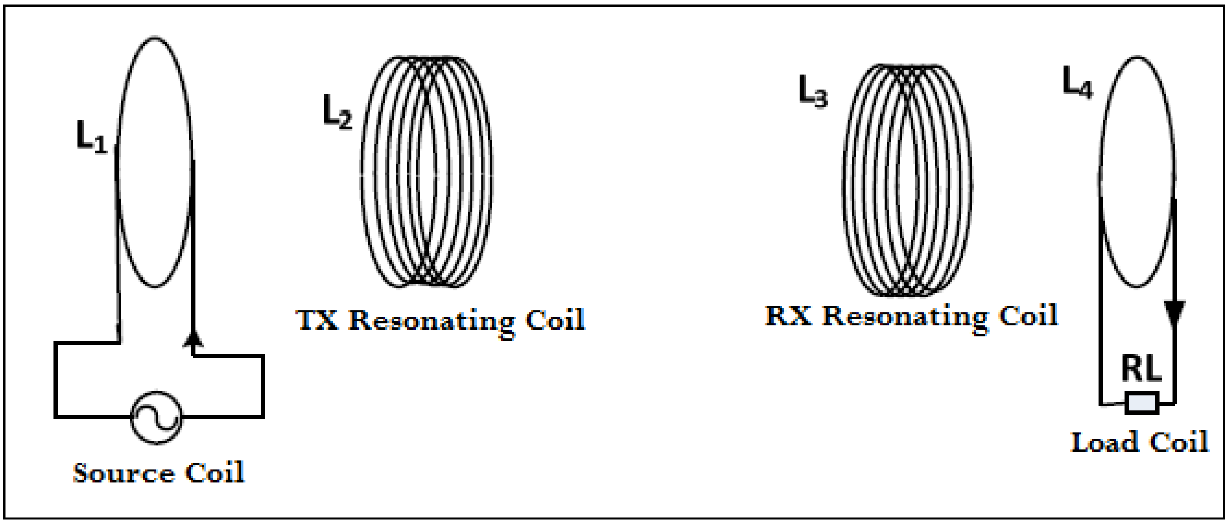


Figure-1. Basis for an SCMR system

In the earliest SCMR experiments performed at MIT, large 5-turn, resonating coils with a radius of 30 cm (2 feet in diameter) were used to transfer 60W over 2 meters at 40% efficiency (60W received / 150W transmitted). As revolutionary as this first SCMR system was, its large size makes it impractical for use in everyday low-power, mobile electronics. The most recent work in SCMR was performed in 2014 with the goal of creating SCMR systems to charge batteries in medical devices implanted under the skin. This however, is still only intended for use in a controlled environment, with a stationary patient, positioned directly in front of the resonating source. As wonderful as the application of preventing invasive surgeries is, SCMR in this application context defeats the original motivation of allowing an end user to use their mobile device without the requirement of fixing themselves to a power source. Our goal is to design and build a scaled-down version of the original SCMR system, with the intended application of mobile, embedded-systems.

III. RESULT

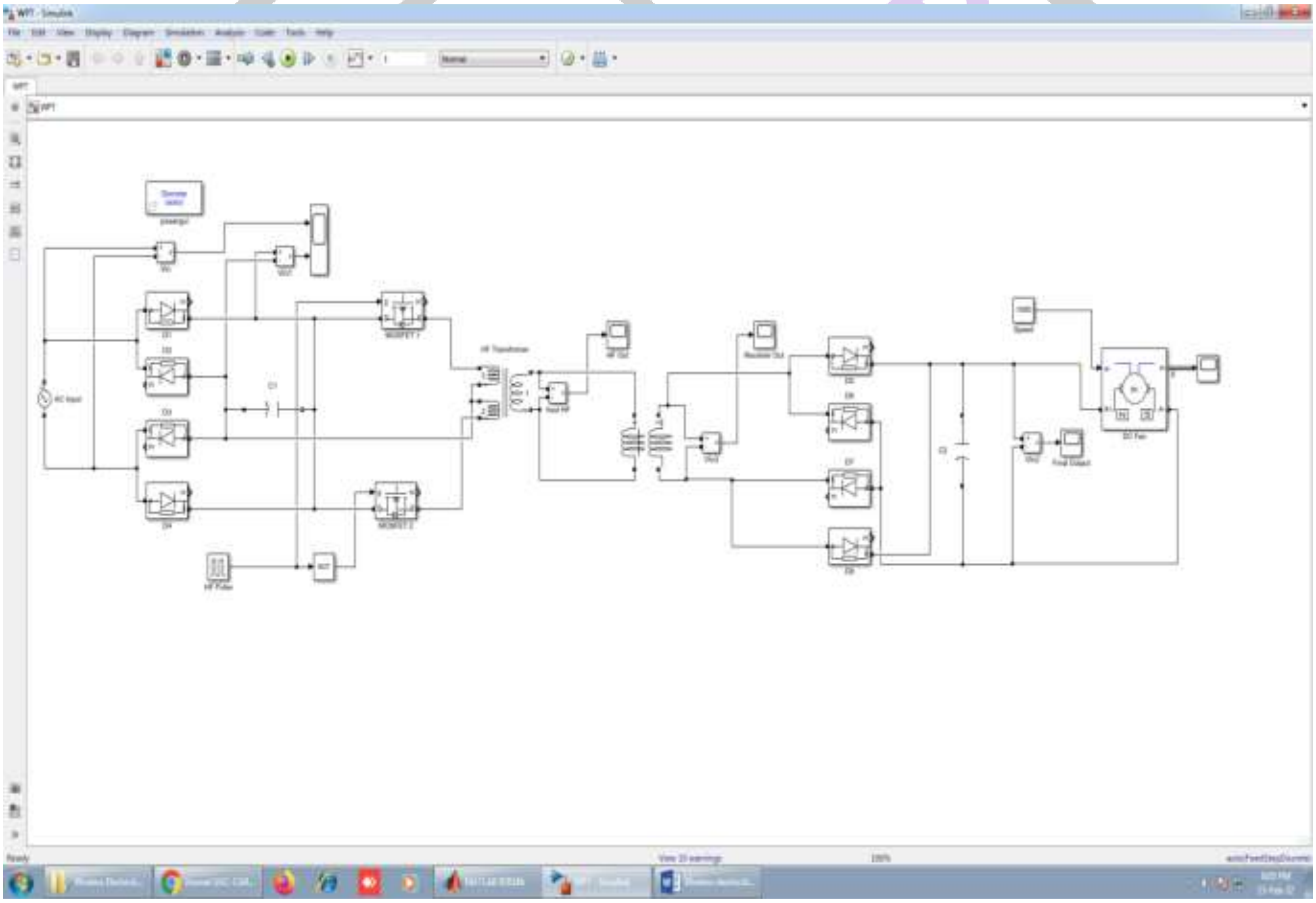
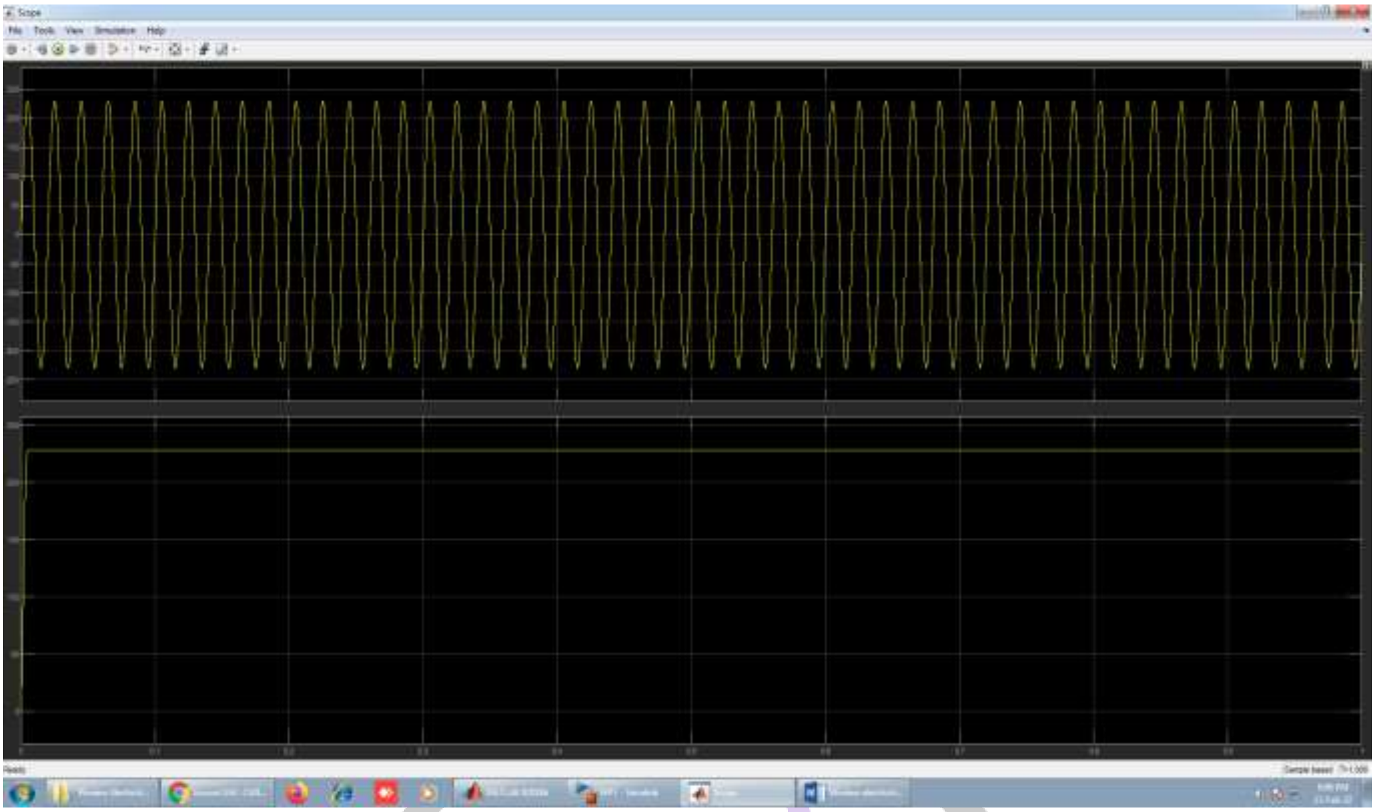
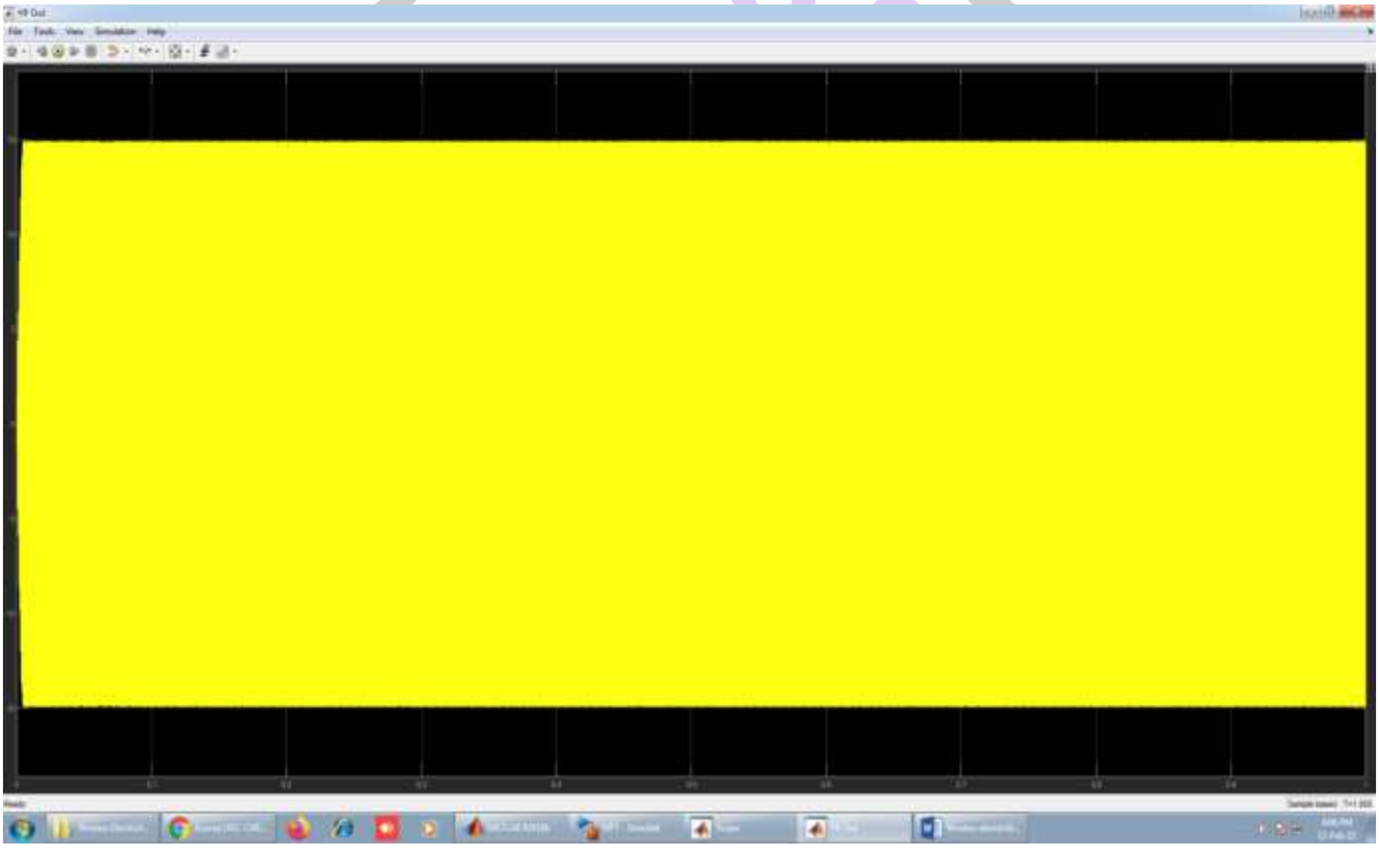
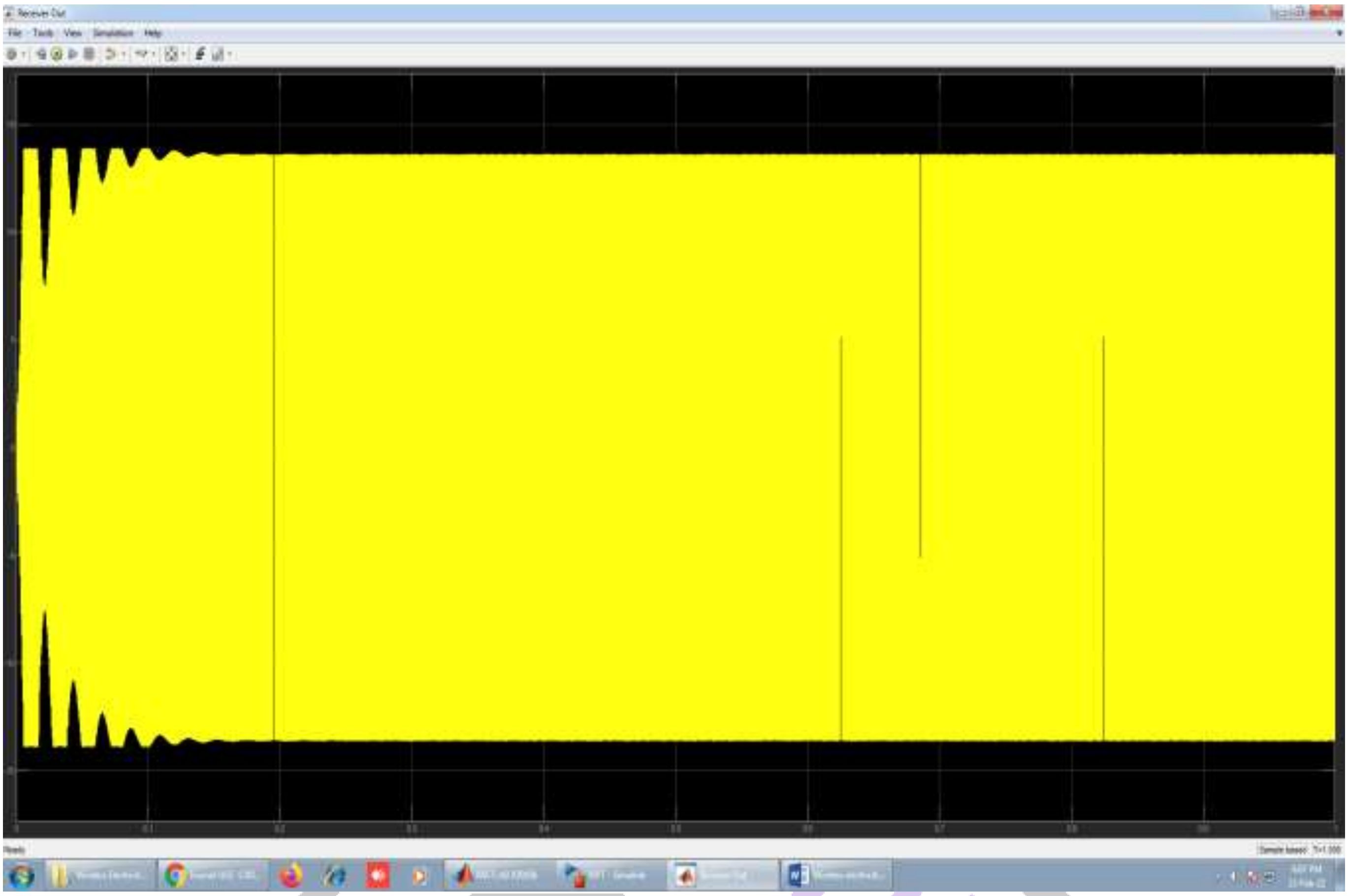


Figure-2. Wireless Power Transmission Matlab Simulink







IV. CONCLUSION AND FUTURE WORK

In conclusion, we successfully developed a scaled-down version of an SCMR system intended for use in future embedded systems. It is lightweight, economical, consistent with the model, relatively easy to maintain, and can be built in just a few hours with proper training. The MATLAB model is accurate within 10% of the experimental values. While our SCMR system is indeed a viable solution, the next challenge to tackle is that of efficiently driving the resonators at higher power. The alternative of using a Colpitts oscillator reliant on large 500W tube amplifier is not nearly efficient or small enough to be used in a personal router-like form factor. Finally, experimentation with a phased-array of multi-harmonic resonators, the effects of superconductive temperatures on SCMR, cylindrical waveguides as field directing mechanism, and of course, a sustainable flight drone, are all untouched areas of research that we plan to explore.

The original team from MIT went on to form a company called WiTricity. Their products, wireless cell phone charger and wireless electric car battery charger are commercially available but significantly scaled down and therefore, shorter range than 2 meters.

We picture a future where wireless power is available in homes, cafes and offices just like wireless internet. Devices ship with RX resonating coils built-in and a standardized SCMR system with dedicated resonant frequencies to operate on. One would simply walk into a building and their devices would start charging in its wireless power cloud.

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