Magnetic Localization for Capsule Endoscopy

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Introduction

A variety of wireless medical devices have the potential to treat or diagnose medical conditions along the gastrointestinal tract in a non-invasive manner through imaging, drug delivery, and many more systems. However, these devices can only be useful when used in conjunction with a positioning system to know where exactly the device will treat or has diagnosed a medical condition.

The ACME (Analog/RF IC, Microsystems, and Electromagnetics) lab, led by Prof. Constantine Sideris, is developing and implementing a magnetic localization technique to track the position and orientation of wireless medical devices, specifically capsules, as they move through the human body. Our research is challenged by limited power consumption due to the small size of capsule battery and achieving a high signal strength with limited bandwidth. This summer, I simulated the magnetic induction (MI) model.

Experimental Setup

Since our localization technique is based on magnetic field communication, the model needs to consist of a magnetic field source and sensor to measure it. These components will be in the form of:

- Three transmitter (TX) coils situated around the body
- A receiver (RX) coil placed inside the capsule

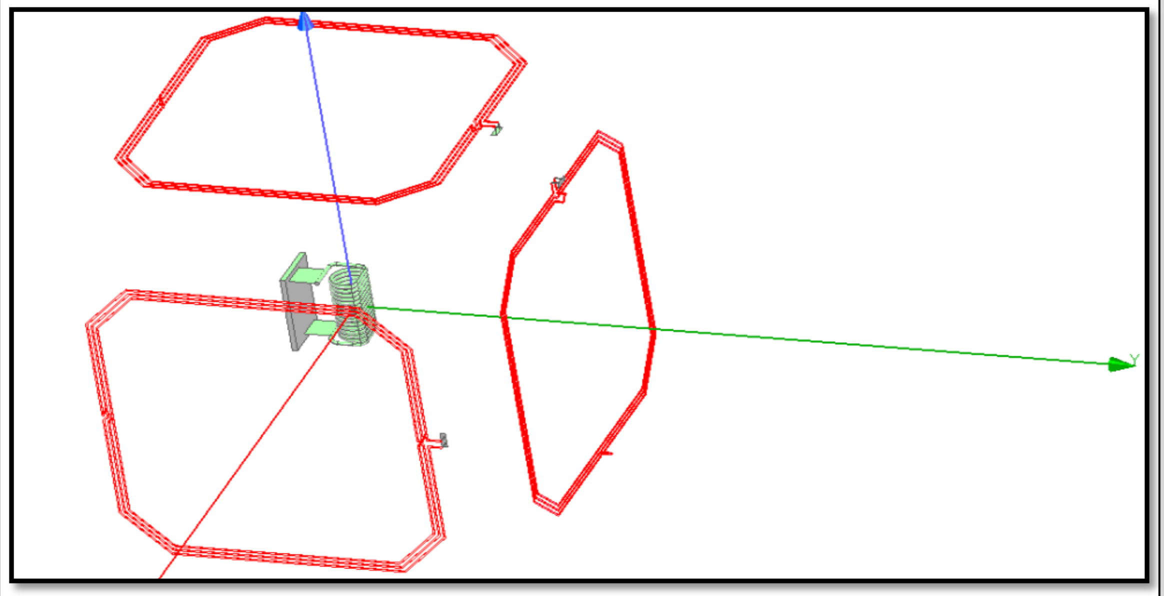


Figure 1 - TX and RX coils in HFSS. PC: Eric C.

Process

Principles behind the Research:

- We can establish magnetic communication between the TX and RX coils due to **two characteristics of magnetic induction**, which are:

1) A coil creates a changing magnetic field when an alternating current flows through it.
2) A changing magnetic field induces a voltage on the RX coil.

- Using the TX and RX coils, we can model these effects. The TX coils are excited with an alternating current, and an induced voltage can be picked up at the RX coil depending on its position and orientation.

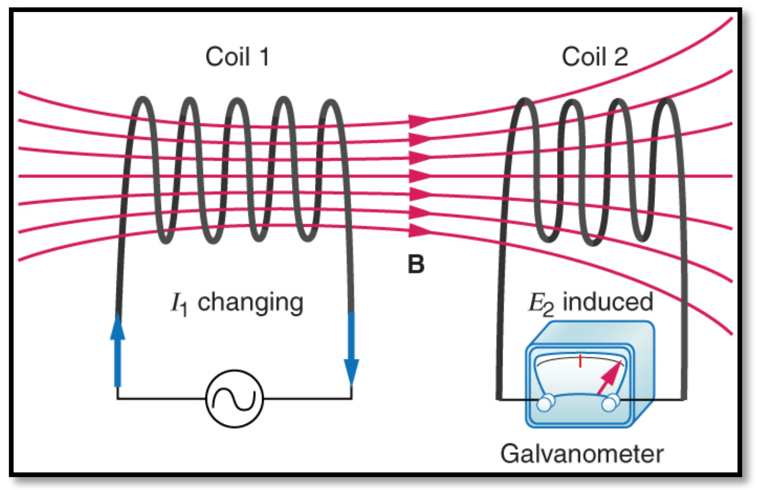


Figure 2 – Coil 1 acts as TX, coil 2 acts as RX. < PC: www.openstax.org >

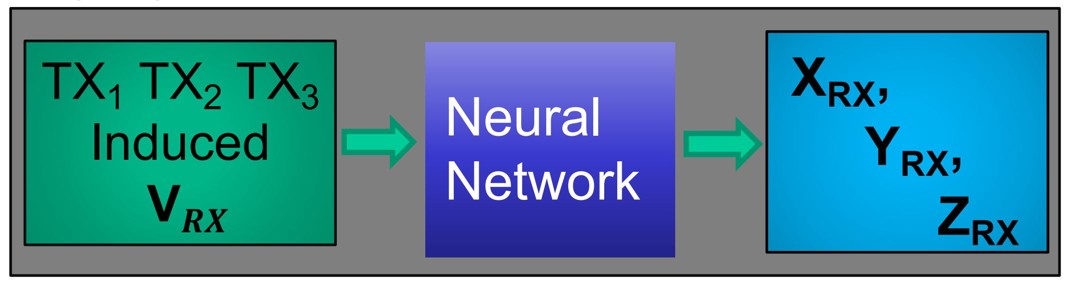
Simulating the Model:

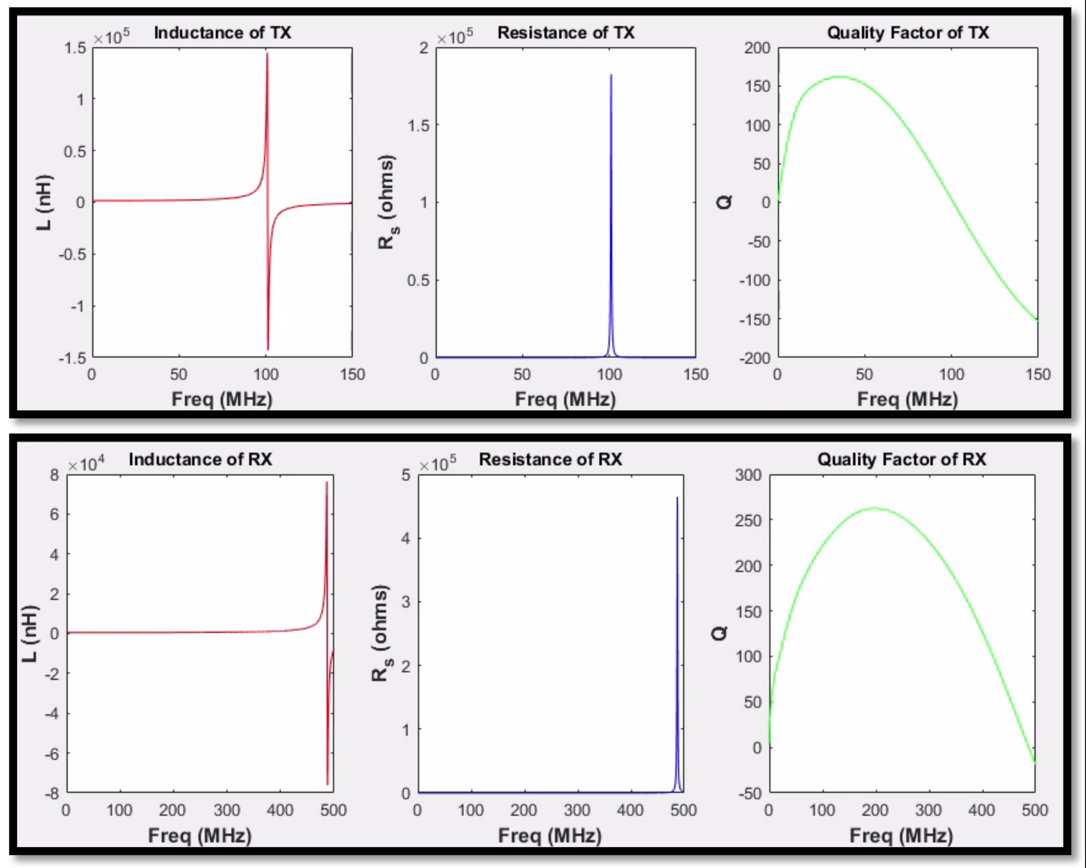
- Using ANSYS HFSS software, I simulated a model with the RX at the origin and a TX at each axis 50 mm away from the origin, as shown in Fig. 1.
- Using MATLAB, the magnetic field strength is plotted across each axis for every excited TX coil.

- For the TX and RX coils, their inductance(L), resistance, and quality factor parameters were extracted over a range of frequencies, which are important because they are correlated to the voltage produced in RX. In the following equation shows the correlation:

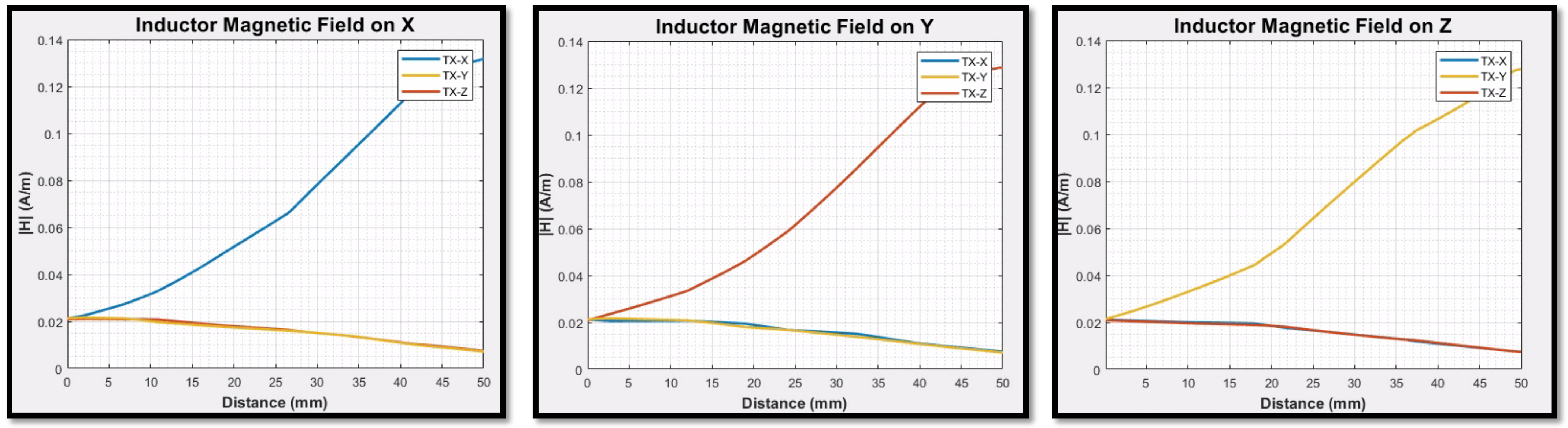
$$V_{RX} = -k\sqrt{L_{RX}L_{TX}}\frac{dI_{TX}}{dt}$$

- From the induced voltage at RX from 3 different TX coils, we can predict the position and orientation of the RX coil using a neural network.





Figures 6,7 - Inductance, Resistance, and Quality of the coils. PC: Eric C.



Figures 3,4,5 – These graphs demonstrate a decaying magnetic field as the distance from each excited TX coil increases along a given axis. PC: Taken by Eric C. in MATLAB.

Relevance to my STEM Coursework

My SHINE experience has reinforced my interest and fascination in STEM, specifically electrical engineering. The feeling of working in a lab and creating new innovations is one that I connected to well.

In addition to the enjoyable experience, I also gained some practical knowledge ranging from electromagnetic principles to coding skills. Also, the ability to absorb information from research papers is a valuable skill I learned, which I will use to further my STEM knowledge throughout my high school career.

Advice for Future SHINE Students

Experiencing SHINE is a rare opportunity, so it is to your advantage to make the most of it through these main points:

- Don't just do the minimum of what is asked of you. Self-learn more about your research topic to where you curiosity takes you.
- Think about the big picture. Ask questions each step of the process to understand its importance to the research.
- Build meaningful and lasting relationships. Understand that research has a social aspect to it as much as an academic aspect.

Acknowledgements

I want to thank Professor Sideris for generously welcoming me into his lab. I would also like to thank my SHINE lab mentor, Michella Rustom, for guiding me throughout the research process and ensuring a challenging yet feasible environment. I am also very grateful to Dr. Mills, Cathalina Juarez, Dr. Herrold, and the rest of the SHINE team for a rare and unique experience.