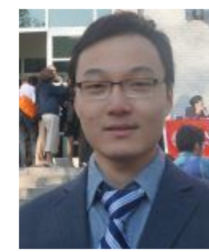
NSF Cooperative Agreement EEC-1160504

TANMS

Northeastern University
Advanced Materials and Microsystems Laboratory (AMML)

Thursday, April 25, 2019 | 3:20 PM EST

Principle Investigator: Nian Sun **Mentor**: Cunzheng Dong
Undergraduates: Sebastian Ardila, Jacob Puderbach, Ann Waye



UCLA | CSU Northridge | UC Berkeley
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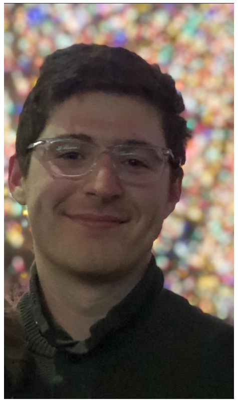
Research Team Introduction

Sebastian Ardila

- Mechanical Engineering first-year student
- Pursuing a path in prosthetics
- Born and raised in South Florida

Jake Puderbach



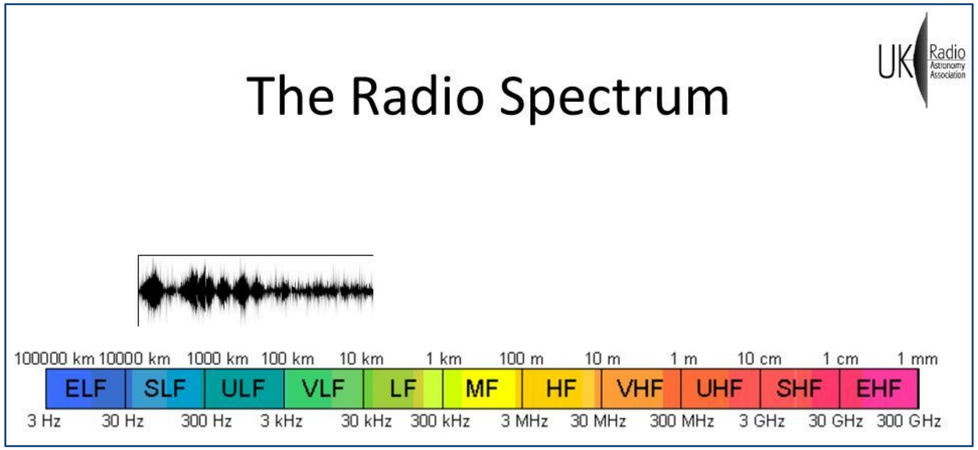
- Electrical Engineering and Physics first-year student
- Interested in IP law and circuitry
- Originally from (near) Philadelphia, PA

Annie Waye

- Computer Engineering second-year student
- Pursuing a path in robotics and energy
- Hometown: Bethesda, Maryland
- Upcoming co-op RKF Engineering in Washington, DC

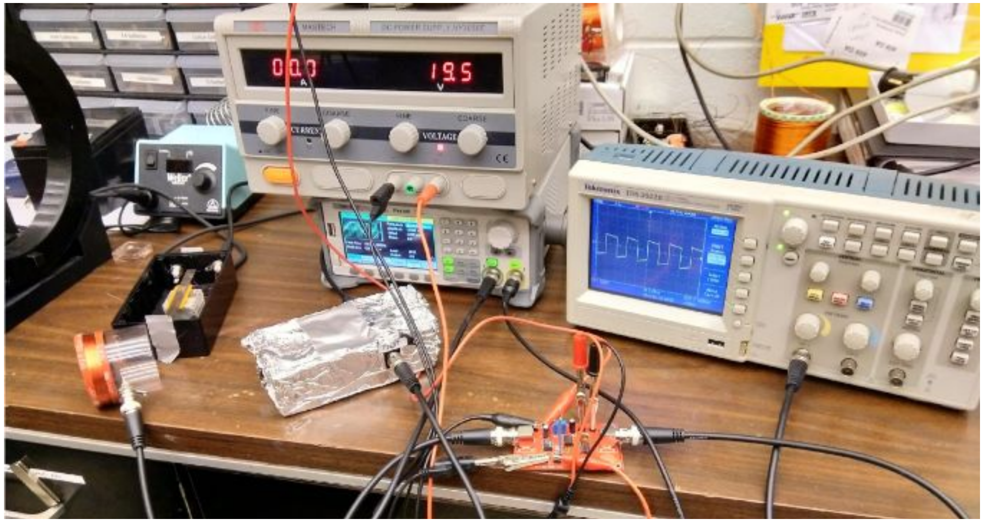
Definitions

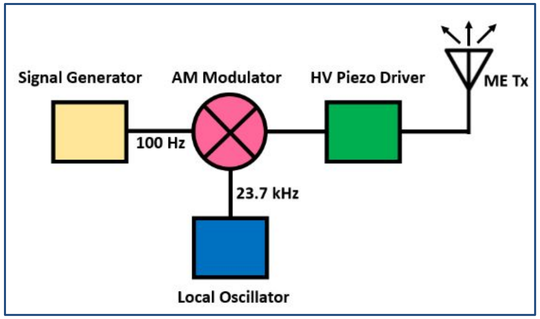
- **Magnetometer:** detects signals
- Very Low Frequency (**VLF**): 3 to 30 kHz range
- **Signal-to-Noise Ratio:** how clearly the signal is detected
- **Sensitivity:** ability to detect weaker signals
- **Core:** changes the permeability of a coil transceiver
- **Supermalloy core**: ferromagnetic alloy
  - high magnetic permeability: support the formation of a magnetic field
  - low coercivity: withstand an external magnetic field without demagnetizing



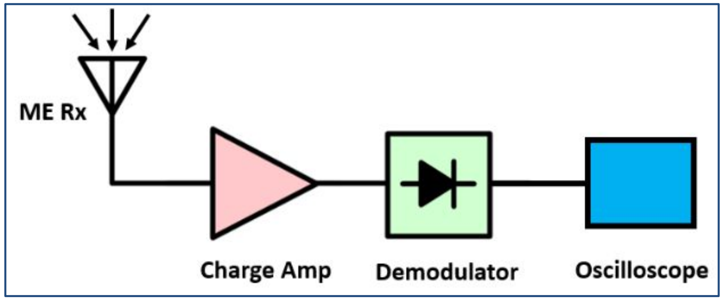
KHz ME Antenna OOK Modulation & Demodulation Test

- Testing modulator and demodulator
- Magnetoelectric (ME) antennas transmit and receive VLF EM waves
- ME coupling at their mechanical resonant frequencies, not EM resonance
- Coil transmitter with ME Antenna receiver vs.ME Antenna transmitter and receiver
- Designed custom coil receivers
- Analyzed impedance of various coil designs





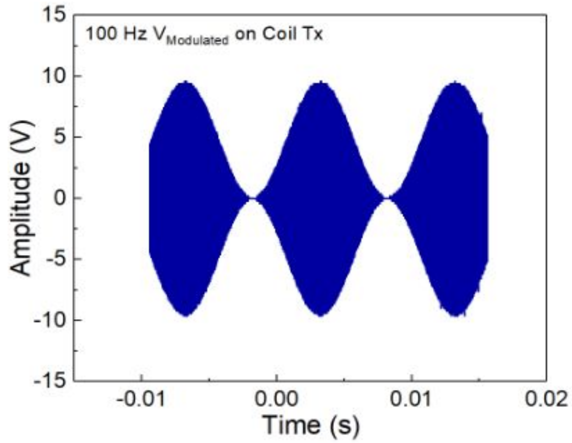
Transmitter (top)
Receiver (bottom)

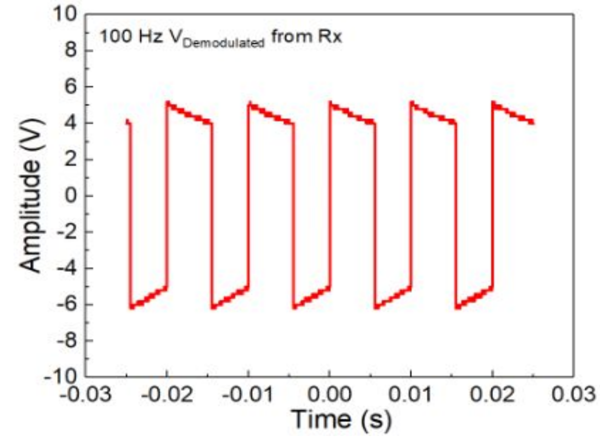


Primary Findings: Modulation & Demodulation Test

Coil Transmitter:

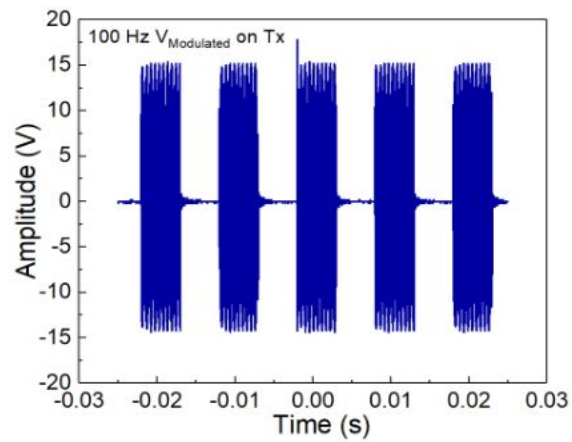
- Amplitude modulation by function generator
- signal modulated to step function, transmitted, received, and demodulated to read the carried step function

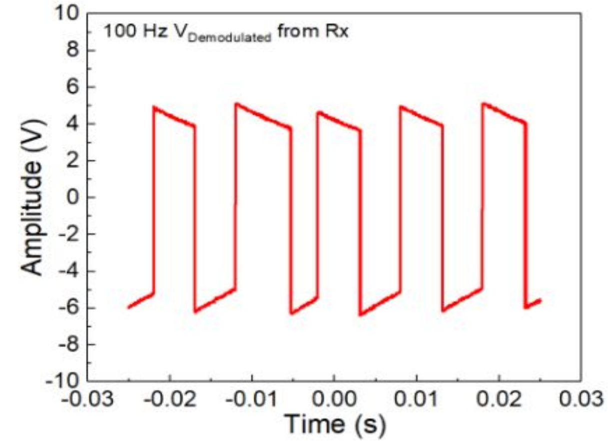




ME Transmitter:

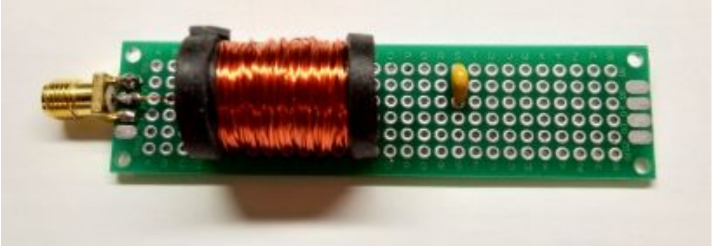
- 100 Hz modulated signal (generated by self-designed high voltage piezoelectric driving circuit)
- Confirms successful VLF communication link between ME transceivers





Coil Magnetometer for VLF Communication

- Coil geometry critical to performance and sensitivity
- Aiming for a magnetometer with 10 femtotesla sensitivity
- Began with an air-core coil magnetometer
- Most recent design uses a permalloy core and smaller cross-sectional area
- Following the work of H. C. Séran, and P. Fergeau, authors of "An optimized low-frequency three-axis search coil magnetometer for space research"[1]



(air core)

(supermalloy core)

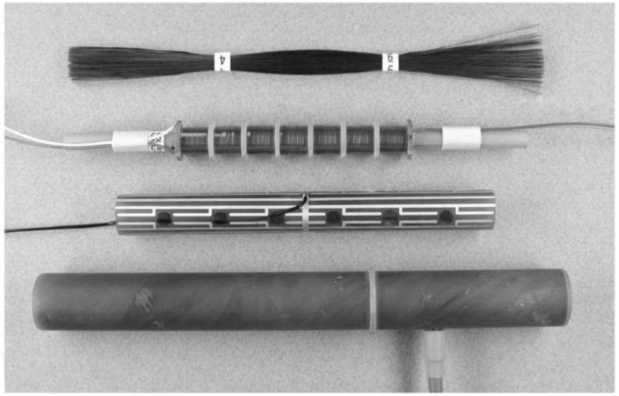
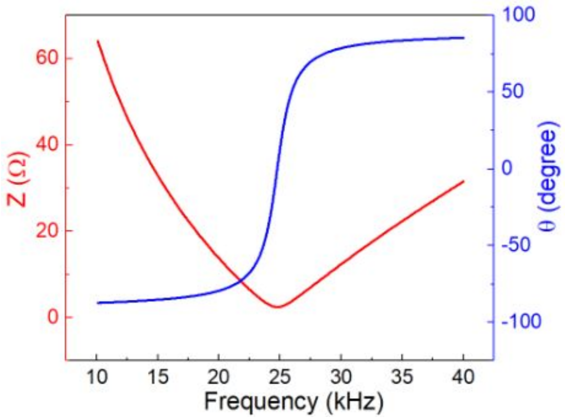
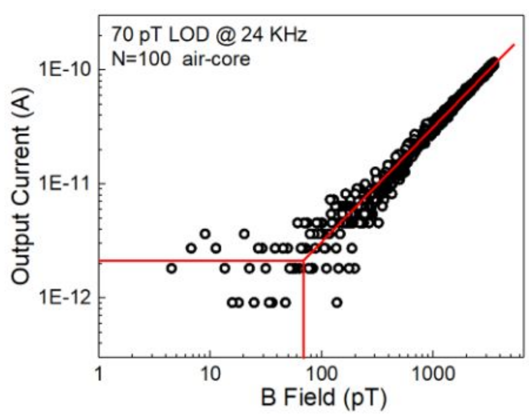


FIG. 1. Breakout view of one search coil. From top to bottom: Stacked strips of permalloy, epoxy mandrel and winding, electrostatic shield, and potted search coil in final epoxy tube. [1]

Primary Findings: Coil Magnetometer

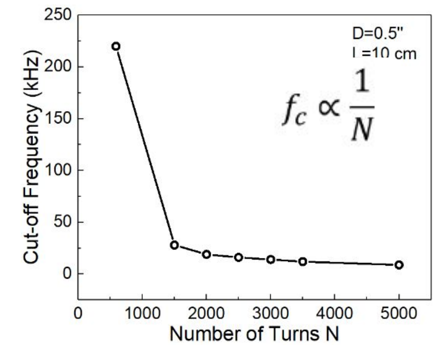
AIR CORE



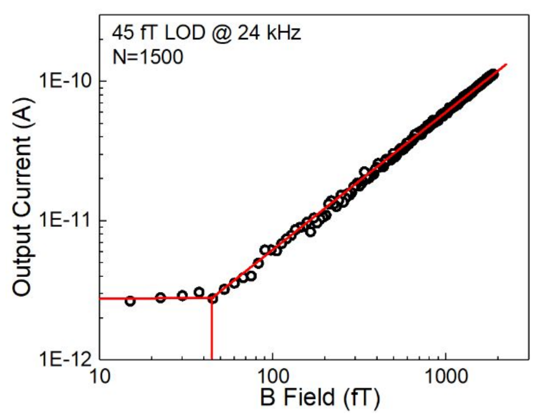


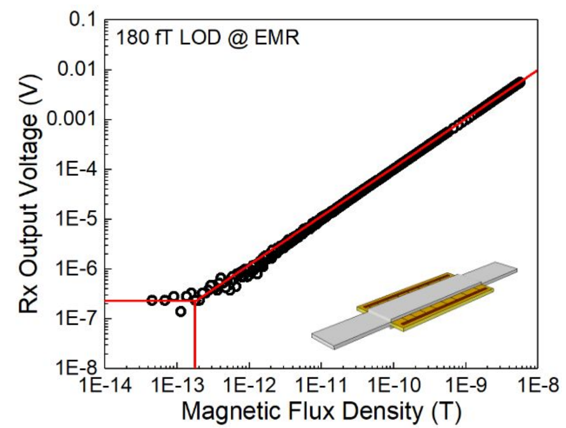
SUPERMALLOY CORE

- understanding the tradeoff/ proportionality between cutoff frequency and number of turns



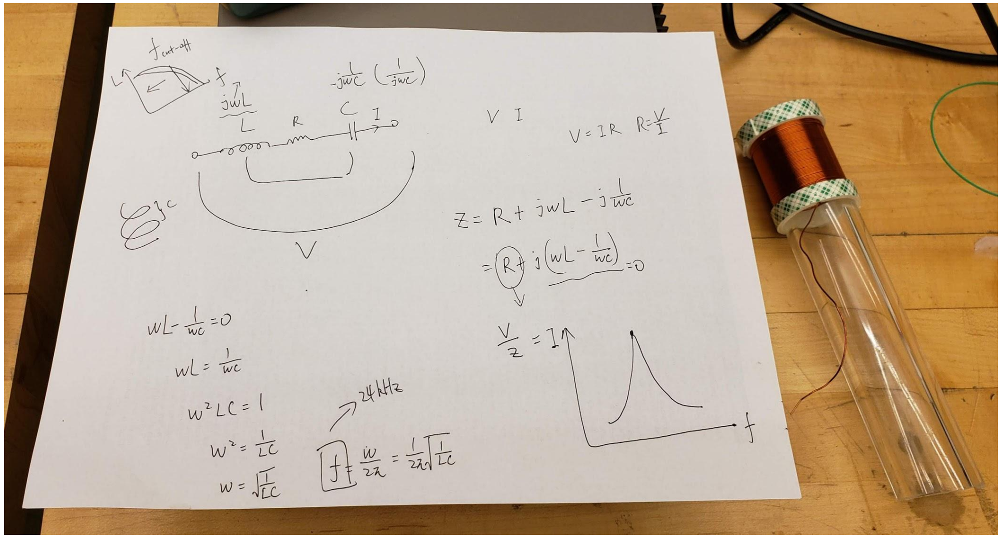
Results of coil (below) vs. flat antenna (below right)





Research Challenges and TANMS Connection

- Two papers published to accredited journals with topics too similar to our subject
- Acquiring/creating/winding materials and coils takes time
- Testing was slow, postponing experiments occasionally
- Parasitic capacitance causing problems
- TANMS connection: Translational Applications of Nanoscale Multiferroic Systems
- VLF ME/piezoelectric antenna research is highly connected
- TANMS publication suggested that “an electrically small multiferroic antenna is superior to a conventional compact antenna of similar size”



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Takeaways

Lab Experience

- Learning outside of a lecture room
- Throughout the lab and TANMS Modules/Workshops
- Experience/training with lab equipment and lab safety
- Appreciative of specific goals and real results

Literature Review

- Comprehensive literature review
- Apply the research to our designs, learning from others
- Gaining a strong understanding of specific topics through professional publications

Future work

- Hoping to apply this research/work in the future
- Keep in touch with our mentor and the lab
- Real-world experience with electrical/computer engineering

Sources

[1] H. C. Séran and P. Fergeau, "An optimized low-frequency three-axis search coil magnetometer for space research," *Review of Scientific Instruments*, vol. 76, No. 4, p. 044502, Apr 2005.

[2] M. A. Kemp, M. Franzi, A. Haase, E. Jongewaard, M. T. Whittaker, M. Kirkpatrick, and R. Sparr, "A high Q piezoelectric resonator as a portable VLF transmitter", Nature Communications, 10 (1), 1715 (2019)

[3] J. Xu, C. M. Leung, X. Zhuang, J. Li, S. Bhardwaj, J. Volakis and D. Viehland, "A Low Frequency Mechanical Transmitter Based on Magnetoelectric Heterostructures Operated at Their Resonance Frequency", Sensors 19 (4), 853 (2019).

[4] A.Grosz, and E. Paperno, "Analytical Optimization of Low-Frequency Search Coil Magnetometers", IEEE Sensors Journal, vol. 12, No. 8, 2719-2723, Aug 2012

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Questions?

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