Electronic Feedback Loop Sustaining Magnetic Resonance

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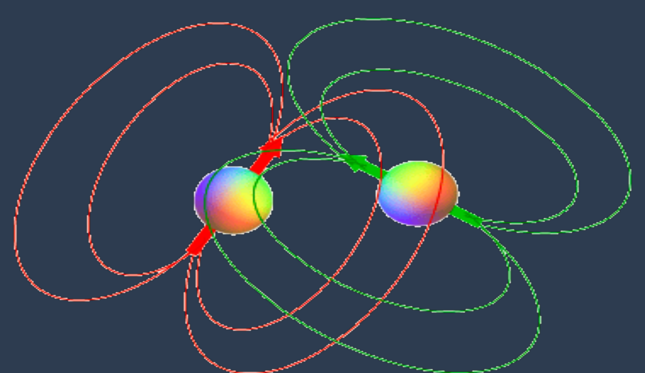

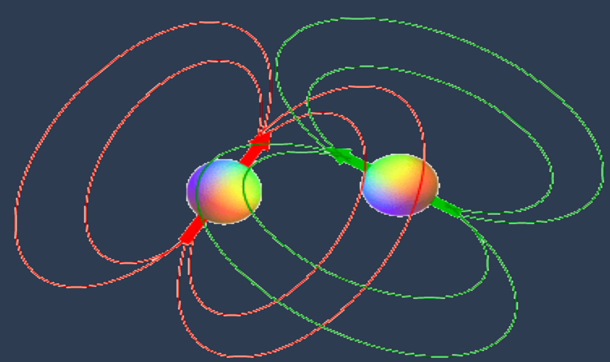

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Introduction

Resonance is a phenomenon where the response amplitude of a system is largest when the frequency of a periodic external applied force is close to the natural frequency of the system. The driving force can either add energy into the system as a gain, overcoming natural friction so that the amplitude increases indefinitely, or removes energy, contributing to the frictional loss.

To obtain resonance of a magnet we developed a feedback loop by using a pick-up coil to sense the frequency of the magnet as it oscillates. The sensory info gets sent into the Pi module to the Python code, which mathematically implements an amplifier, band-pass filter, and a phase-shifter based on the parameters required for precise feedback control of the desired gain or loss. Then the python code applies a force back at the magnet with a drive coil connected to the audio output sustaining the dipole's oscillatory behavior at resonance giving more info for the pick-up coil. If the optimal configurations are changed physically or computationally we get exponential decay.

Motivation/Applications

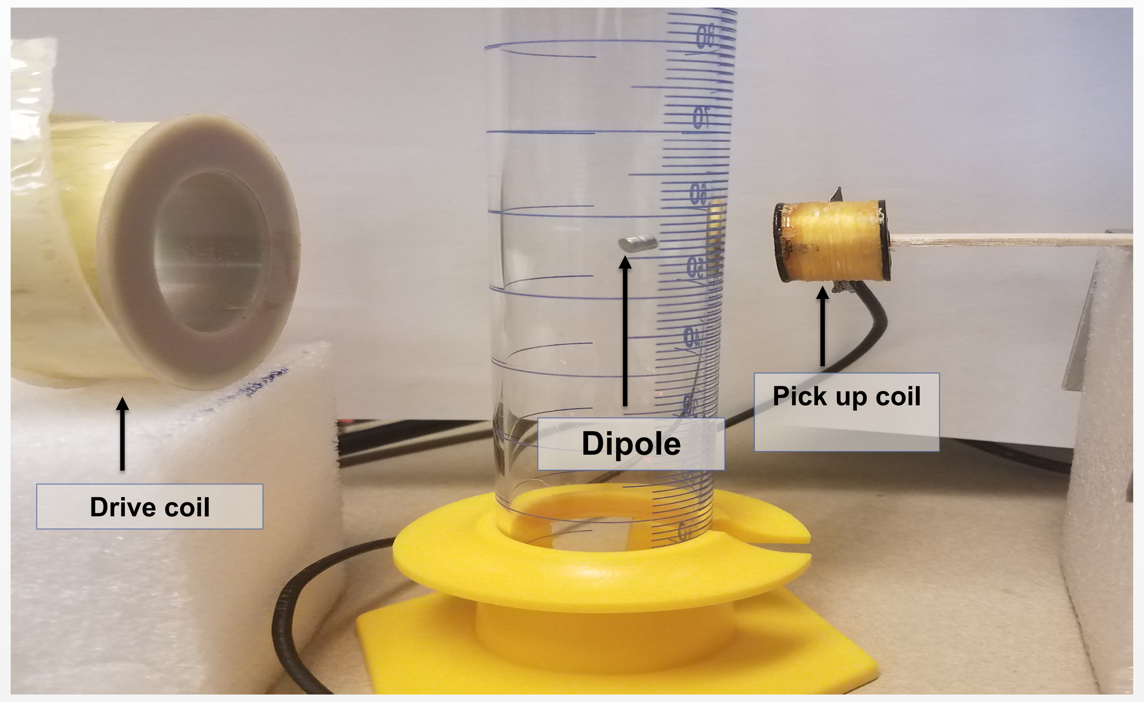
We aim to understand the behaviors of magnetic systems for further understanding of the nature of magnetic two and one-way signal transmissions in hopes of controlling electromagnetic waves.

Integration of software with hardware allows for increased sensitivity of the parameters in resonant systems. Implementing a new method of driving systems at resonance provides researchers with new instrumentation to use for research. The interchangeability and adaptive nature of the feedback loop enable users to alter input and output devices as well as change the parameters in the program to match their system. Using the necessary sensors to measure/drive systems with the feedback loop we can oscillate various object at their resonant frequency.

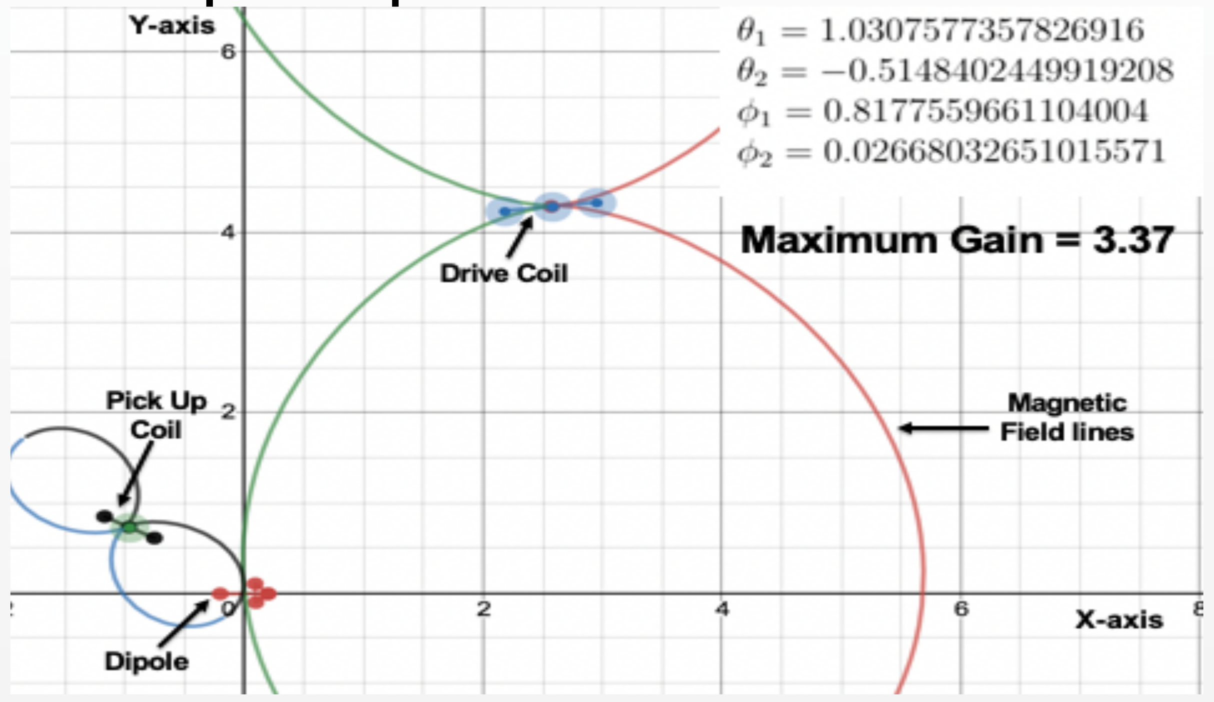
The introduction of these magnetic systems into switch devices can in creases their efficiency. Furthermore, they can be utilized for the future development of photonic and optical like single-mode microlasers with super-sensitive sensors. As well as NMR excitation and detection strategies.

Experimental Design

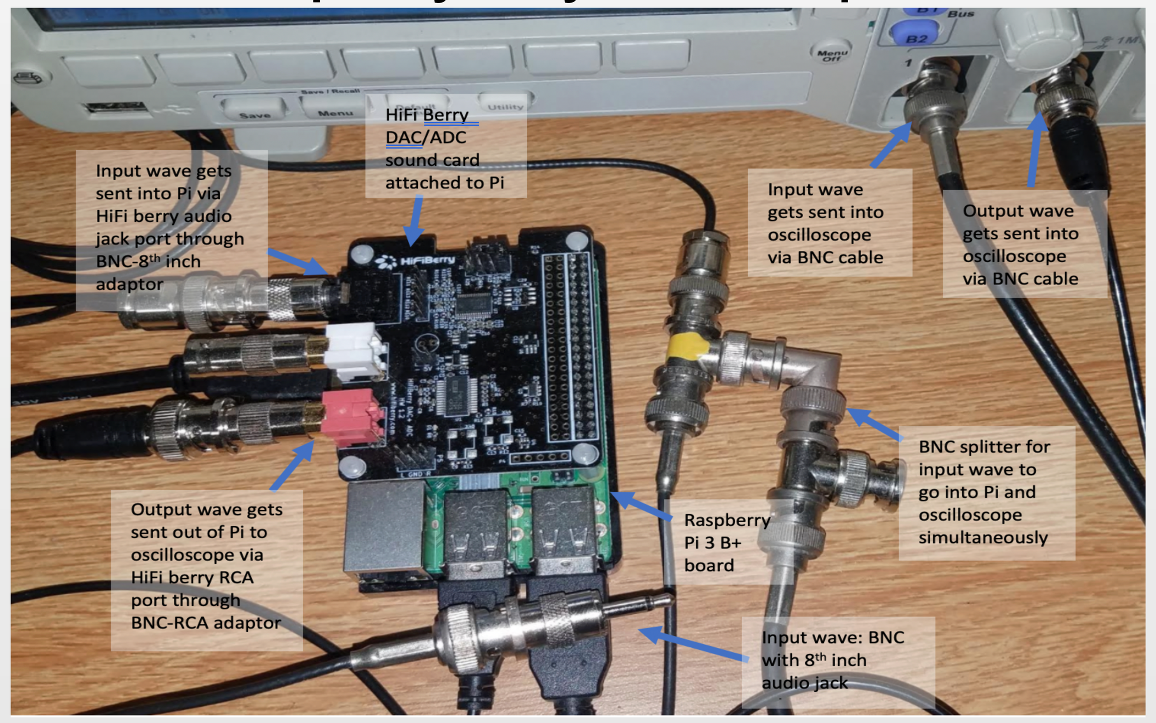
Coil/Magnet Set-Up



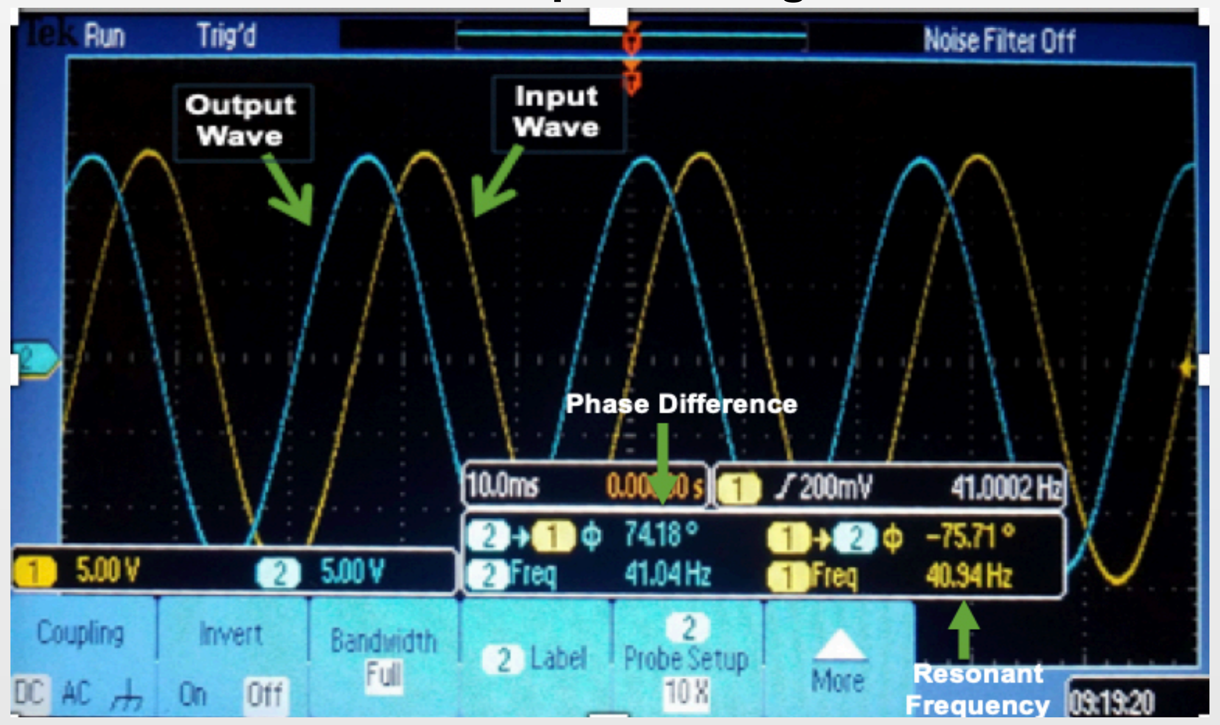
Optimal Spatial Orientations Identified



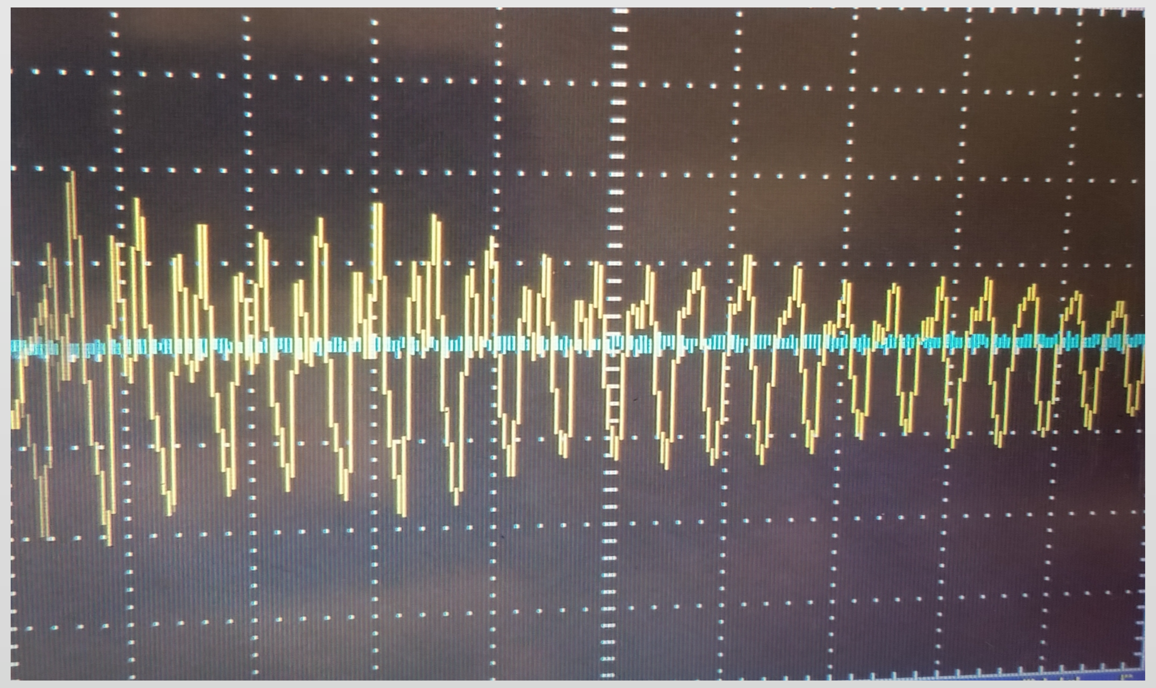
Raspberry Pi System Set-Up



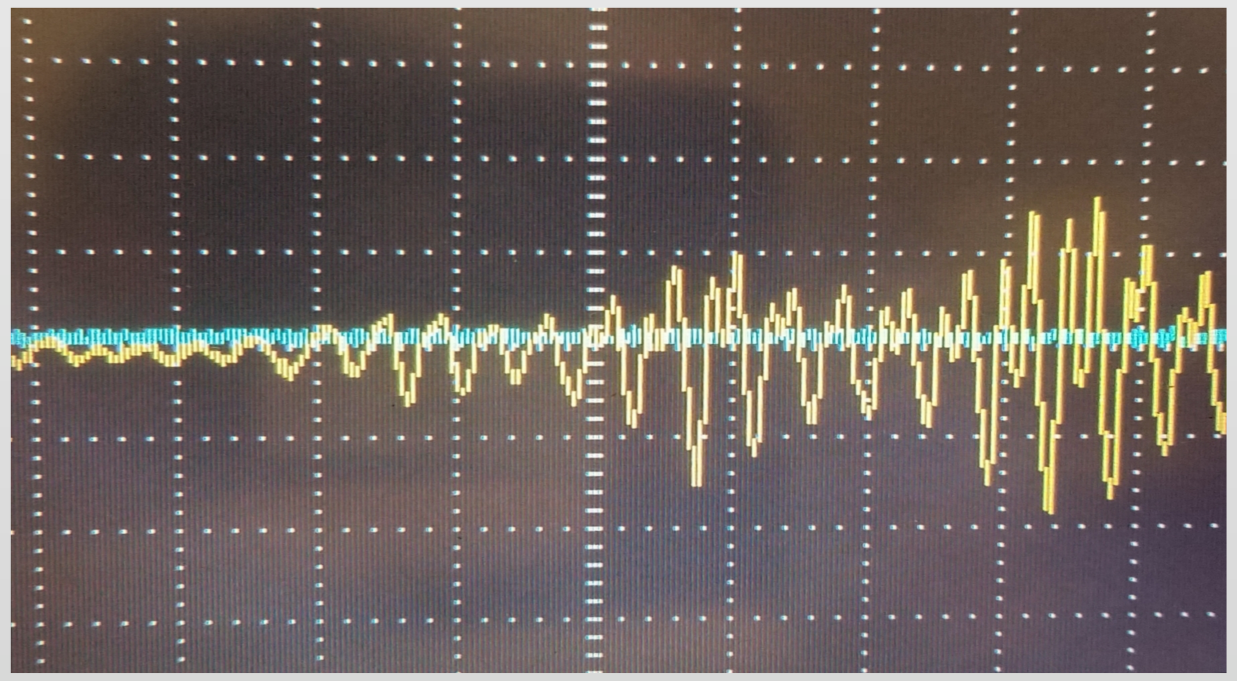
Oscilloscope Readings



Dipole Spin Loss Exponential Decay



Dipole Spin Gain Exponential Growth



Phase Difference Equation

$$\frac{d\emptyset}{df} = \frac{2Q}{f_0} + 2\pi\tau$$

To determine the internal processing time delay (τ) measurements of phase difference due to small changes in the input frequency were obtained giving a linear result. Using the slope from the date we found (τ) to be 92 milliseconds.

Phase Based on Delay Parameter

$$d\emptyset = 2\pi * \text{Delay} * \frac{\text{Resonant Frequency}}{\text{Sample Rate}}$$

Any phase shift can be predicted by the formula above for any resonant frequency, sampling rate, or delay value in the program. The correct phase if chosen enables maximum electronic gain of the system. Total delay is (τ + additional delay).

Materials | Methodology | Results

We used a Raspberry Pi module with a HiFi Berry DAC ADC converter to filter electromagnetic waves and phase shifts them. We used an oscilloscope to observe the changes in the waves. BNC adapters were used to interface with the Pi.

PyAudio package was used to handle all the data inputs, outputs, and processing in the callback mode. A recursive filter was implemented with Numpy to restrict the allowed bandwidth of frequencies around the resonant frequency of interest. Phase-shifting was done using a delayed parameter to shift data by a discrete number of zero points. The inherent delay in processing was determined to be 92 milliseconds corresponding to a 3-4 cycle delay. Adding additional time delays with the delay parameter enables the output to be at any phase from 0°-360° or any multiple of those phases.

The feedback loop has a physical maximum gain determined by the orientation of the coils and a maximum electronic gain associated with a particular phase. Running the feedback loop program at the correct phase at resonance will cause the magnet to grow in amplitude even if it starts with zero oscillatory behavior. With the right phase, thermal fluctuations can cause the magnet to oscillate at resonance causing exponential growth.

Conclusion

Testing the feedback loop demonstrated sustained self-oscillatory behavior of the magnet for 24+ hours, while correct phases enabled oscillatory behavior at resonance to start from thermal fluctuations. We will continue to test the feedback loop at various frequencies and utilize it in projects in place of other more expensive instrumentation. We hope to obtain more data on magnetic systems using the feedback loop and identify unique modes or boundary conditions for applications in novel technologies while improving upon the feedback system to increase its versatility and compatibility.

Acknowledgments

1. McNair Program: Ronnie Hendrix and Erika Taylor
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