NMR RF Lab

Nuclear Magnetic Resonance Radiofrequency Lab

Quadrature Trombone Coil for 3 Tesla Small Animal Imaging

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Introduction

The traditional design of a radiofrequency (RF) **birdcage coil** is advantageous in producing a **strong, homogeneous magnetic field** for MRI scans [1]. However, constructing such a coil is **time-consuming**, particularly due to the large number of **capacitors relative to other RF coils**. Moreover, these minor adjustments can cause difficulty re-tuning a single-tuned birdcage coil, effectively **inhibiting its use for multinuclear studies** where only a single transmit coil may be utilized [2,3]. This project seeks to supplement this issue by creating a birdcage coil for small animal scanning that is **adjustable through inductance**, which can be varied by the length of the coil rather than capacitance. This facilitates an easier, more efficient tuning method [3].

Methods

Coil Construction:

- Rungs: nested copper rods (3.18 mm and 3.97 mm diameter)
- End rings composed of custom copper-clad FR4 boards.
- Support inside Shield: Four ¼ inch acrylic boards laser cut /
- Shield: 3D printed PETG casing wrapped in copper (seen in Figs. 1 and 2).
- Tuning Capacitance found with BirdcageBuilder: 47 pF [4].

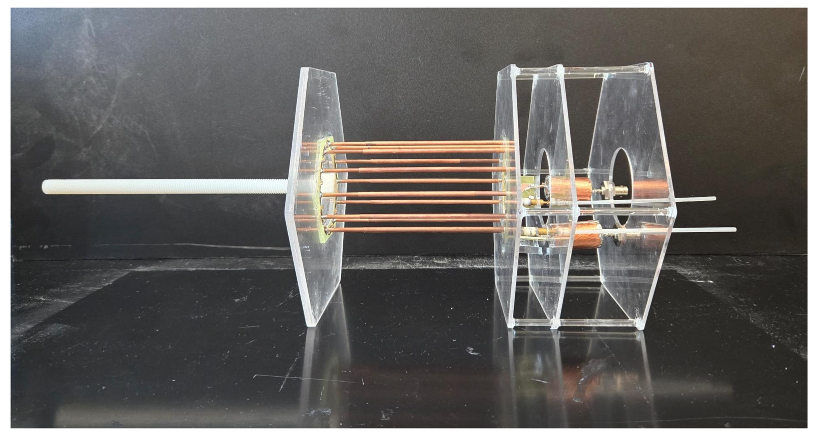

***Figure 1**: Trombone Coil Shield Off*

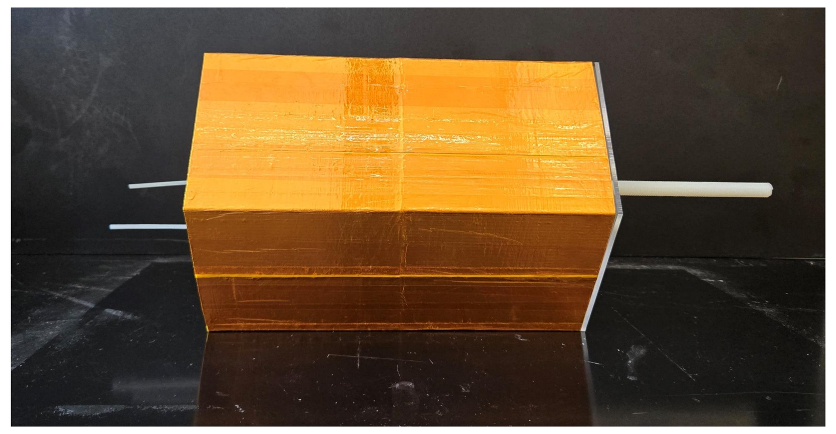

***Figure 2**: Trombone Coil Shield On*

Bench Testing:

- Used Network Analyzer to determine the resonant frequency.
- 1st measurement at 12cm (min).
- 2nd measurement at 15 cm (max).
- 3rd measurement tuned to the resonant frequency of hydrogen-1 at 3 T (123.20 MHz)

Scanner Imaging:

- Coil was placed within the bore of the MRI and tuned to 123.20 MHz.
- Power Calibrations were executed manually using FID pulses.
- A 25.4 mmol/L saltwater phantom was scanned using a Spin Echo pulse sequence to measure coil SNR.
- A cucumber and pork tenderloin were scanned using a Gradient Echo pulse sequence to show the sensitivity of the coil and the contrast between tissue layers.

Results

Benchtop Testing/ Q-Factor Results:

Measurement Number	Resonant Frequency (MHz)	Q-Factor
1st (12cm)	129.67	69.8
2nd (15cm)	115.22	51.9
3rd (tuned to hydrogen-1)	123.20	53.2

***Table 1**: Trombone Coil Measurement Results*

MRI Gradient Echo Phantom Results:

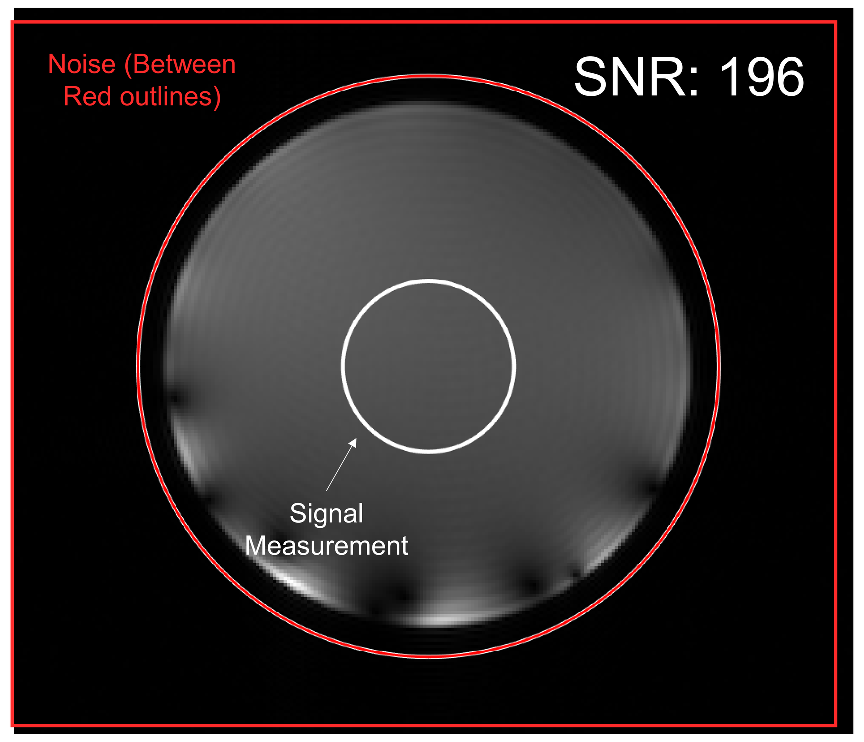

***Figure 3**: SNR Acquisition and Calculation of 25.4 mmol/L Saltwater Solution*

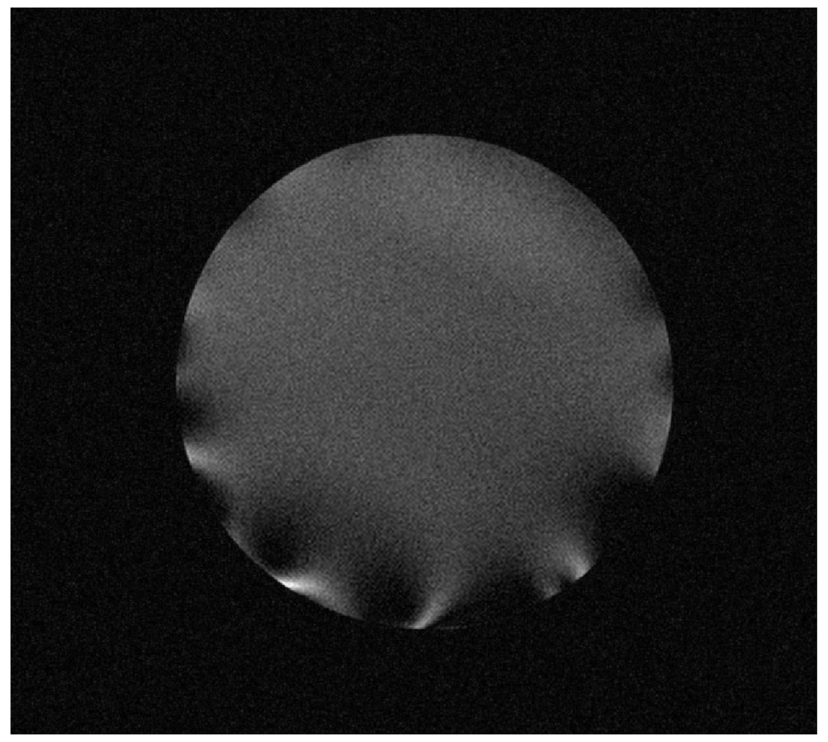

***Figure 4**: Gradient Echo of 25.4 mmol/L Saltwater Solution*

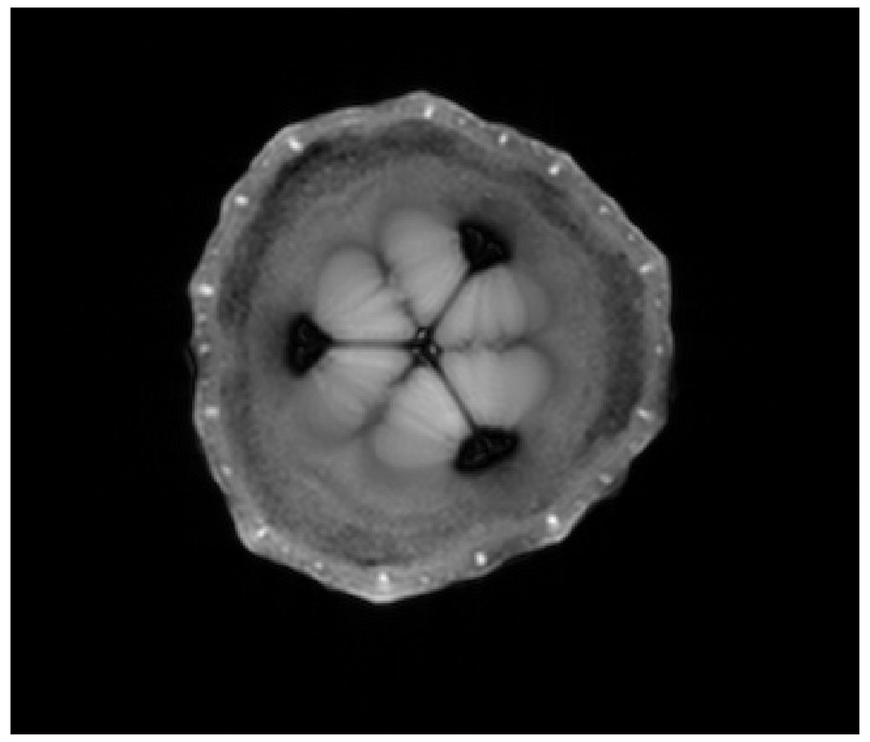

***Figure 5**: Gradient Echo of Cucumber showing the contrast between different elements in the phantom.*

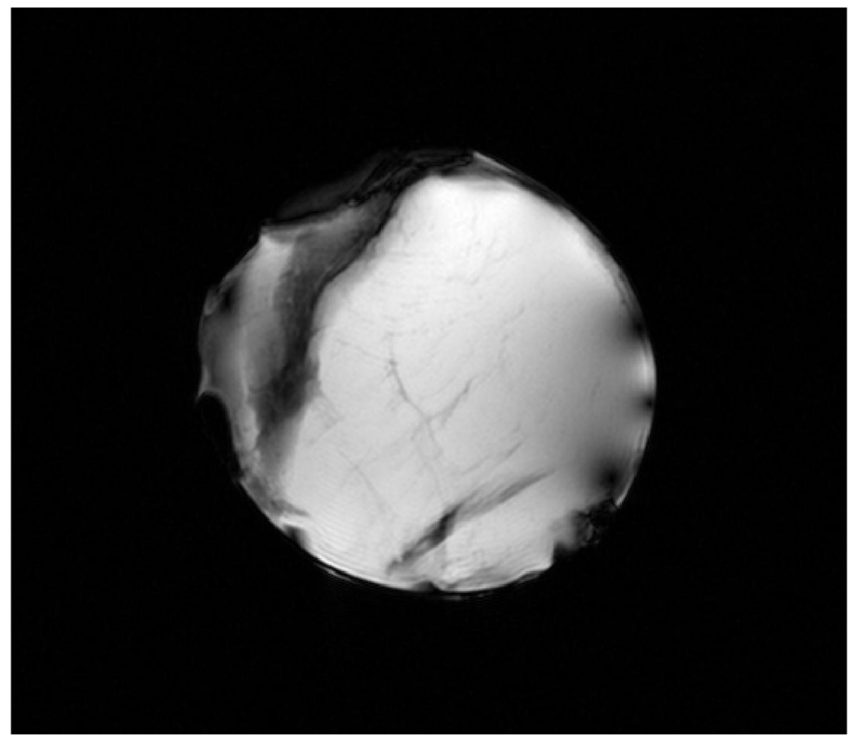

***Figure 6**: Gradient Echo of pork tenderloin showing the contrast between different fat tissue (dark) and muscle tissue (light).*

Discussion

The data collected through benchtop tests shows that the **frequency range** can be adjusted between **115 – 129 MHz (14 MHz span)**. The **Q factors** at each length vary from **50 to 70**, decreasing as the coil length increases.

The variance in the Q factor is most likely due to the increase in the coil's resistance [5]. **As the coil gets longer, the resistance of the entire system increases.** Therefore, there is a slight loss of stored energy.

This could contribute to a lower signal-to-noise ratio (SNR) for in-vivo scans, so the coil design must be adjusted accordingly. **Overall, the Q factor was acceptable**.

Figure 3 shows the spin-echo image of the saltwater solution and illustrates how the SNR was obtained. The SNR calculation was done by taking the mean of the signal intensity divided by the standard deviation of the noise outside of the sample. Before SNR was measured, the coil was properly tuned and calibrated to the saltwater phantom that mimicked the conductive properties of the human body. A Spin Echo pulse sequence was acquired on the phantom, and was used to calculate the **SNR, yielding a value of 196.** This high SNR demonstrates that the coil operates with **sufficient sensitivity for clinical-scale imaging applications.**

The cucumber and pork tenderloin phantoms were also imaged, (shown in **figures 5 and 6**). These images demonstrate the sensitivity of the coil, with distinct internal structures clearly visible and represented in **strong contrast**.

Conclusion

These findings suggest that the coil is well-suited for fine adjustments between subjects, thus allowing the user to maintain high coil efficiency across a wide subject range such as mice and rats. Future improvements would be to add a platform for samples to stay centered within the coil.

Acknowledgements

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References

To access references, please scan this QR code!