Low Field MRI Gradient Group: Final Report

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Introduction

Magnetic Resonance Imaging (MRI) is a powerful non-invasive imaging technique used in medical diagnostics to visualize internal structures of the body. The role of magnetic field gradients is crucial in achieving spatial encoding within MRI systems. In high-field MRI, these gradients work alongside a strong magnetic field to localize the signals originating from different parts of the body. However, in low-field MRI systems, where the primary magnetic field is weaker, the importance of gradients becomes even more pronounced. Gradients in a low-field MRI serve to create subtle variations in the magnetic field, enabling spatial localization of the protons' resonance frequencies.

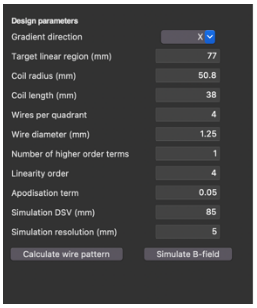
The gradients are applied along the three spatial dimensions (x, y, and z axes) and are responsible for encoding position information in the resulting images. This process enables low-field MRI systems to achieve sufficient spatial resolution despite the weaker magnetic field. Additionally, advancements in gradient **coil design and pulse sequence optimization have allowed** for improved image quality in low-field MRI, making it more affordable and accessible, particularly in resource-limited settings. Understanding and optimizing the role of gradients is therefore critical to enhancing the diagnostic capabilities of low-field MRI systems.

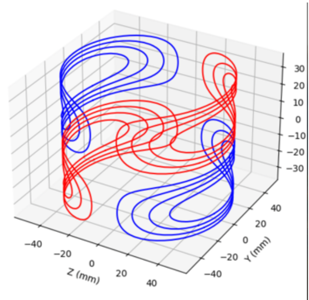
Our group was assigned the task of designing gradient coils for our low-field MRI scanner.

Method

To model the gradient fields in the x and y directions for our low-field MRI system, we utilized a pre-coded software specifically designed for gradient field simulations. The software enabled us to input custom design parameters for both the x and y gradients, optimizing the coil geometries to ensure spatial encoding of MRI signals. The image attached show the key design parameters used in the simulation. For the x-gradient, we set the coil radius to 50.8 mm, with a coil length of 38 mm and a wire diameter of 1.25 mm. Similarly, for the y-gradient, the coil radius was set at 53.98 mm, with the same coil length of 38 mm and a wire diameter of 1.25 mm. Both designs also incorporated 4 wires per quadrant and adhered to the same linearity parameters to maintain uniformity in the field.

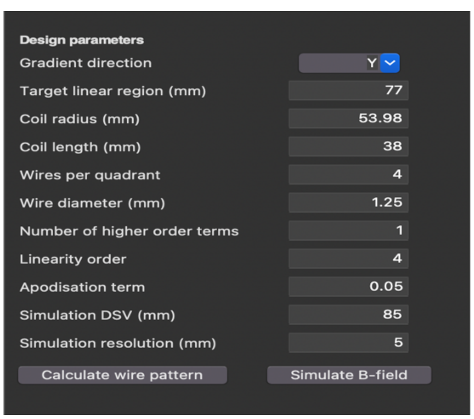
One significant design consideration was ensuring that the y-coil could fit over the x-coil. This was essential because the spatial arrangement of the coils influences the generation of gradient fields in each axis without interference. We adjusted the coil dimensions accordingly to allow the y-gradient coil to be placed concentrically over the x-gradient coil, optimizing both for performance and ease of assembly.





Unfortunately, due to technical issues with the software, we were unable to simulate the gradient field for the z-direction. As a result, we focused our efforts on the x and y coils, which were crucial for our experiment.

Once the simulations were completed, we 3D-printed both the x and y gradient coils based on the simulated wire patterns and dimensions. After printing, we manually taped the wires into the grooves of the printed coil forms using duct paper tape. This process ensured that the wires stayed in place and followed the desired coil pattern accurately.



Results

With the x and y coils assembled, we measured the inductance, achieving a value of 8.32 µH. This level of inductance was deemed appropriate for our low-field MRI setup and provided the necessary field strength to conduct effective imaging experiments. The coils produced stable gradient fields, effectively encoding spatial information in the x and y directions during MRI testing. Although we could not simulate or construct the z-gradient coil, the results from the x and y coils were sufficient to demonstrate spatial encoding in two dimensions, validating the accuracy of our design and manufacturing methods.