Exploring the Effect of Ferroshims on Magnetic Field Homogeneity

Ahsly Mota and Ilya Litvak

Introduction

Nuclear magnetic resonance spectroscopy (NMR) requires <1 ppm magnetic field homogeneity. A typical commercially built superconducting NMR magnet has a built-in shim system to enhance the uniformity of its magnetic field. Usually, rough filed correction is achieved using superconducting shim coils integrated with the magnet, with fine-tuning using room-temperature shim coils inserted into the magnet bore. For magnets which do not have built-in shims - such as unique magnets developed at the National High Magnetic Field Laboratory - passive ferromagnetic patterns can be used as an alternative to superconducting shims. This type of shimming can also be useful when magnets are old or defective. Ferroshims can be used in non-industrial settings because they are easy to apply; however other methods that also improve uniformity also exist.

Methods & Results

- We looked at the effect of a simple pattern - a solid thin ring. We varied the position of the ring and watched the change in six lowest axial components at each new position.
- To explore the effect of ferroshims on the magnetic field, I cut a 1 mm wide strip of iron foil and taped it around the cover of the probe to create a solid ring pattern.

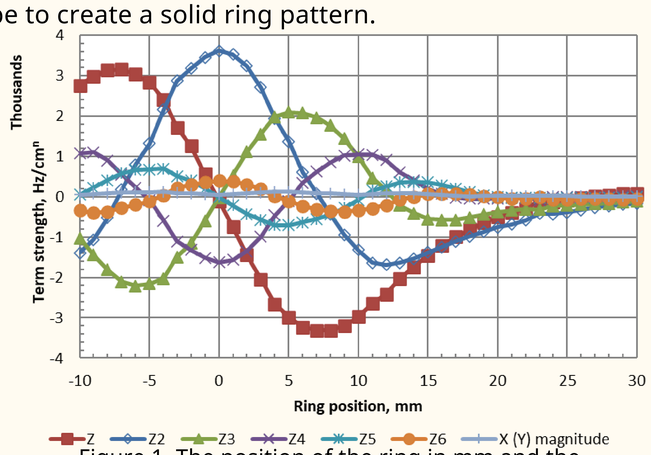


Figure 1. The position of the ring in mm and the frequency at each position.

Conclusion

- The results showed a correlation between the experimental and theoretical plots.
- This could mean that solid ring pattern could be successful in making the magnetic field more uniform.
- In the middle of the research, I increased the number of terms analyzed from Z6 to Z11.
- I realized that the more terms that you include in the analysis, the more similar the data is to the theoretical calculations.

Magnetic Field of a Solid Magnetic Ring

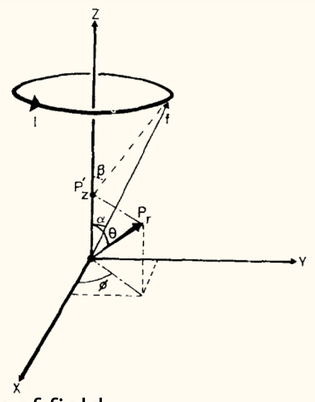
Ferromagnetic shims are placed on a tube surrounding sample space. The simplest pattern for this geometry is a solid ring coaxial with the tube. The field generated by a ring can be expanded into infinite series as:

$$B_{z,ring} = \sum_{n=0}^{\infty} Z_n \cdot [r^n P_n(\cos\theta)]$$

which will only contain axial components - colloquially denoted as Z0, Z1, Z2, etc.

$$Z_n = -\frac{J\Delta R}{6R^{n+2}}(n+2)(n+1)(\sin\alpha)^{n+3} P_{n+2}(\cos\alpha)\, h$$

The strength of each component depends on the position of the ring with respect to the center of field.



Romeo & Hoult 1984

Future Directions

- Future research should focus in exploring new ferroshim patterns and their effects on the magnetic field.
- Also, it is important for future research to investigate the importance of including more terms when analyzing the maps.

References

A portion of this work was performed at the **National High Magnetic Field Laboratory**, which is supported by **National Science Foundation Cooperative Agreement No. DMR-2128556 and the State of Florida**.

***IL is grateful for support from the National Institutes of Health, award RM1GM148766**