Canadian Association of Physicists

Association canadienne des physiciens et physiciennes

Contribution ID: **422** Type: **Oral not-in-competition (Graduate Student) / Orale non-compétitive (Étudiant(e) du 2e ou 3e cycle)**

# Design of Gradient Coil Geometry for a Halbach-Based Ultra Low-Field MRI System

*Monday 9 June 2025 12:00 (15 minutes)*

Introduction: Magnetic Resonance Imaging (MRI) is a powerful diagnostic tool that provides detailed images of soft tissues, making it essential for a wide range of medical applications. However, conventional MRI systems rely on high-field (1.5 –3.0 Tesla [1, 2]) superconducting magnets, resulting in high cost [3, 4], significant infrastructure requirements, and limited accessibility in many healthcare settings. Ultra-low-field (ULF) MRI systems operate below 0.1 Tesla [5, 6], and introduce an alternative approach, leveraging permanent magnet arrays and modern image-processing techniques to achieve clinically relevant imaging at a fraction of the cost. This research project focuses on the design, simulation, and evaluation of gradient coils optimized for a Halbach-based ULF MRI system. The magnetic field in a Halbach array is oriented perpendicular to the bore, requiring gradient coils that can operate effectively in this non-traditional geometry.
Methods: By integrating coil design methodologies such as the target field and stream function method [7, 8], and numerical simulations done within COMSOL Multiphysics, this project aims to identify the feasibility of a Halbach-based ultra-low-field system and enhance image quality and system performance by designing and developing physically realizable coil windings and custom geometries for x- and y-gradient coils. Simulation studies were conducted in COMSOL Multiphysics to evaluate magnetic field linearity and generate profiles of the x and y direction gradients.
Results: Gradient linearity was quantitatively assessed by comparing simulated magnetic field profiles using a percentage difference calculation over ideal linear gradients. Results showed gradient linearity values of 2.41% and 0.89% for the x- and y-gradient coil geometries, respectively, indicating strong encoding fidelity and minimal distortion over a 20-centimeter imaging region.
Discussion: We show an effective design for a ULF MRI. Further studies include expanded parameters in the simulations, such as differing wiring materials, time dependence, and thermal performance of the gradient coils.

[1] M. Sarracanie, C. D. LaPierre, N. Salameh, D. E. J. Waddington, T. Witzel, and M. S. Rosen, Sci Rep, vol. 5, no. 1, p. 15177 (2015)
[2] C. D. E. Van Speybroeck, T. O'Reilly, W. Teeuwisse, P. M. Arnold, and A. G. Webb, Physica Medica, vol. 84, pp. 116–124 (2021)
[3] S. Huang, Z. H. Ren, S. Obruchkov, Ji. Gong, R. Dykstra, and W. Yu, Investig Magn Reson Imaging, vol. 23, p. 179 (2019)
[4] M. Sarracanie, C. D. LaPierre, N. Salameh, D. E. J. Waddington, T. Witzel, and M. S. Rosen, Sci Rep, vol. 5, p. 15177 (2015)
[5] B. De Vos et al., Front. Phys., vol. 9, p. 701157, (2021)
[6] C. D. E. Van Speybroeck, T. O'Reilly, W. Teeuwisse, P. M. Arnold, and A. G. Webb, Physica Medica, vol. 84, pp. 116–124 (2021)
[7] R. Turner, J. Phys. D: Appl. Phys., vol. 19, no. 8, pp. L147–L151 (1986)
[8] D. Tomasi, Magn. Reson. Med., vol. 45, no. 3, pp. 505–512 (2001)

**Author:** BEAUDOIN, Jacob (Dept. of Biomedical Engineering, University of Calgary)

**Co-authors:** MACDONALD, M Ethan (Depts. of Biomedical Engineering, Hotchkiss Brain Institute, Radiology, Electrical and Software Engineering, U. of Calgary); LOFROTH, Nicole (Dept. of Biomedical Engineering & Hotchkiss Brain Institute)

**Presenter:** BEAUDOIN, Jacob (Dept. of Biomedical Engineering, University of Calgary)

**Session Classification:** (DPMB) M1-9 | (DPMB)

**Track Classification:** Technical Sessions / Sessions techniques: Physics in Medicine and Biology / Physique en médecine et en biologie (DPMB-DPMB)