



UNIVERSITÀ DEGLI STUDI DI NAPOLI
FEDERICO II

itee^{PhD}
information technology
electrical engineering



PhD student: Vincenzo Miranda

High Permittivity Material for RF field control in High Field MRI

Tutor: Giuseppe Ruello

Cycle: XXXVIII

Year: 2023/2024

Candidate's information

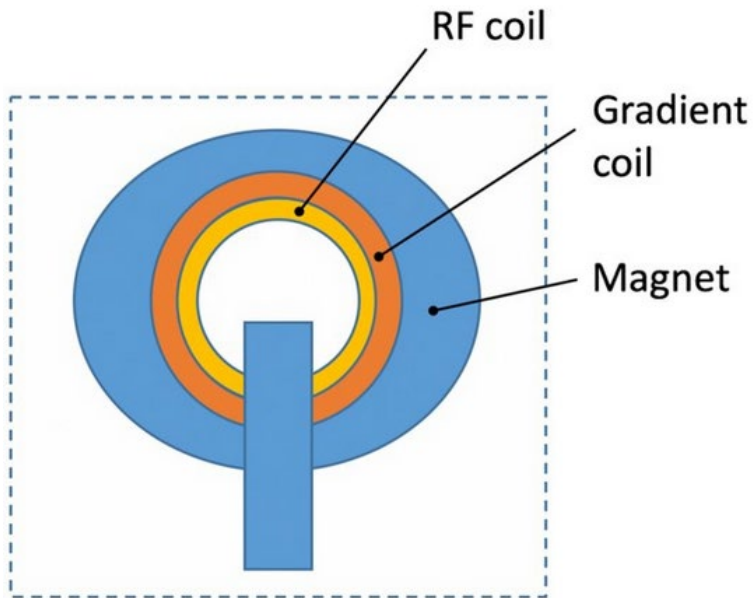
- **MSc degree:** Biomedical Engineering, Medical Devices
- **Research group/laboratory:** Numerical Antennas Laboratory, DIETI
- **PhD start-end:** 01/11/2022 – end 01/11/2025
- **Scholarship type:** PNRR - DM 351 Public Administration
- **Periods abroad:**
 - 23/06/2024 – 23/09/2024 Public Administration Pascale Foundation of Naples
 - 30/10/2024 – 30/03/2025 NYU Langone Radiology Department, 660 First Avenue, New York.

Summary of study activities

<u>Ad hoc PhD courses</u>	<u>Seminars</u>	<u>Conference/Workshop</u>
Radiofrequency ablations in liver surgery: a multidisciplinary point of view	CBI Science Day NYU	BioEM 2024 conference (Bioelectromagnetic), Chania, Greece
Innovation and Entrepreneurship	Rewire the brain: the potential of neuroplasticity	Federico II New York “800 years of culture and innovation”, Cornell University, New York
Matrix Analysis for Signal Processing with MATLAB Examples	Myelin Mapping in the brain’s white matter using a new data-driven analysis	
Numerical methods for thermal analysis, modelind, and simulation	Some aspects of virtual medicine and human space science research	
official type B tutoring activities	MRI Electromagnetic compatibility and optimization	

Research area(s)

Electromagnetic efficiency and safety in high field magnetic resonance imaging ($\geq 3T$)



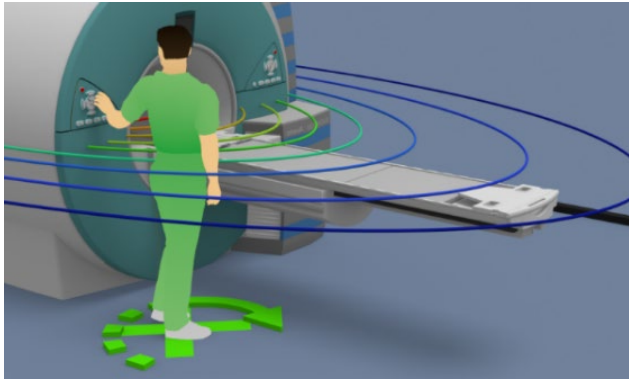
- Signal to noise ratio proportional to the static magnetic field

$$\text{SNR} \propto B_0$$

- Resonance Larmor Frequency for RF coils

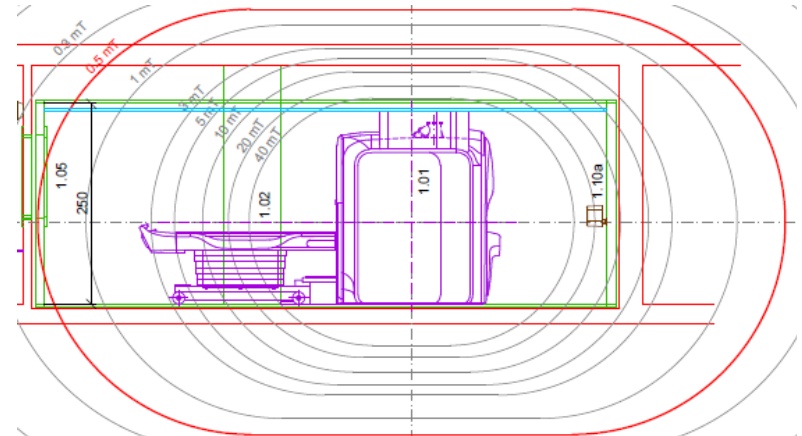
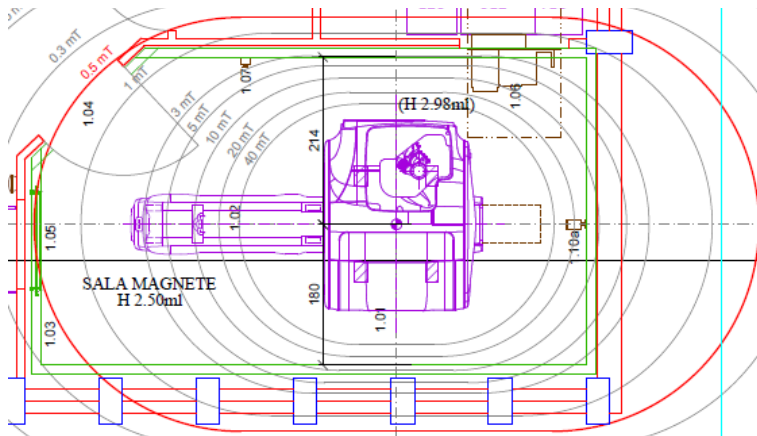
$$f_0 = \gamma B_0$$

Foundation Pascale of Naples



- Assess risks associated with worker exposure to gradients field due to movement in the patient room

$$|E| = \frac{r}{2} \left(\left| \frac{dB}{ds} \right| * v \right)$$

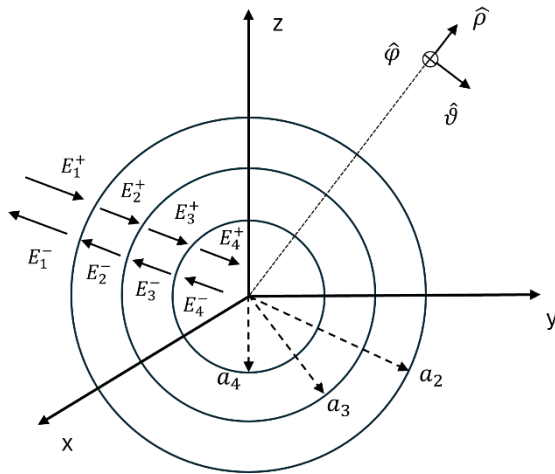


PhD thesis overview

- **Problem statement**: As static magnetic field strength increases, RF field inhomogeneities grow due to higher Larmor frequency , resulting in artifacts on medical images.
- **Objective**: Control the RF field through high permittivity materials (HPMs) and provide a physical insight into their design
- **Methodology**:
 - Analytical approach to understand the effect of HPMs on RF field distribution
 - Numerical simulations to validate and support analytical data
 - Experimental data obtained from the exposure of MRI phantoms employing HPMs

Research results (1)

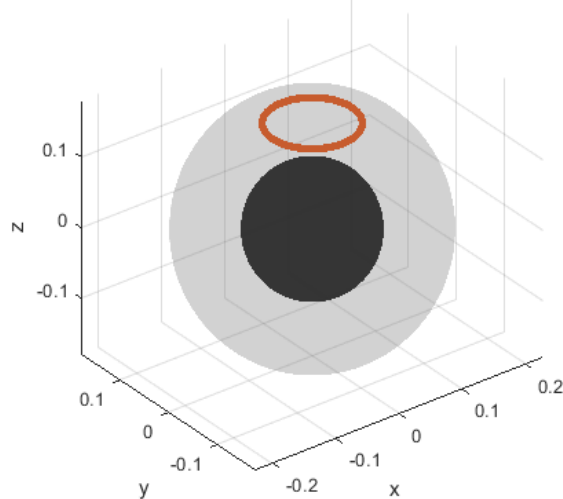
Analytical Scattering Model



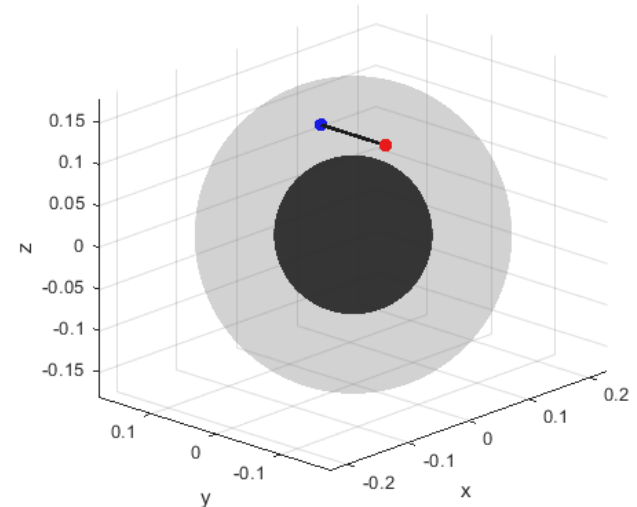
$$\mathbf{E}_l(r) = \sum_{n=1}^{\infty} \sum_{m=-n}^n E_{lnm}^+ \mathbf{M}_{nm}^{(3)} + E_{lnm}^- \mathbf{M}_{nm}^{(4)}$$

$$\mathbf{H}_l(r) = \frac{k_l}{i\omega\mu_l} \sum_{n=1}^{\infty} \sum_{m=-n}^n E_{lnm}^+ \mathbf{N}_{nm}^{(3)} + E_{lnm}^- \mathbf{N}_{nm}^{(4)}$$

Loop Coil as Field Source



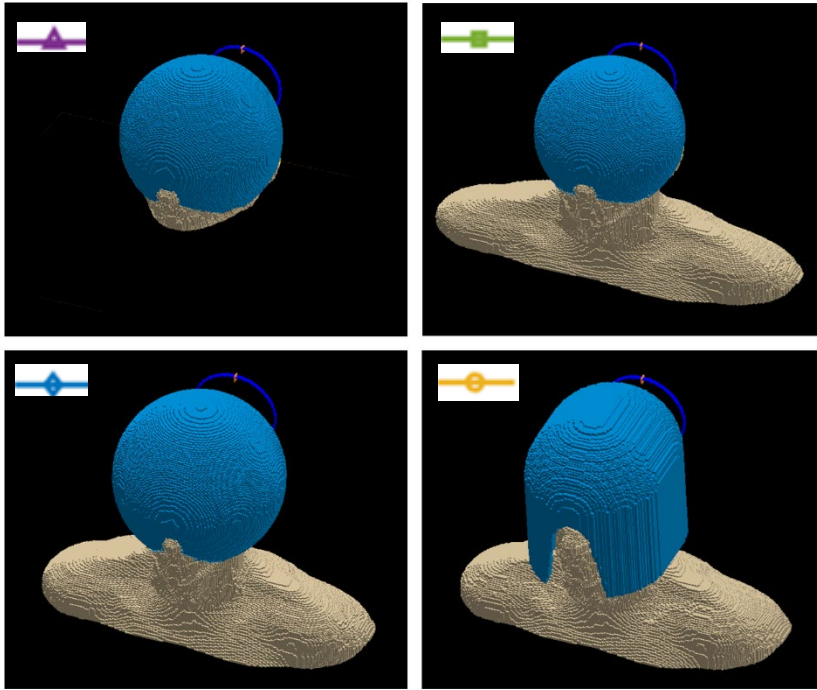
Electric Dipole as Field Source



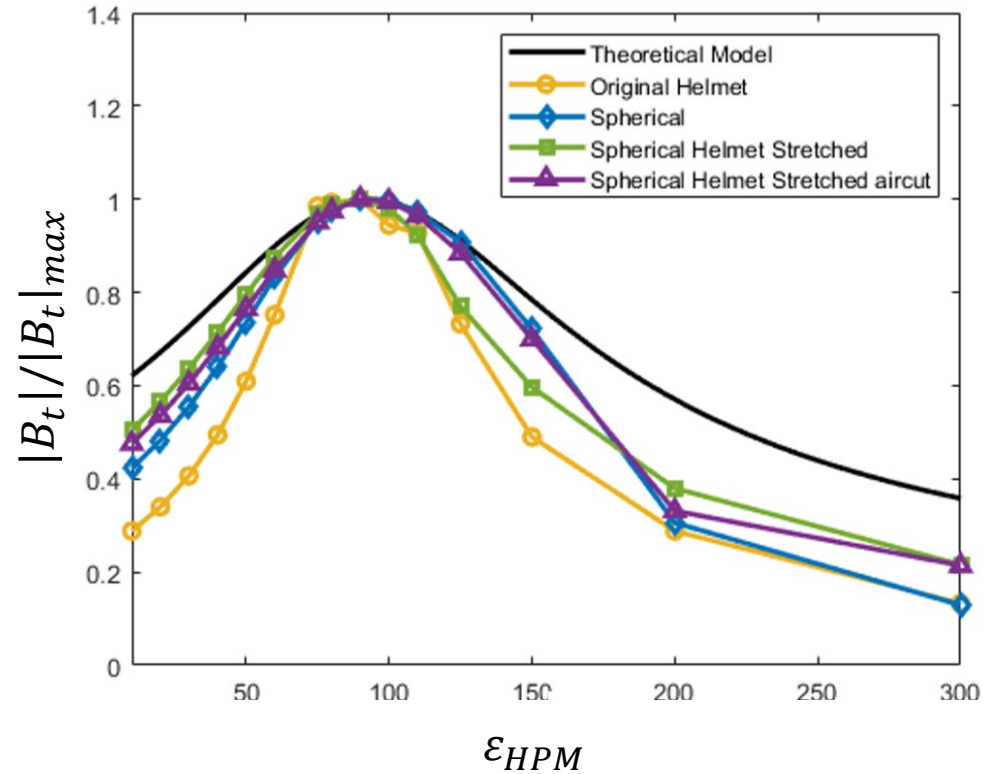
Research results (2)

Numerical Analysis

Numerical Simulation Setup

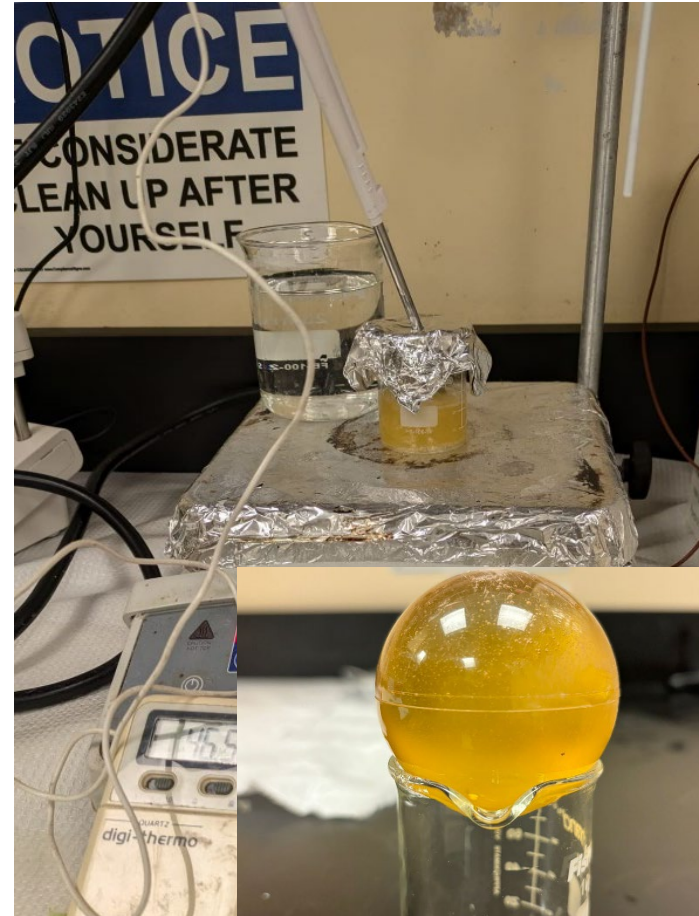
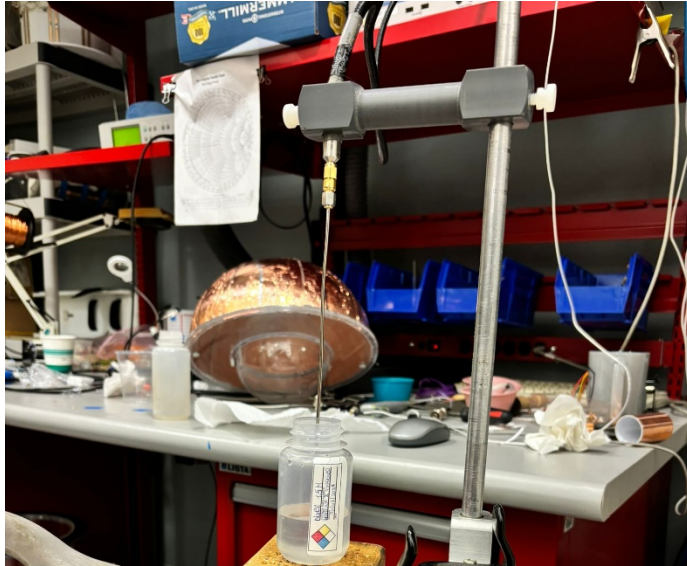


Comparison with analytical data



Research results (3)

Experimental Results



Research products

[P1]	<p>Vincenzo Miranda, Giuseppe Ruello, Riccardo Lattanzi</p> <p><u><i>A Theoretical Framework to Investigate the Effect of High Permittivity Materials in Magnetic Resonance Imaging using Anatomy-Mimicking Cylinders</i></u></p> <p>Magnetic Resonance in Medicine</p> <p>DOI: https://doi.org/10.1002/mrm.30063</p>
[P2]	<p>Vincenzo Miranda, Daniele Riccio, Giuseppe Ruello, Riccardo Lattanzi</p> <p><u><i>A Novel Electromagnetic Method to Interpret Scattering Suppression from Spheres</i></u></p> <p>2023 Seventeenth International Congress on Artificial Materials for Novel Wave</p> <p>DOI: 10.1109/Metamaterials58257.2023.10289295</p>
[P3]	<p>Vincenzo Miranda, Daniele Riccio, Giuseppe Ruello, Giuseppe Carluccio, Christopher Collins, Riccardo Lattanzi</p> <p><u><i>An Analytical Solution to Investigate the Impact of an Insulating Layer with High Permittivity Materials in Magnetic Resonance Imaging Applications</i></u></p> <p>2023 International Conference on Electromagnetics in Advanced Applications (ICEAA)</p> <p>DOI: 10.1109/ICEAA57318.2023.10297874</p>
[P4]	<p>Vincenzo Miranda, Giuseppe Carluccio, Giuseppe Ruello, Riccardo Lattanzi, Daniele Riccio</p> <p><u><i>Effect of an air layer on the design of high permittivity material helmets for 7 tesla magnetic resonance imaging</i></u></p> <p>IEEE Journal of Electromagnetics, RF and Microwaves in Medicine and Biology</p> <p>Status: Submitted</p>

Thanks for the attention!