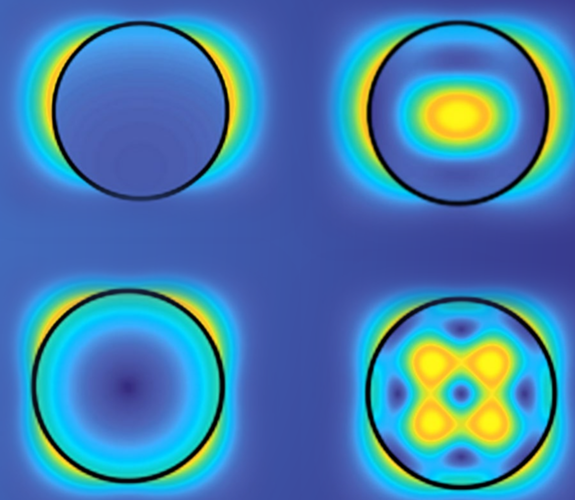
Università degli Studi di Napoli Federico II

A NEW FRAMEWORK TO INVESTIGATE THE ROLE OF HIGH PERMITTIVITY MATERIALS IN MRI



Tutor:

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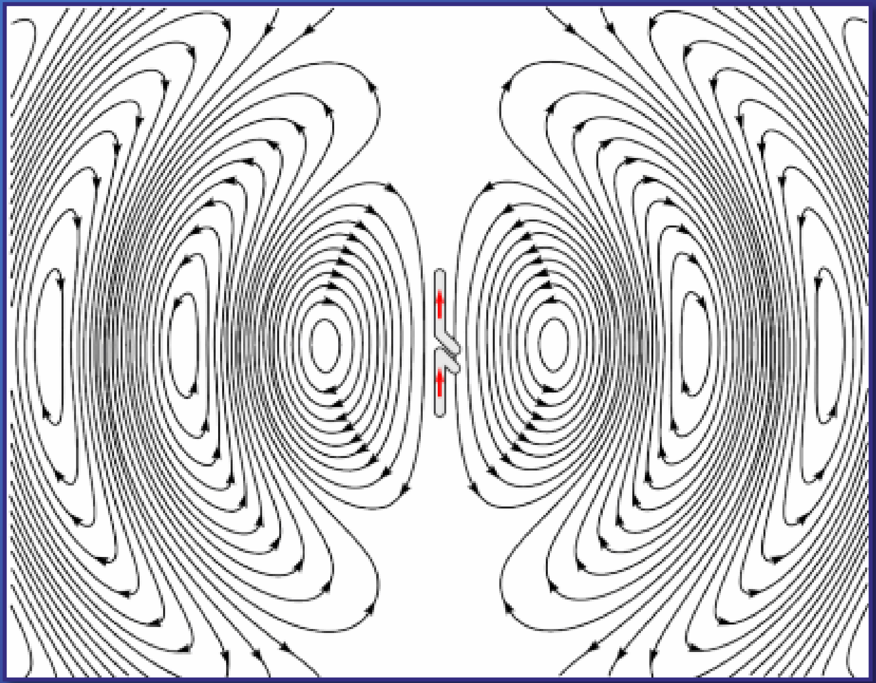
PhD student:

Vincenzo Miranda

SUMMARY

- My Background
- Research Field and Activities
- Results
- Future Developments



MY BACKGROUND

- **MSc Degree:** Biomedical Engineering, Medical Devices
- **Research Laboratory:** Numerical antenna laboratory, DIETI
- **PhD start Date**: 01/11/22
- **Scholarship Type:** PNRR - DM 351 Public Administration

COLLABORATIONS

- Non ionizing radiation laboratory (**NIR**), Ettore Pancini Physics Department
- Department of Radiology, New York University (**NYU**)

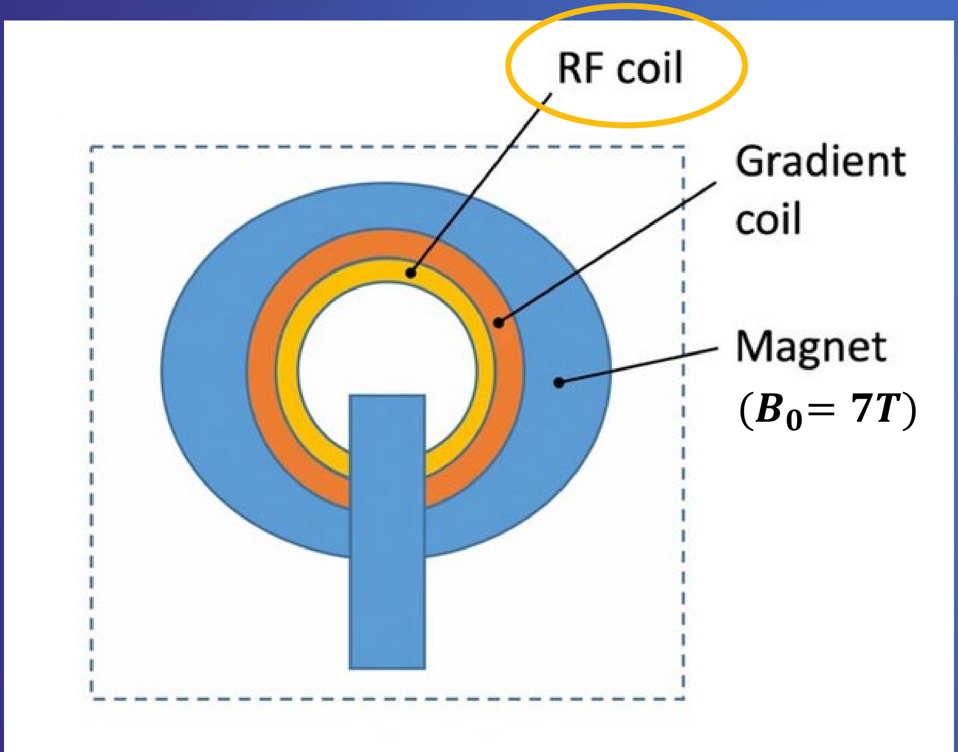
MUR
Ministero dell'Università e della Ricerca

SUMMARY OF STUDY ACTIVITIES

Ad hoc PhD courses/ schools	Courses from MSc curricula	Seminars
How to boost your PhD	*Electrodynamics of continuos media*	*Insights into the Design of Transmit and Receive Coils for Ultra-High Field MRI*
Statistical Data Analysis for Science and Engineering Research		*Electromagnetic Characterisation of Coatings and Structured Surfaces for Particle Accelerators*
Surface Electromagnetics Ph.D. school in Trento		*Electric Regularized Maxwell Equations with Singularities ERMES software*
Scientific Writing		*Electroporation techniques*
Corso formazione rischi specifici ingegneria		*Electrophysiology techniques and High Density Mapping and RF Ablation using Carto*
Antenna Modeling on Ansys Fundamentals and Hands-On Exercises		*Algorithm Unrolling: Efficient, Interpretable Deep Learning for Signal and Image Processing*
Formazione sulla progettazione europea (PON)		

RESEARCH FIELD

Electromagnetic efficiency and safety in ultra-high field magnetic resonance imaging



- Signal to noise ratio proportional to the static magnetic field

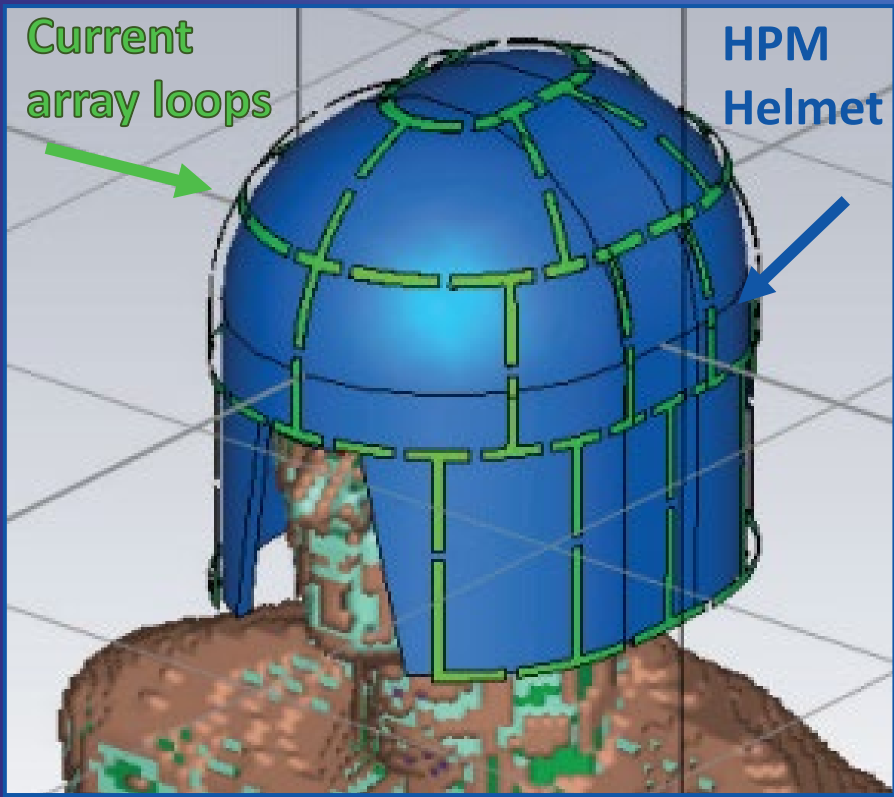
$$\mathrm{SNR} \propto \mathrm{B}_0$$

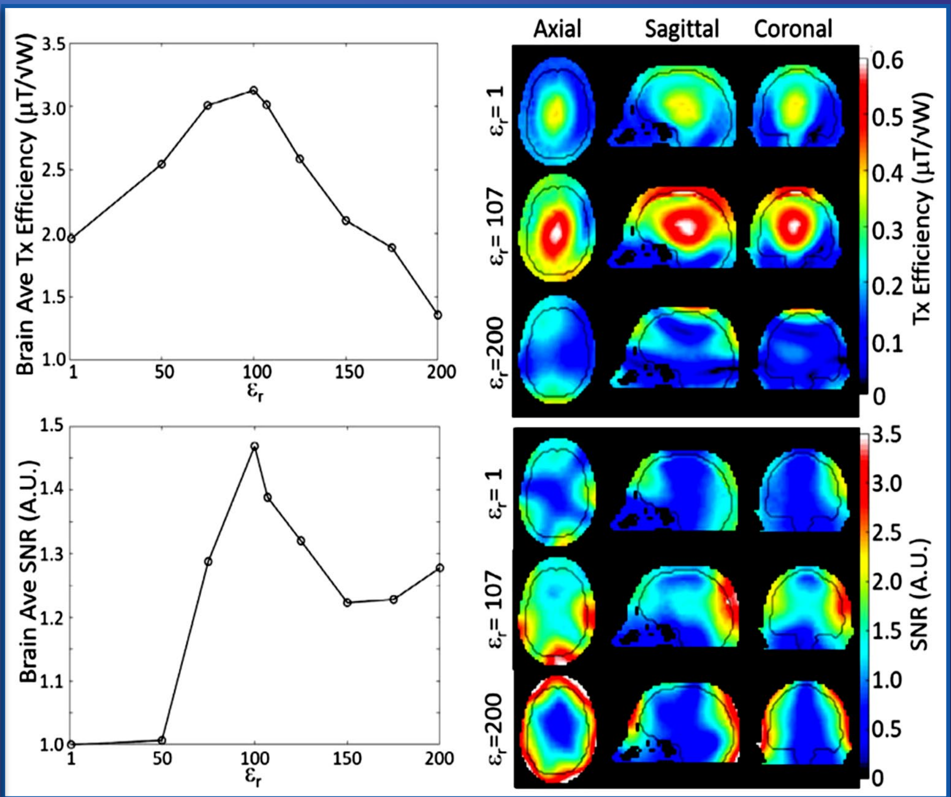
- Resonance Larmor Frequency for RF coils

$$f_0 = \gamma \mathrm{B}_0$$

Research Activity:
Problem statement

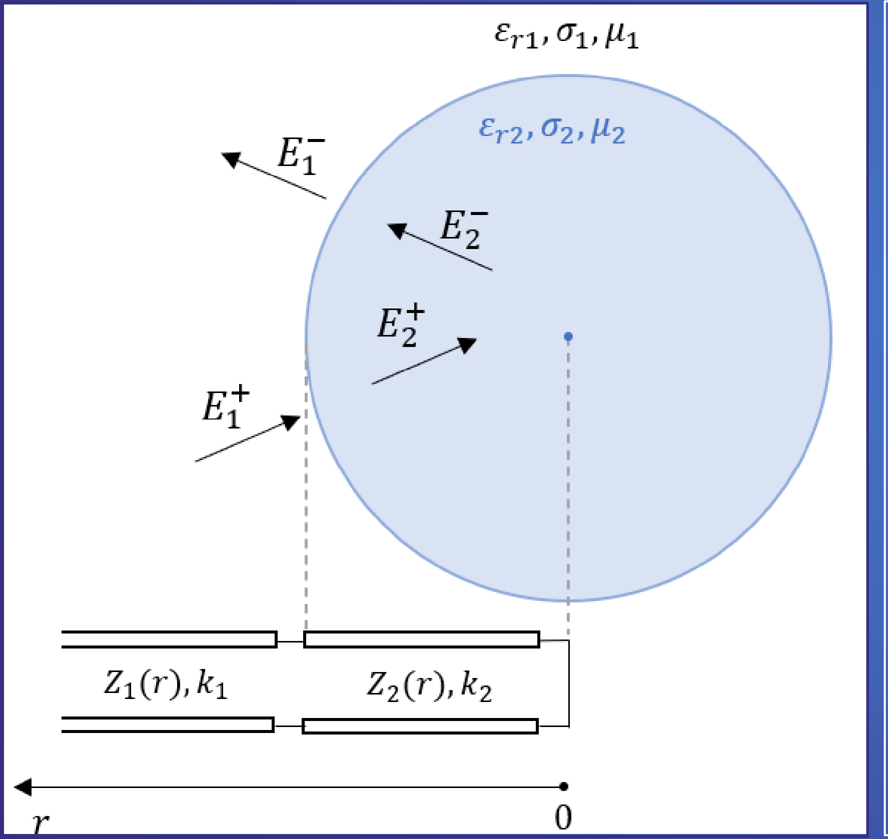
What are **H**igh **P**ermittivity **M**aterials (**HPMs**) and how are they used?





Research Activity: Metodology

New developed model based on Mie Theory



Fields Expression:

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

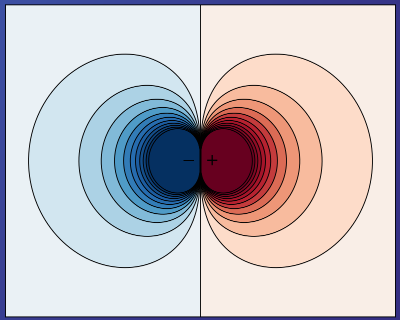
$$\boldsymbol{H}_l(r) = \frac{k_l}{i\omega\mu_l} \sum_{n=1}^{\infty} \sum_{m=-n}^{n} E_{lnm}^{+} \boldsymbol{N}_{nm}^{(3)} + E_{lnm}^{-} \boldsymbol{N}_{nm}^{(4)}$$

$$Z_n^{(1)}(k_l r) = \frac{i\omega\mu}{k_l} \frac{h_n^{(1)}(k_l r)}{h_n^{(1)\prime}(k_l r)}$$

$$\Gamma_n(k_l r) = \frac{E_l^{-} h_{nm}^{(2)}(k_l r)}{E_l^{+} h_{nm}^{(1)}(k_l r)}$$

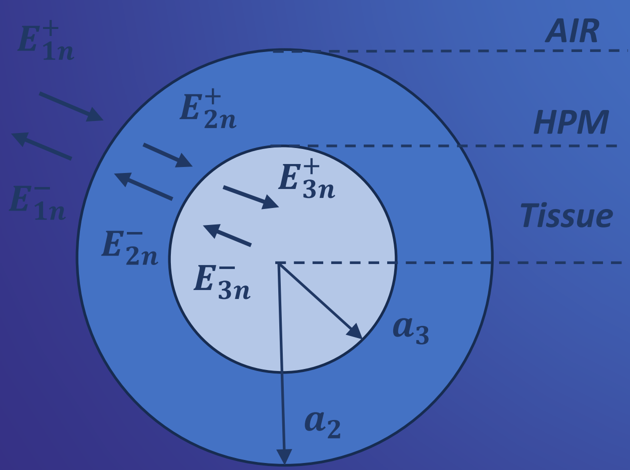
Research Activity:
Results

- **Analytical approach:** implementation of the developed model with Matlab Software
- **Numerical methods:** simulations performed using Ansys HFSS
- **Experimental work:** : Design, fabrication and characterization of solid phantoms to mimic the electrical properties of tissues

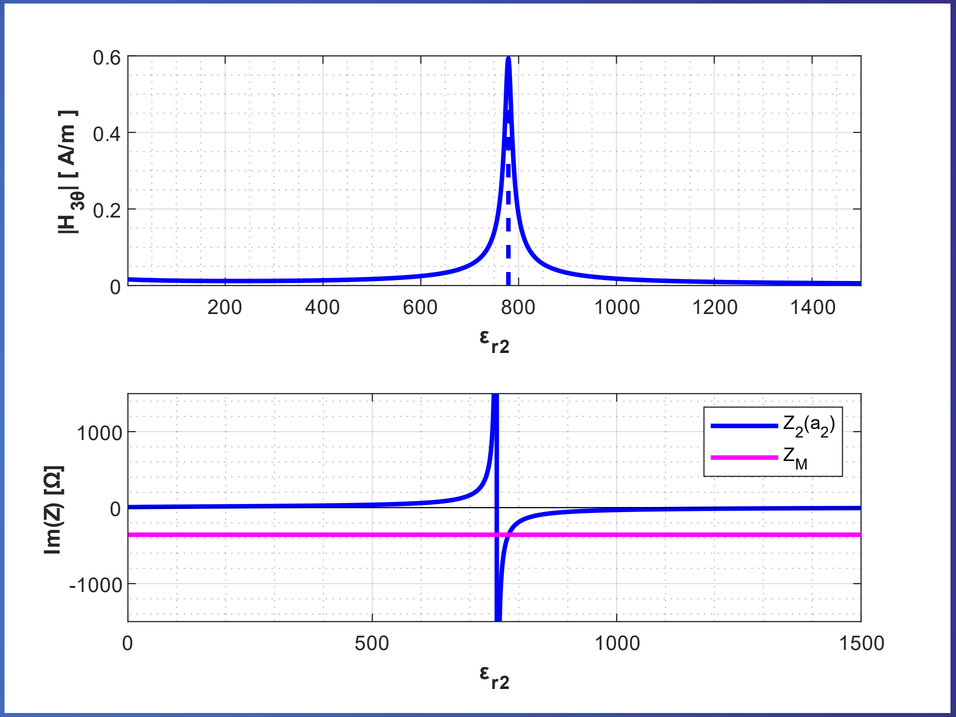


Simulations input Parameters:

- *Frequency 297.2 MHz (7T)*
- *Tissue Radius 9 cm*
- *Tissue Relative Permittivity 50*
- *Tissue Conductivity 0 S/m*
- *HPM Radius 1.596 cm*



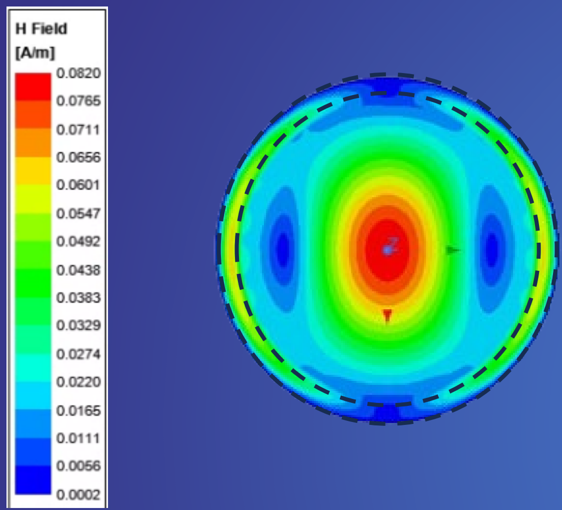
Foundamental mode (n=1)

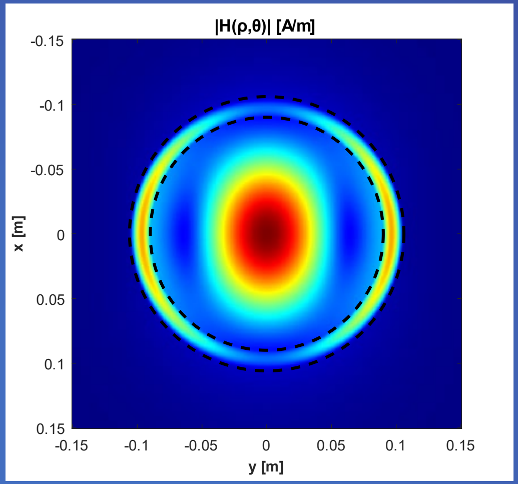


HPM relative Permittivity equal to 780 can amplify selectively the fundamental mode!

Numerical method

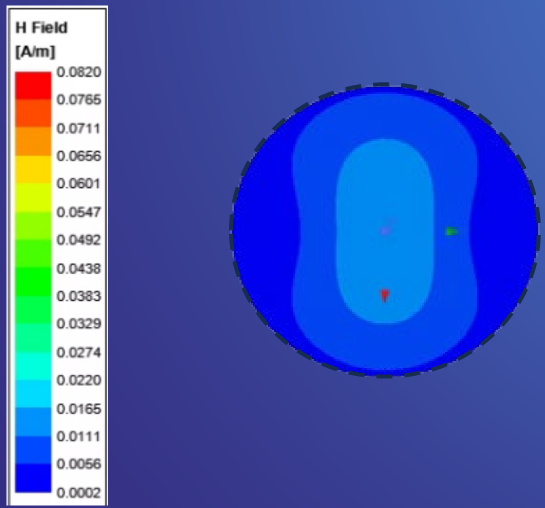
Analytical approach

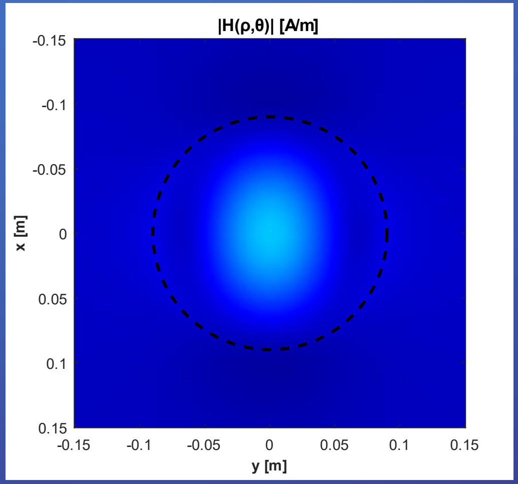




WITH HPM SURROUNDING TISSUE

ε_{HPM}= 780

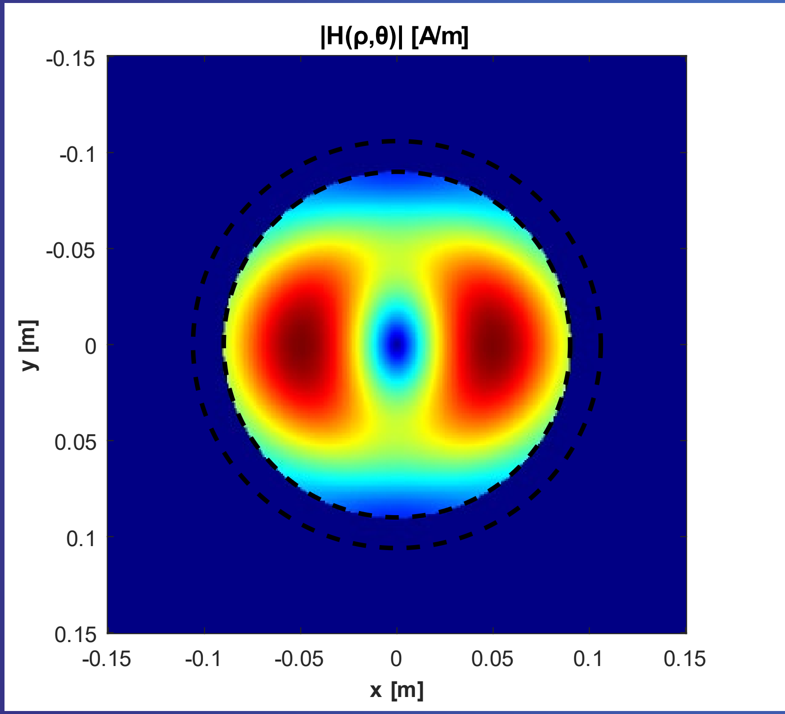




WITHOUT HPM SURROUNDING TISSUE

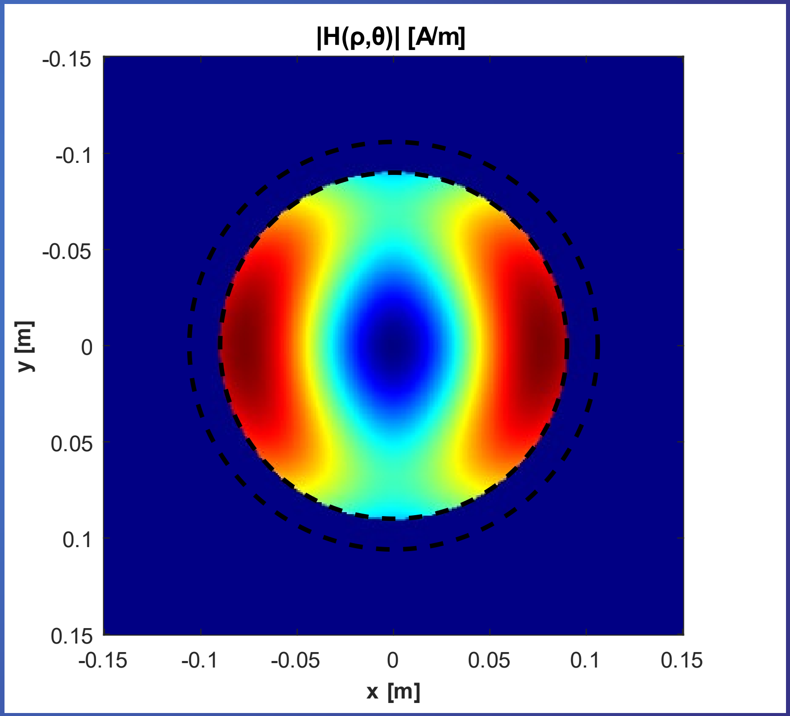
AMPLIFICATION OF SECOND MODE

ε_{HPM}= 1060



AMPLIFICATION OF THIRD MODE

ε_{HPM}= 1180



MATLAB

NIR Laboratory Activity:
Design and realization of MRI Phantoms

Purpose: To realize a phantom for MRI applications in the case of a $7T$ scanner that simulates the dielectric properties of the brain.

$$f_0 = \gamma B_0 \cong 297.2 MHz \qquad \gamma = 42,58 \frac{MHz}{T}$$

Typical values of the average electrical properties of the brain at this frequency can be found in the literature:

$$\varepsilon \cong 50$$

$$\sigma \cong 0,5\ S/m$$

Research Activity: Products

- ***Conference paper***

Title: *A new physical framework to investigate scattering suppression from coated spheres.*
Authors: *Vincenzo Miranda, Daniele Riccio, Giuseppe Ruello, Riccardo Lattanzi*
Status: *Published*
Conference Name: *SPIE 12568, Metamaterials XIV, 125680N (6 June 2023)*

- ***Conference paper***

Title: *An Analytical and Numerical Approach to Investigate the Role of High Permittivity Materials in Magnetic Resonance Imaging*
Authors: *Giuseppe Carluccio, Christopher Collins, Riccardo Lattanzi, Vincenzo Miranda, Daniele Riccio, Giuseppe Ruello*
Status: *Published*
Conference: *IEEE International Symposium on Antennas and Propagation and USNC-URSI Radio Science Meeting*

- ***Journal paper***

Title: *A Theoretical Framework to Investigate the Effect of High Permittivity Materials in Magnetic Resonance Imaging using Anatomy-Mimicking Cylinders*
Authors: *Vincenzo Miranda, Giuseppe Ruello, Riccardo Lattanzi*
Status: *Submitted*
Journal: *Magnetic Resonance in Medicine (MRM)*

Next Year

- Implement new field sources with the developed model, such as circular coils arrays used in MRI.
- Study the case of a layered model that considers all head layer for accurate results.
- Apply the model to different scenarios to expand its use (such as scattering suppression)
- Produce phantoms in the shape of a real head to study the impact of geometry on the obtained results.
- Experimentally validate the developed model by exposing the phantoms in 7T magnetic resonance imaging scanner to acquire and process data.