Department of Informatics
Robotics
Bioinformatics
Computer Science

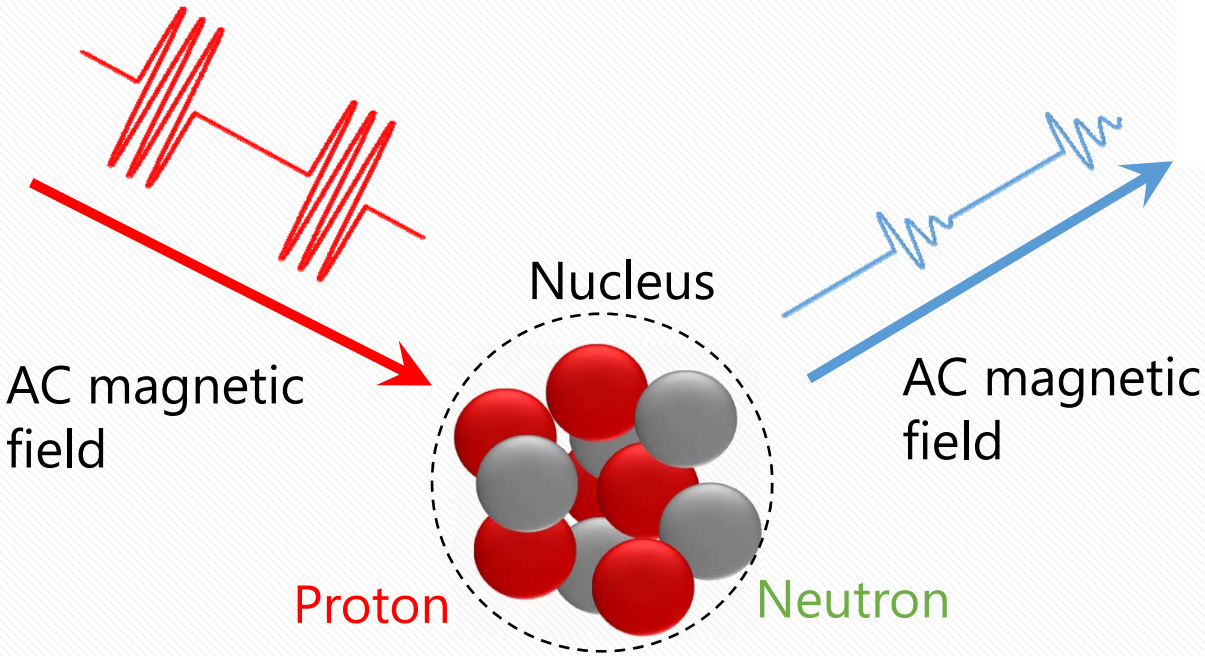
EPSRC
Engineering and Physical Sciences Research Council

Electromagnetic design of a spiral RF-coil for explosive material detection in the humanitarian demining setting

P. Farantatos, Y. Otagaki, W. Rafique, J. Barras, I. Poplett, P. Kosmas

Nuclear Quadrupole Resonance (NQR)

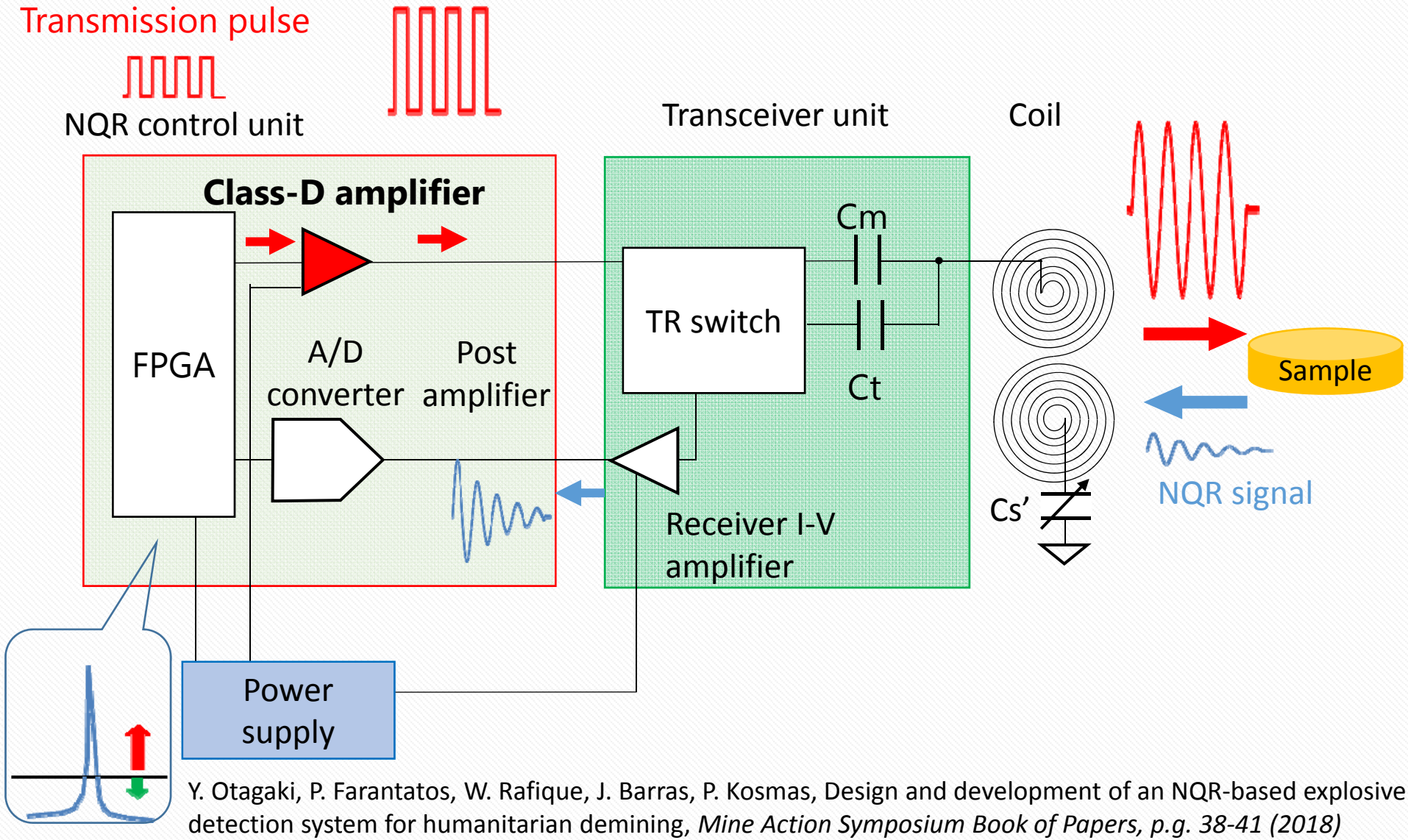
- **"Zero Field NMR"**
  - Detection of "chemical fingerprint"
  - High specificity
  - Stimulation with RF pulses
  - Near-field operation
  - RF-coils (inductive coupling)
  - Applications: Drugs, **Explosive materials**



A Clear Road Ahead: Humanitarian Demining

- A Clear Road Ahead (ACRA)
  - NQR for anti-vehicle mines detection
  - Humanitarian demining setting
  - Design w.r.t. socioeconomic impact
  - Low-cost prototyping
  - Local manufacturing
  - Somalia, Angola, Afghanistan

NQR detection system



Y. Otagaki, P. Farantatos, W. Rafique, J. Barras, P. Kosmas, Design and development of an NQR-based explosive detection system for humanitarian demining, *Mine Action Symposium Book of Papers, p.g. 38-41 (2018)*

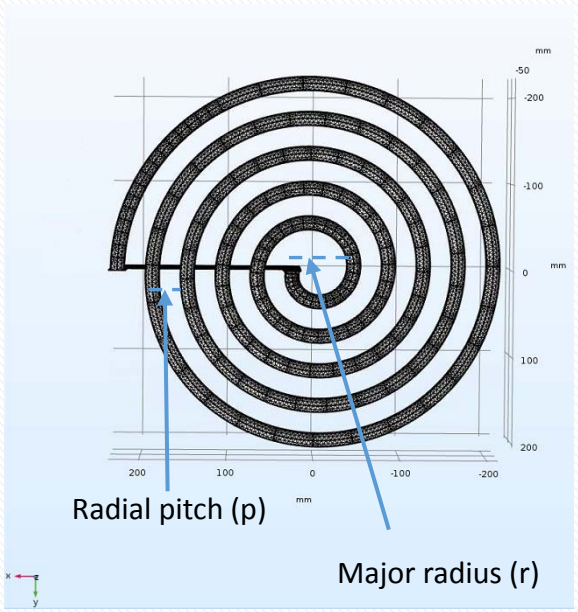
Functional/Engineering Requirements: Coil

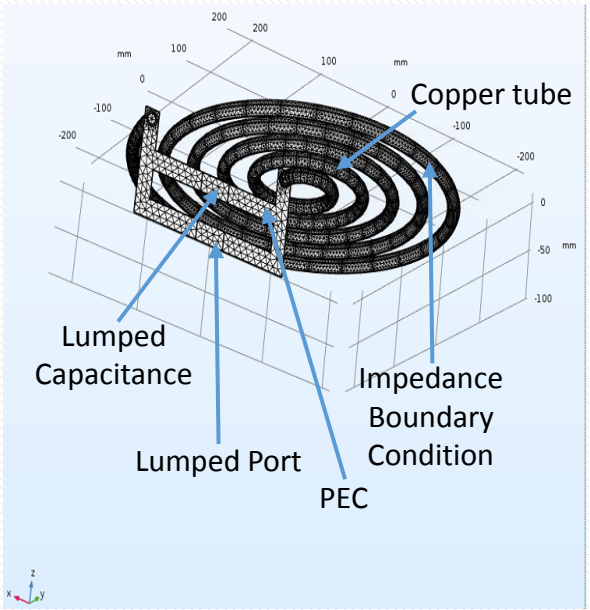
- Low-cost
- Local manufacturing

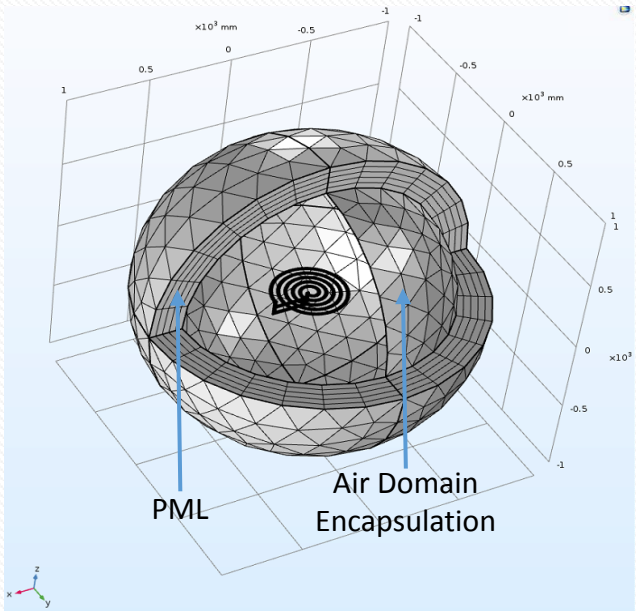
- Copper tube
- 3.41 MHz (RDX)
- DIY construction
- ~400mm coil diameter

COMSOL – RF Module

Aim: Comparative evaluation of geometrical parameters on coil's performance





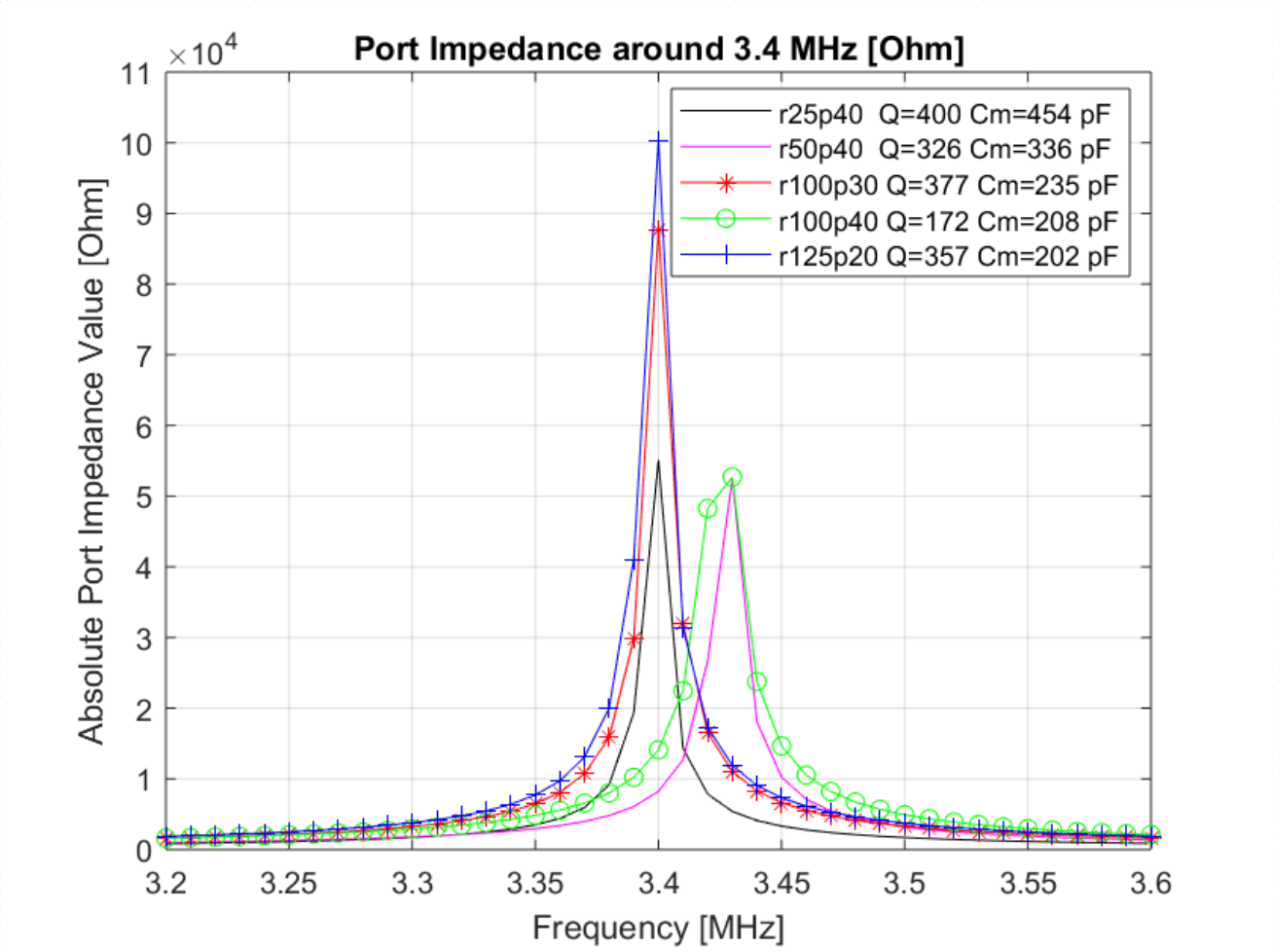


Model name	Major Radius (r) [mm]	Radial Pitch (p) [mm]	Resonant frequency [MHz]	Capacitor matching around 3.4 MHz [pF]
r25p40 (constructed)	25	40	84	454
r50p40	50	40	71	336
r100p40	100	40	95	208
r100p30	100	30	109	235
r125p20	125	20	110	202

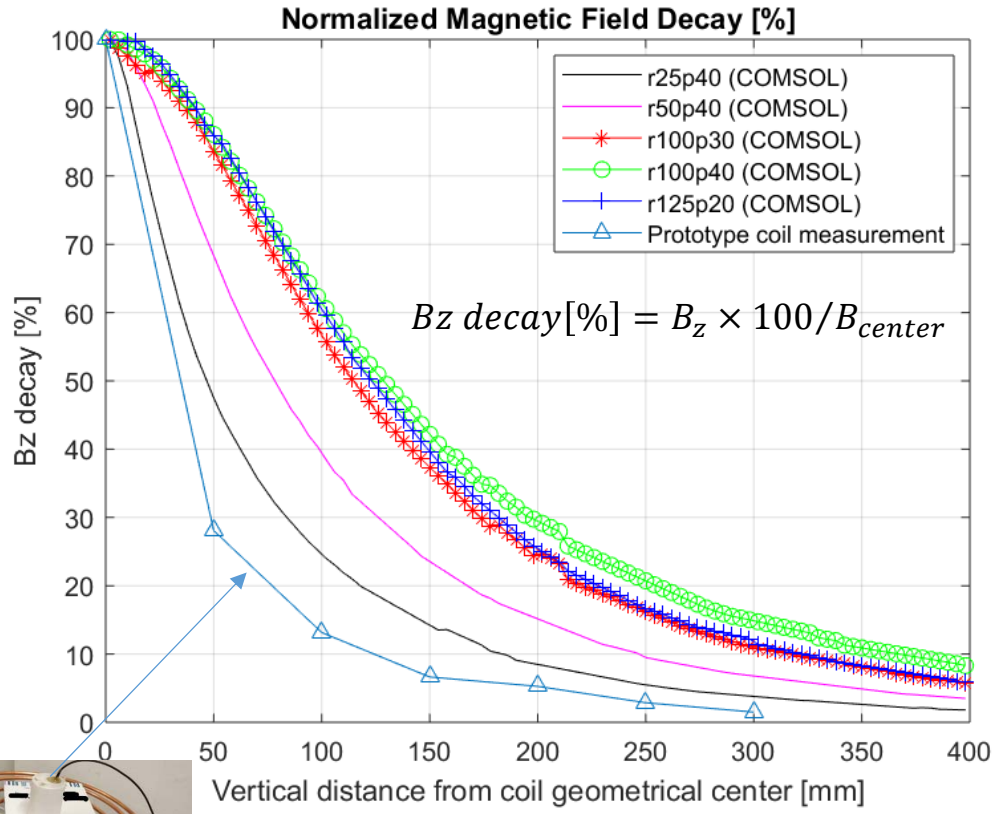
- Copper tube thickness: 2mm, R_{in}=6mm
- Air domain encapsulation: R_{air}=1000mm
- PML layer thicknes: R_{layer}=100mm
- Number of DOF: 1490962
- Average element quality 0.6481
- Minimum element quality 0.1999
- Number of elements: 222189

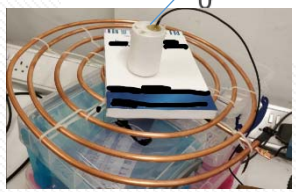
Modeling reference: COMSOL Application Gallery: "RF Coil", ID 6126

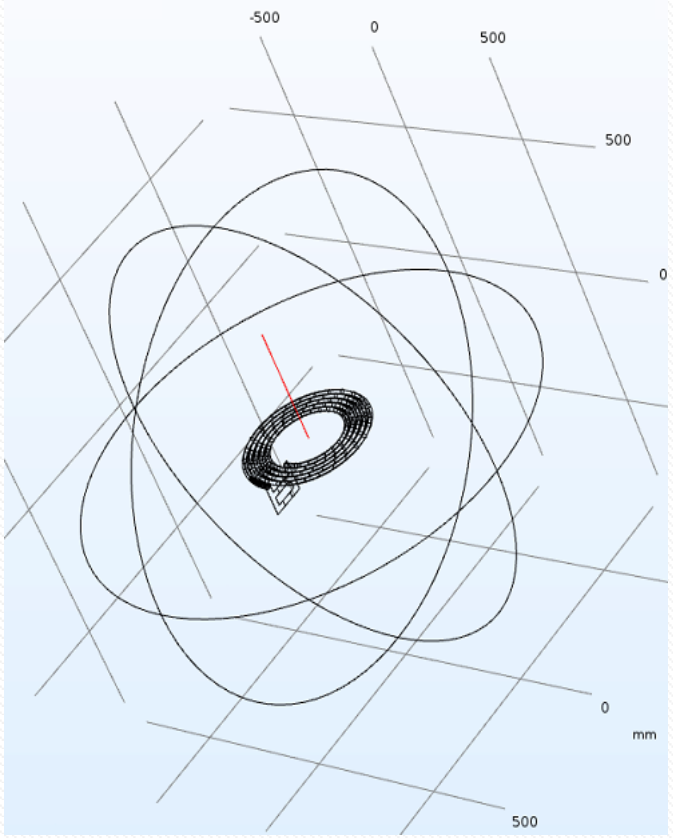
Port Impedance



Normalized Magnetic Field Decay along Zaxis

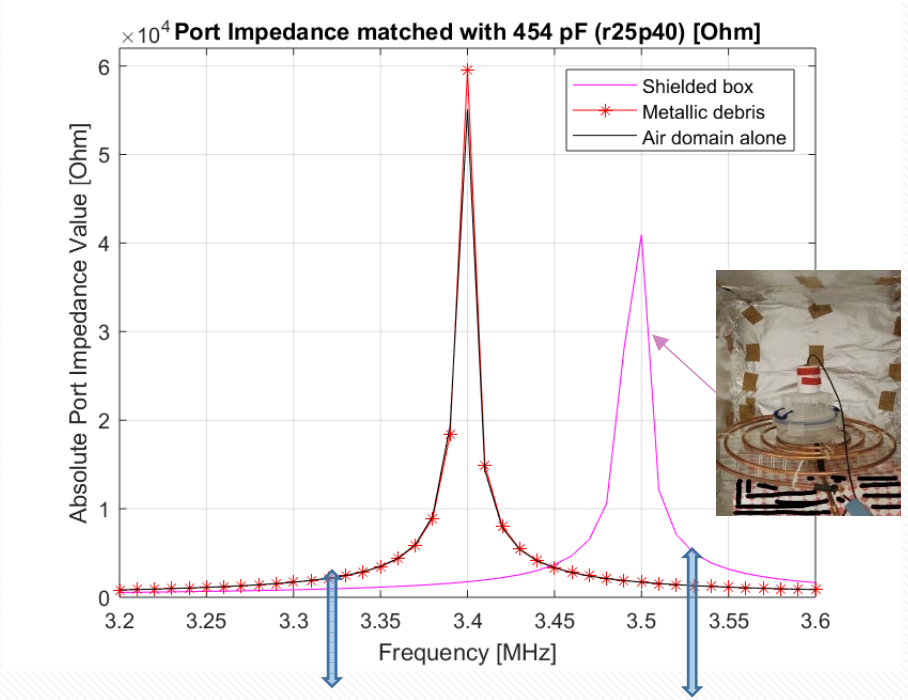




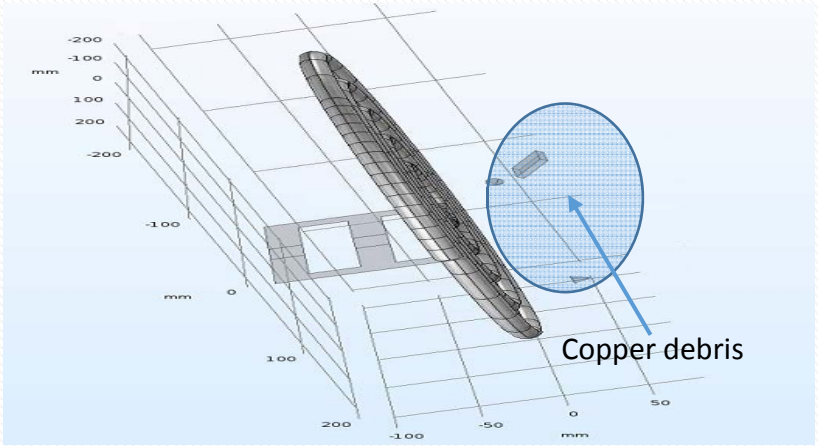


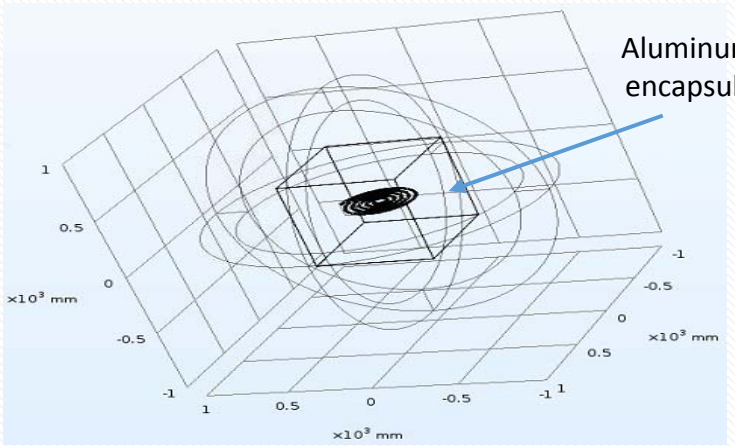
As the major radius and radial pitch combinations approach the dimensions of the coil measured at the lab, the magnetic field decay behaves similarly

r25p40: Influence of operational environment



100 KHz detuning: Observed also during lab testing

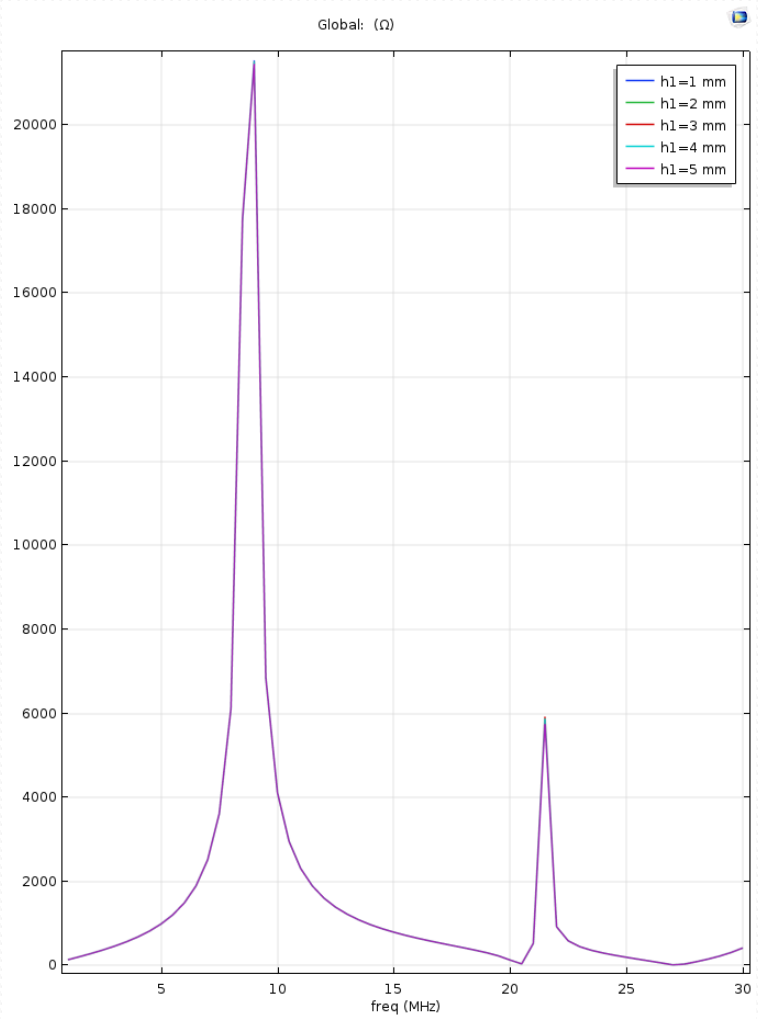


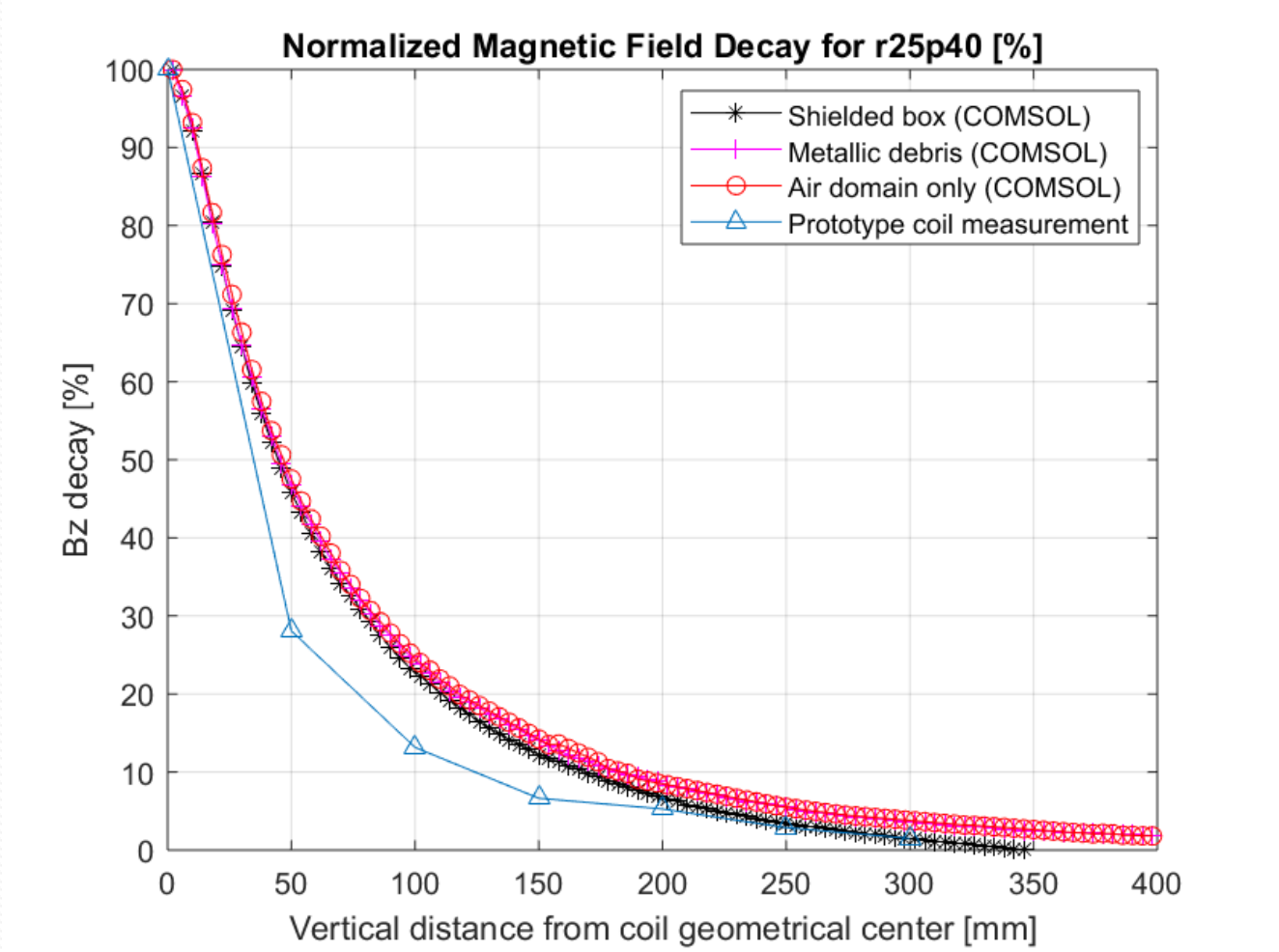


Conclusions and Future Steps

- **Spiral Coil Modeling**
  - Increase of major radius leads to improved field homogeneity
  - Encouraging magnetic field decay patterns w.r.t. prototype coil field mapping
  - Operation in a shielding box in agreement with observations at lab conditions
  - Influence of Q-factor in presence of copper debris
- **Future Work**
  - Further investigation on influence of operational conditions to bandwidth resilience levels (soil properties, clutter, further debris)
  - Magnetic field homogeneity assessed in the whole detection region
  - Utilization of Optimization Module for retrieving optimal geometrical properties w.r.t. magnetic field quality metrics
  - Utilization of AC/DC module (Electrical Circuit Interface) and/or additional TR circuit SPICE model coupled to the electromagnetic model

THANK YOU FOR YOUR ATTENTION!


Global: (Ω)
h1=1 mm
h1=2 mm
h1=3 mm
h1=4 mm
h1=5 mm
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
5
10
15
20
25
30
freq (MHz)


Normalized Magnetic Field Decay for r25p40 [%]
Shielded box (COMSOL)
Metallic debris (COMSOL)
Air domain only (COMSOL)
Prototype coil measurement
Bz decay [%]
Vertical distance from coil geometrical center [mm]
0
10
20
30
40
50
60
70
80
90
100
0
50
100
150
200
250
300
350
400