UNIVERSITÉ DE LORRAINE

COMSOL CONFERENCE 2014 CAMBRIDGE

Multi-Layer Surface Coil Design: Geometry Optimization

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Introduction

NMR
600MHz

NQR
100kHz-6MHz

MRI
100 MHz

Introduction

NMR
600MHz

RF coil

Transmit/receive

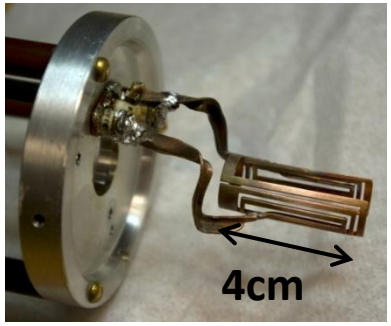
near field radiation

NQR
100kHz-6MHz

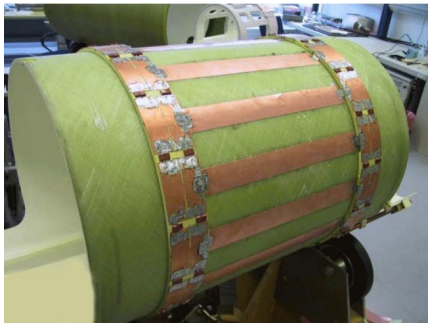
MRI
100 MHz

Motivation

Volume coil



Saddle coil

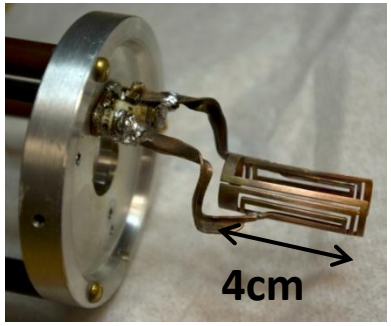


Birdcage coil

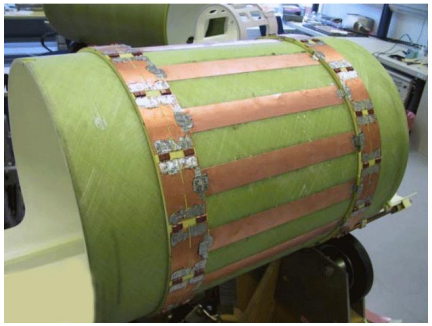
"**Optimizing surface coils and the self-shielded gradiometer**," B. H. Suits and A. N. Garroway, Journal of Applied Physics 94, 4171-4178 (2003)

Motivation

Volume coil

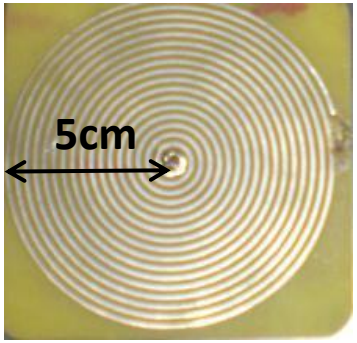


Saddle coil

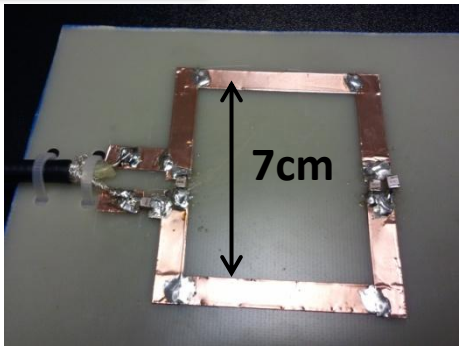


Birdcage coil

Surface coil



Spiral

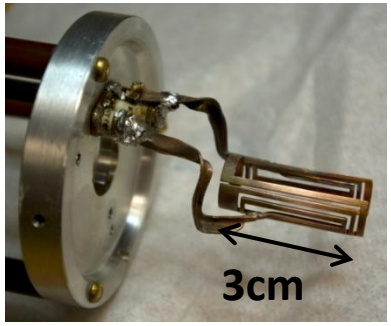


Rectangular

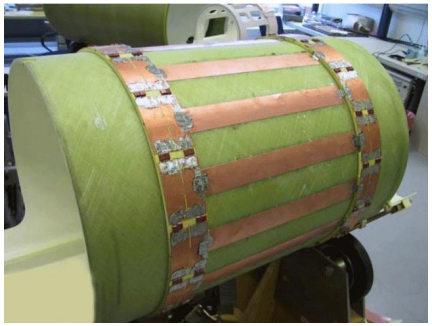
"**Optimizing surface coils and the self-shielded gradiometer**," B. H. Suits and A. N. Garroway, Journal of Applied Physics 94, 4171-4178 (2003)

Motivation

Volume coil

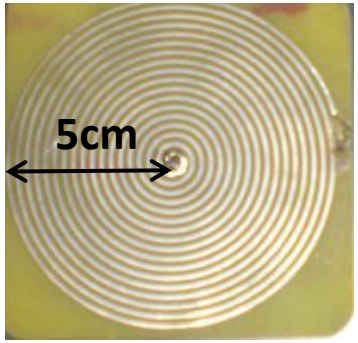


Saddle coil

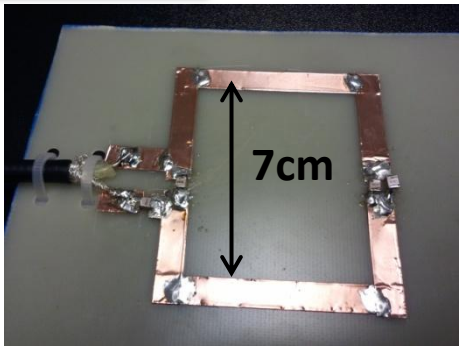


Birdcage coil

Surface coil



Spiral

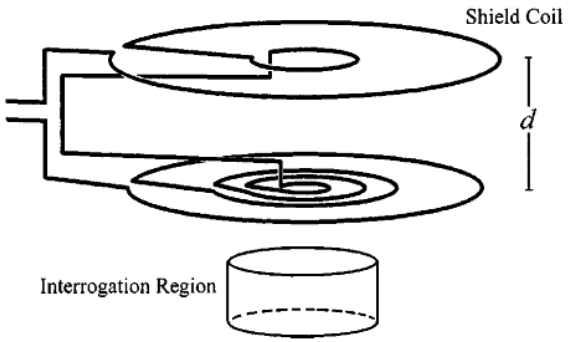


Rectangular

Why using multi-layer surface coil ?

To improve :

- Immunity to interfering noise sources.
- Quality factor.
- Magnetic field homogeneity within a specific region.

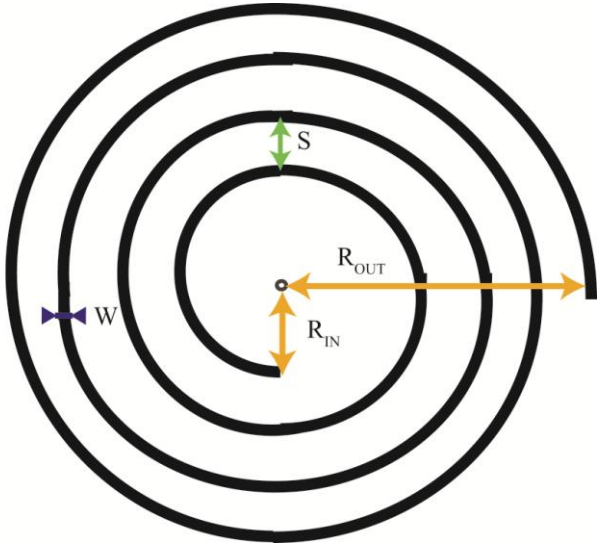


"**Optimizing surface coils and the self-shielded gradiometer**," B. H. Suits and A. N. Garroway, Journal of Applied Physics 94, 4171-4178 (2003)

Motivation

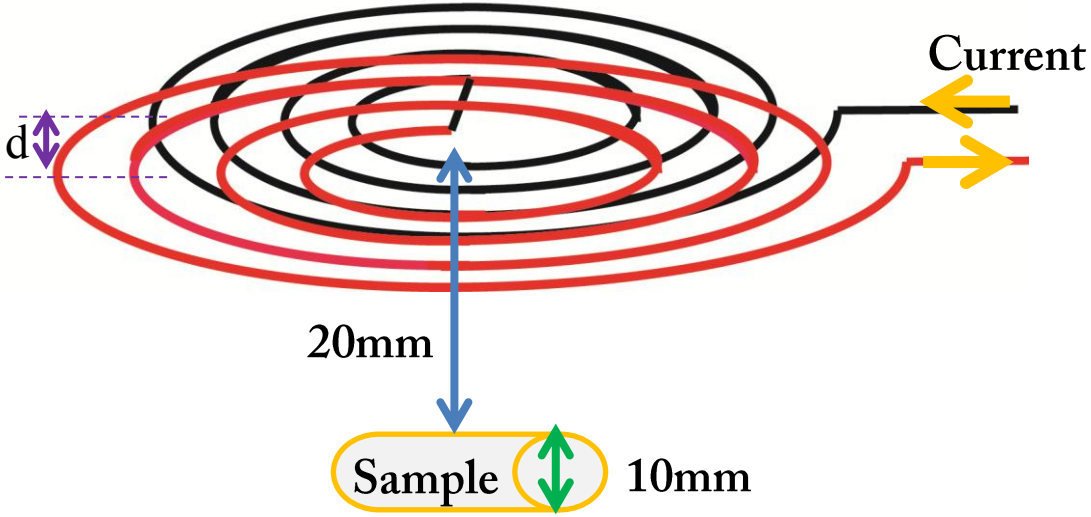
1-Single-layer (principal) coil

- Influence of R_{IN}, S, W and the number of turn N



2-Multi-layer coil

- Distance between layers in addition to R_{IN}, S, W and the number of turn N



Motivation

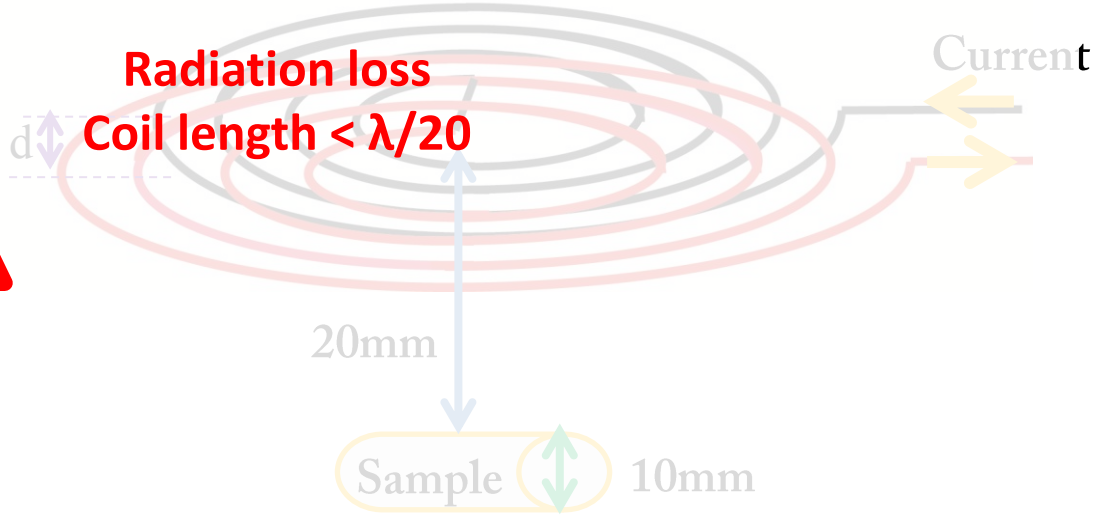
1-Single-layer (principal) coil

- Influence of R_{IN}, S, W and the number of turn N

2-Multi-layer coil

- Distance between layers in addition to R_{IN}, S, W and the number of turn N

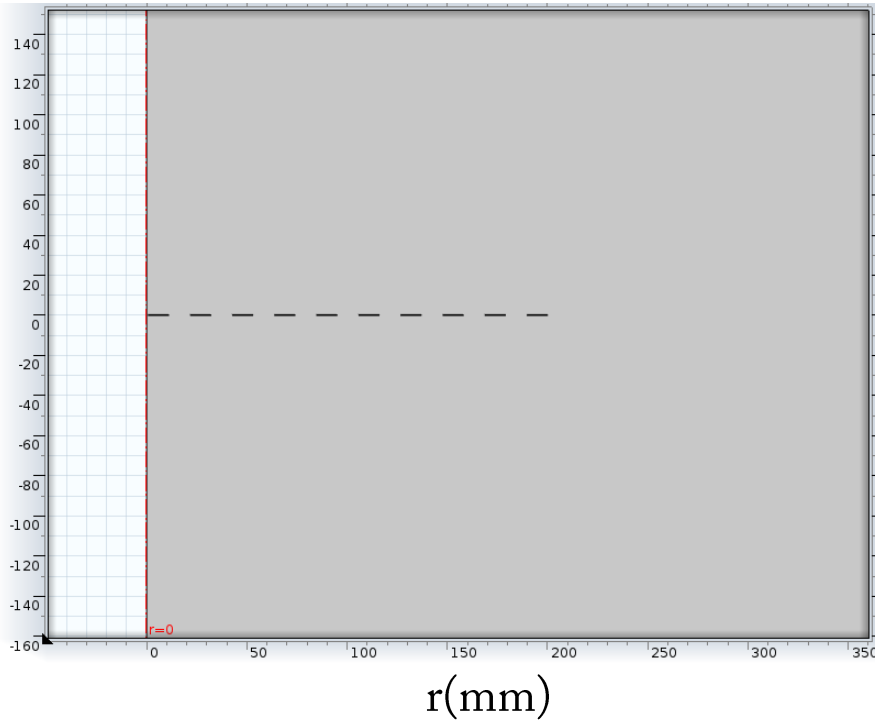
Radiation loss
Coil length < λ/20



Single-layer surface coil

2D Axisymmetric model

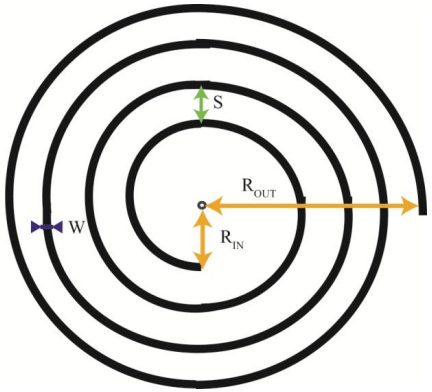
- Thickness of each layer of cooper = 35 μm (PCB – Printed Circuit Board)
- Magnetic and electric field
  - Coil group domain approximation
- Study
  - Parametric sweep
  - Frequency domain (3.3 MHz)
    λ=91m

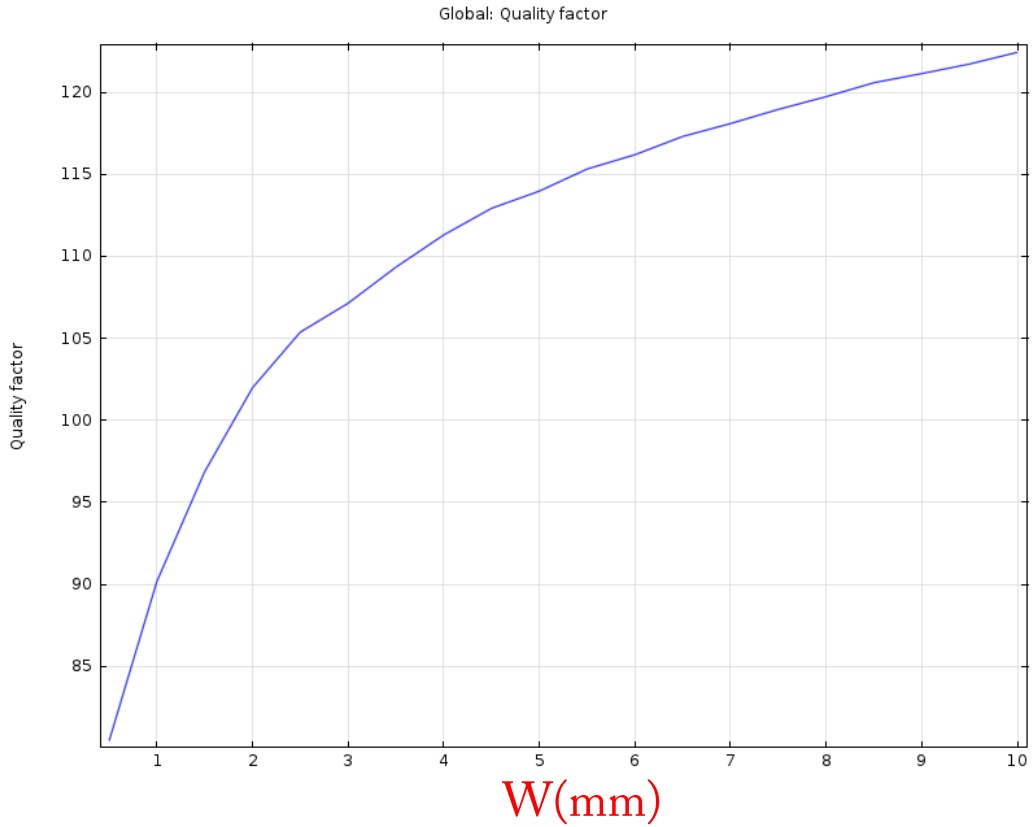


Single-layer surface coil

Quality factor vs. W

- $Q = L\omega_0 / r$
- Parametric sweep : W (0.5,0.5,10)
  S=0.9mm, R_{IN}=0.9mm, N=10

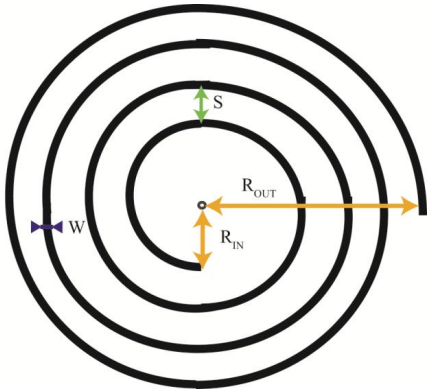


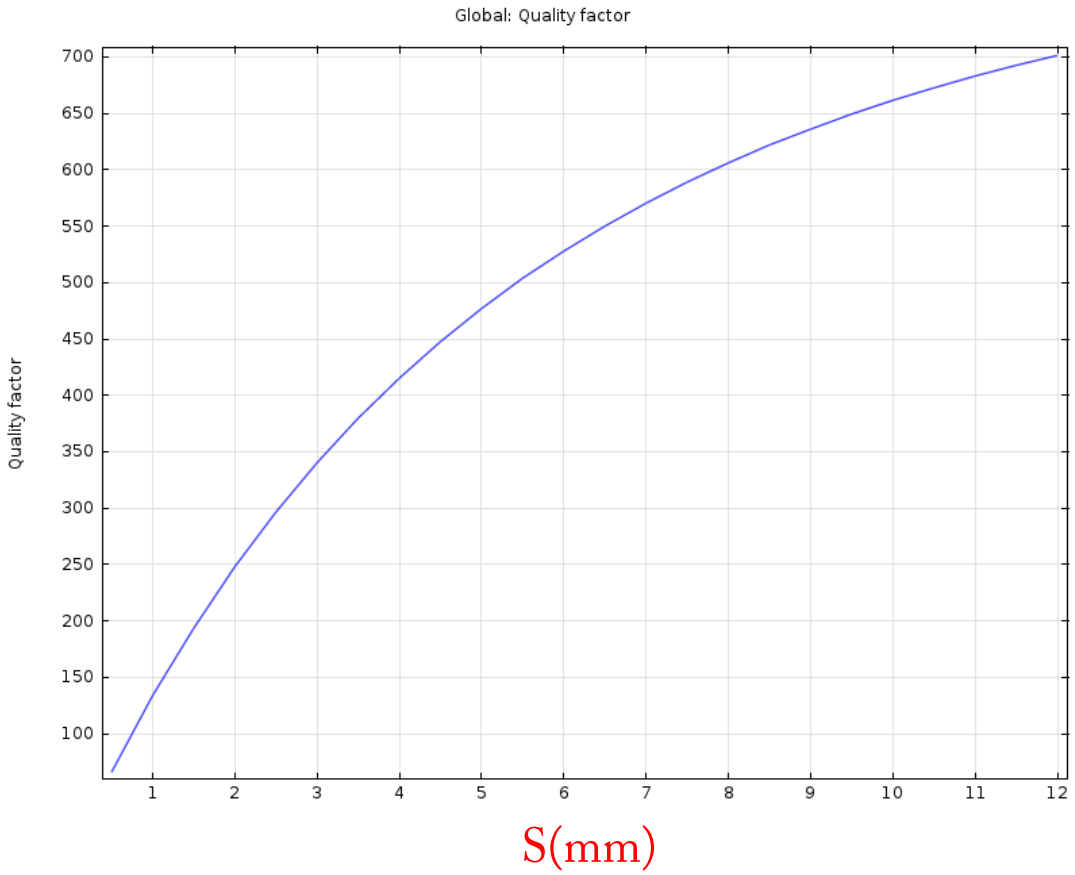


Single-layer surface coil

Quality factor vs. S

- $Q = L\omega_0 / r$
- Parametric sweep : S (0.5,0.5,12)
  W=8mm, R_{IN}=0.9mm, N=10

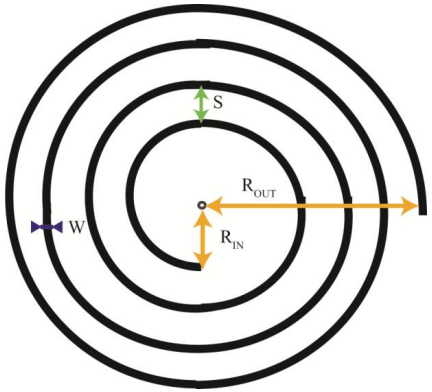


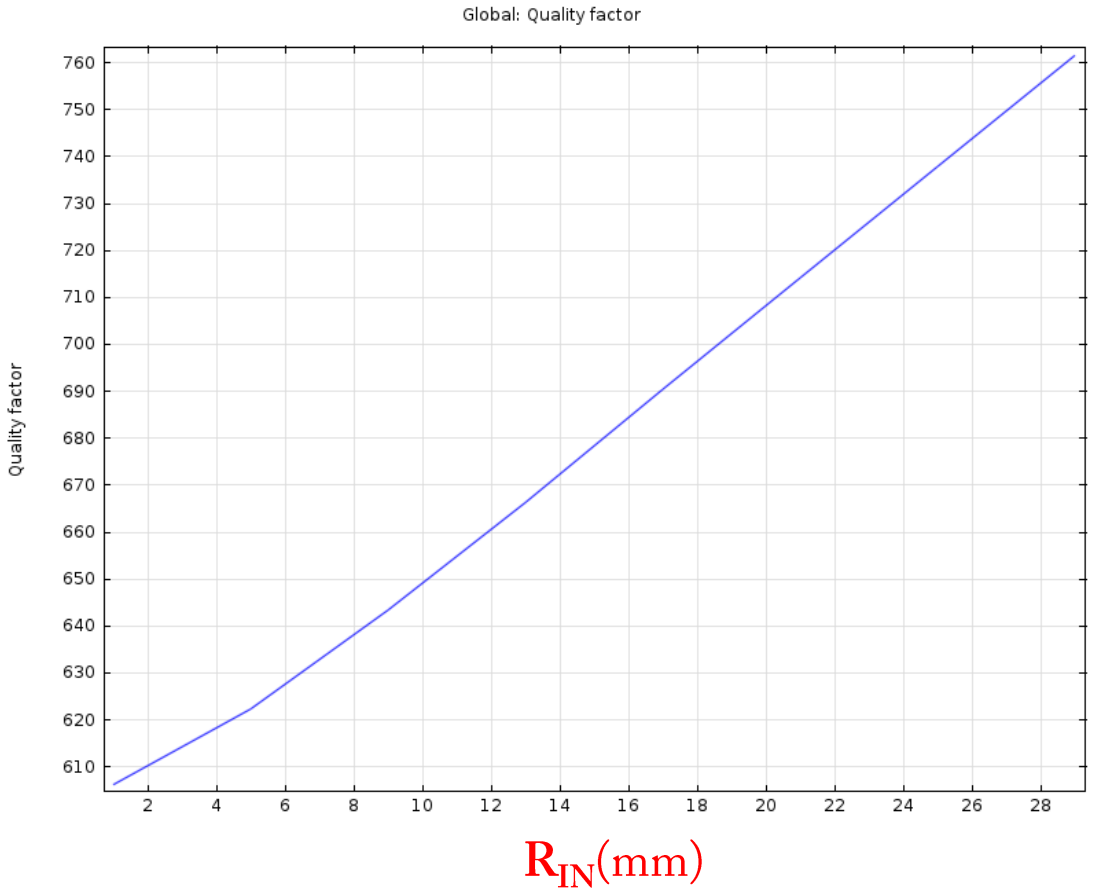


Single-layer surface coil

Quality factor vs. R_{IN}

- $Q = L\omega_0 / r$
- Parametric sweep : R_{IN} (1,4,30)
  W=8mm, S=0.9mm, N=10

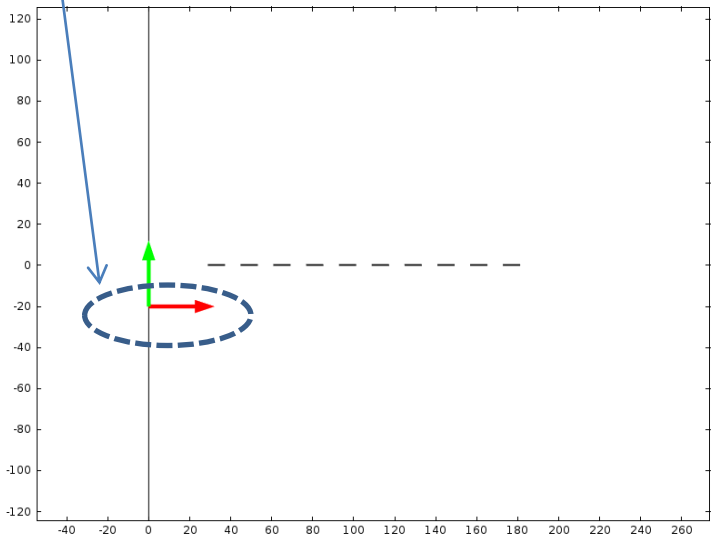


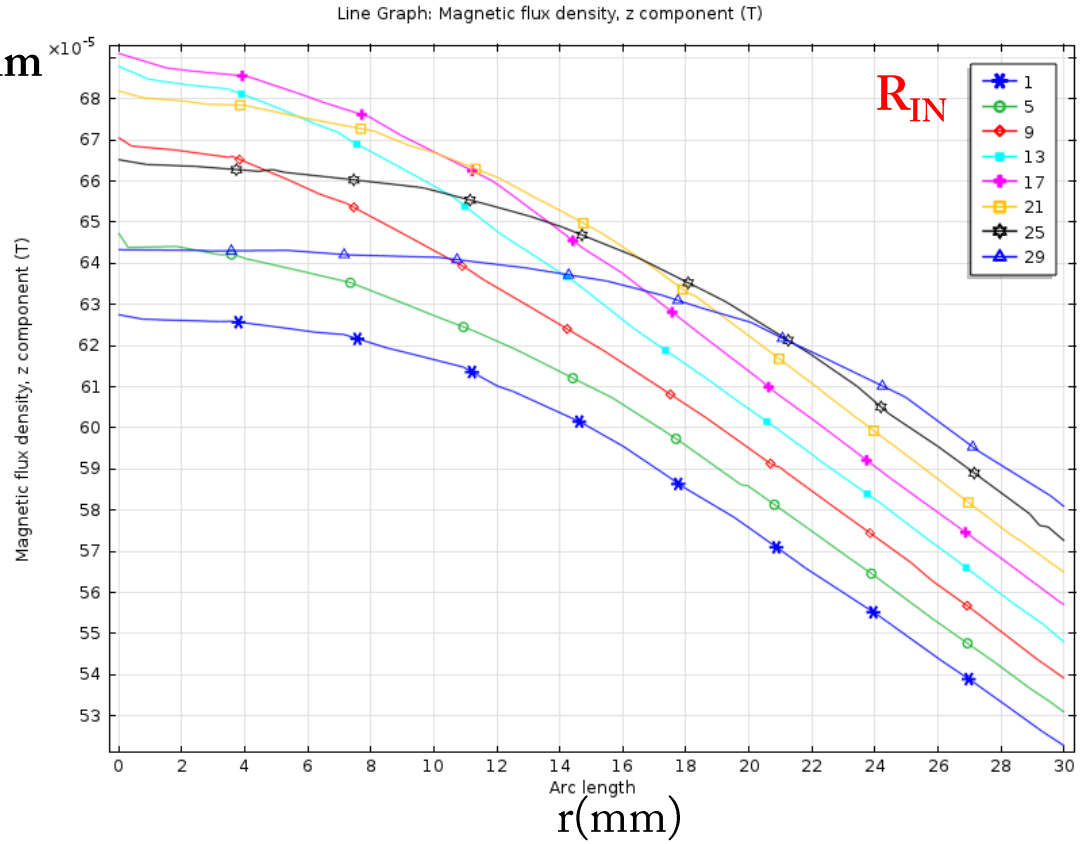


Single-layer surface coil

Magnetic field homogeneity

- Cut line 2D z=20mm and r =0 to 30mm

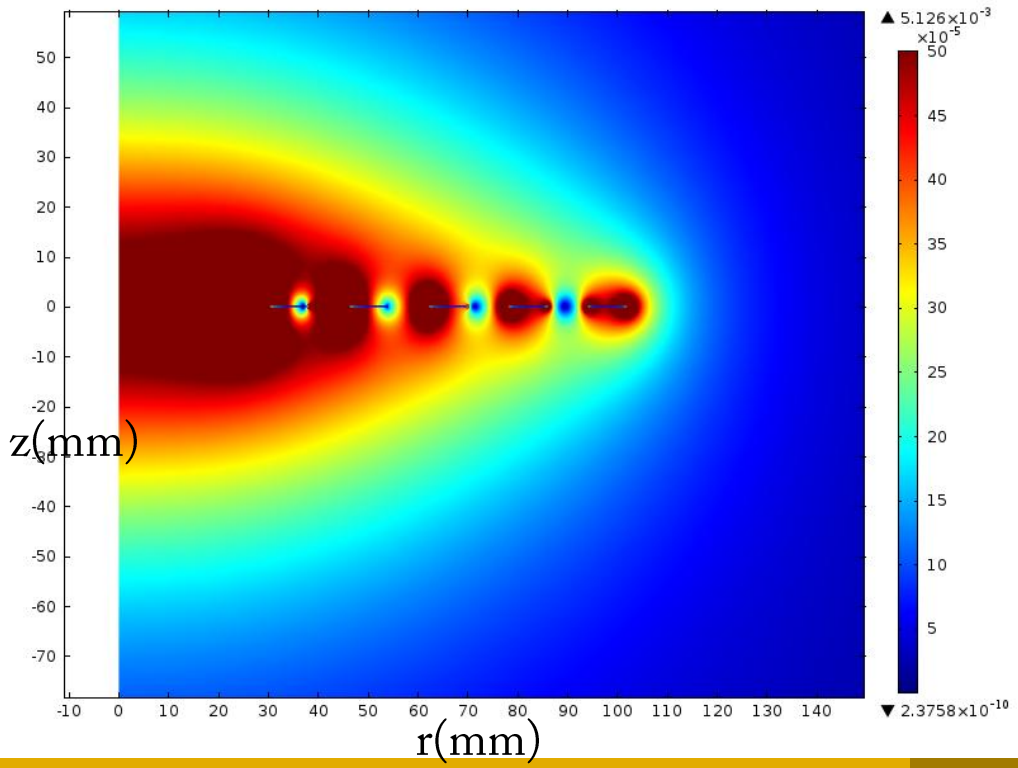




Single-layer surface coil

Magnetic field homogeneity

- R_{IN}=30 mm, W=8 mm, S=9mm, N=5 ($R_{OUT} \leq 120$ mm) ➡ $Q = 484$



Coil length = 2.3 m

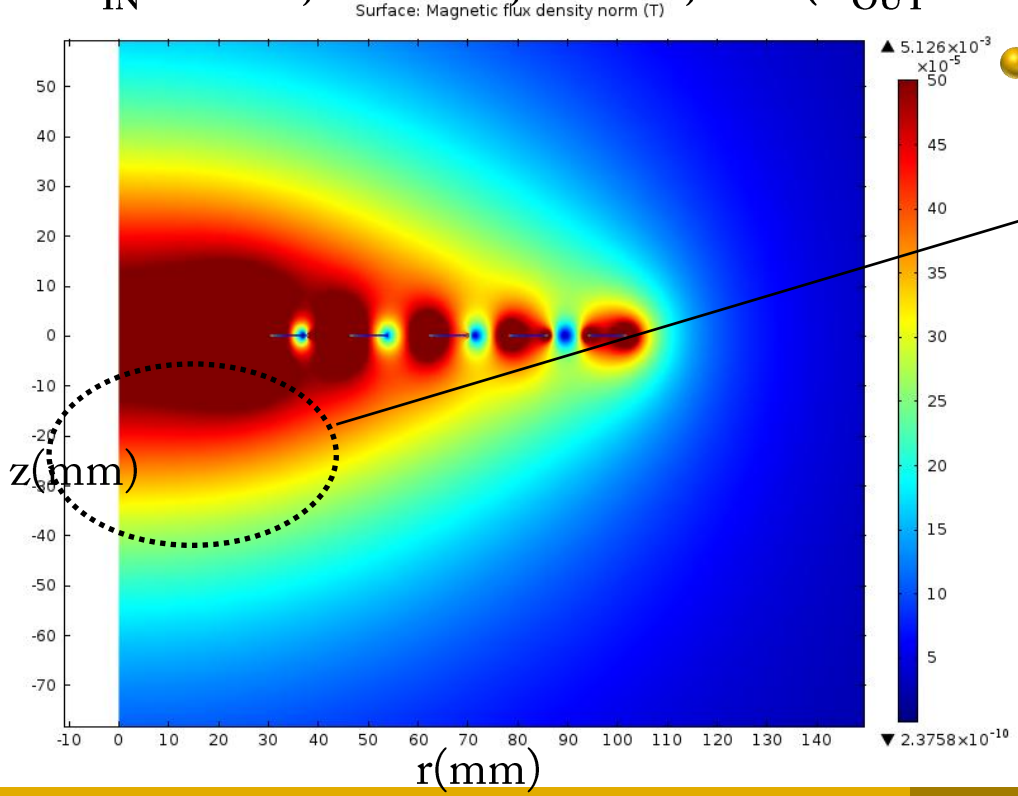
<

$\lambda/20$=4.5m

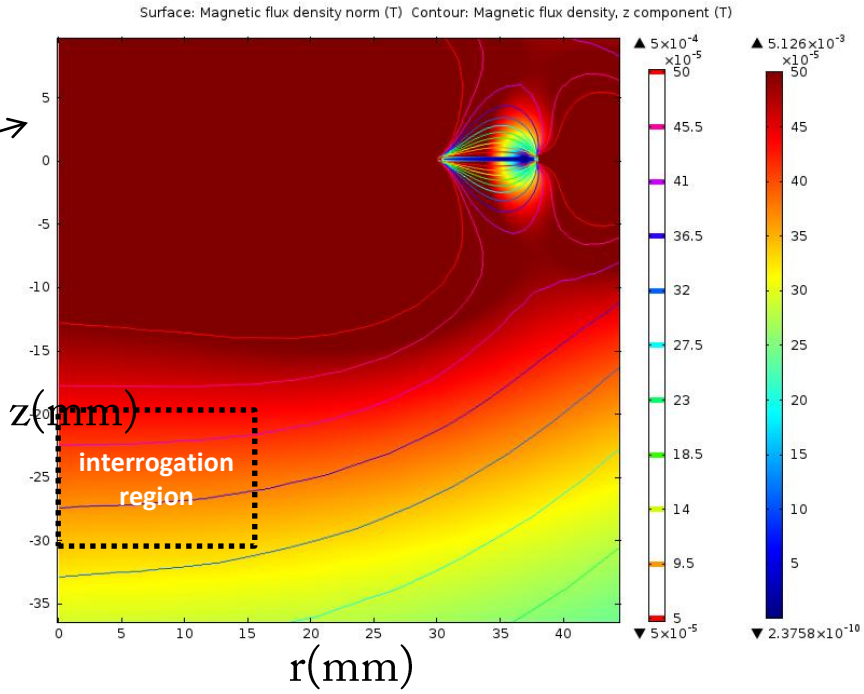
Single-layer surface coil

Magnetic field homogeneity

- R_{IN}=30 mm, W=8 mm, S=9mm, N=5 ($R_{OUT} \leq 120$ mm) → $Q = 484$



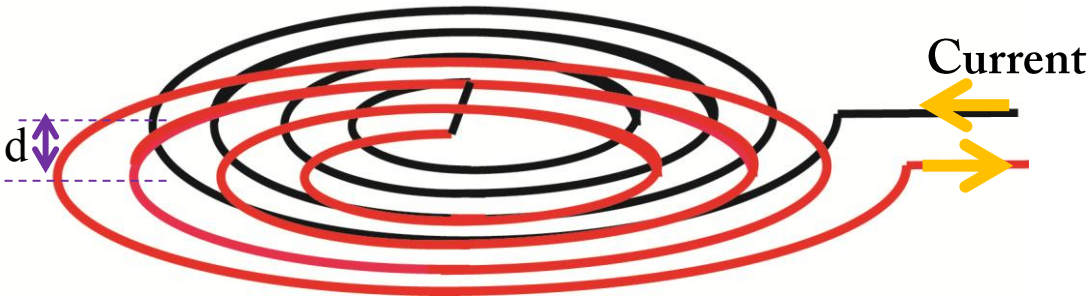
- Variation of 10% of B_z



Multi-layer surface coil

Magnetic field

- Parametric sweep : S_2 (10,3,28), W_2=8mm, R_{IN2}=30mm, N_2=3, d=10mm



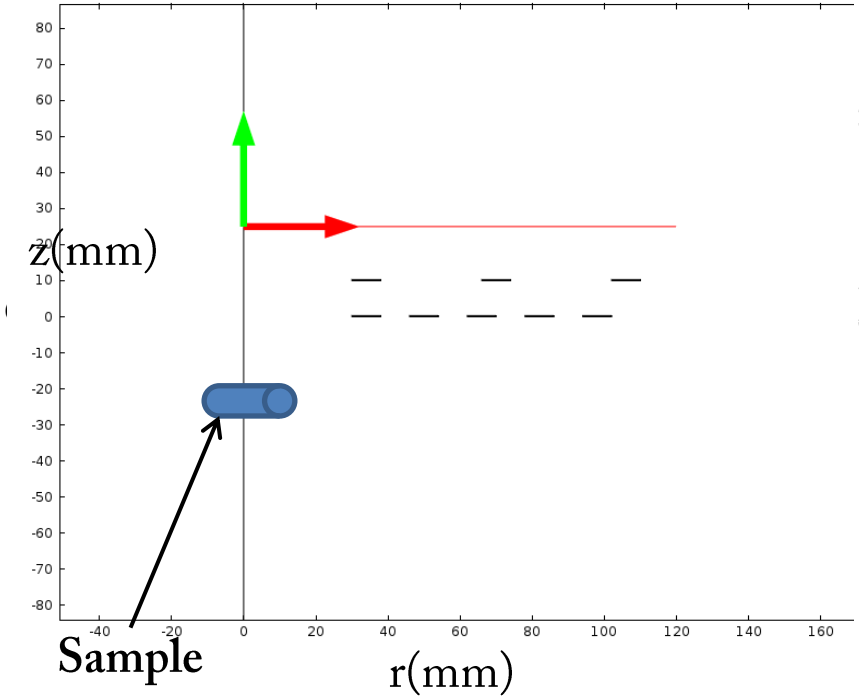
- Coil group domain

✦ Reversed current direction

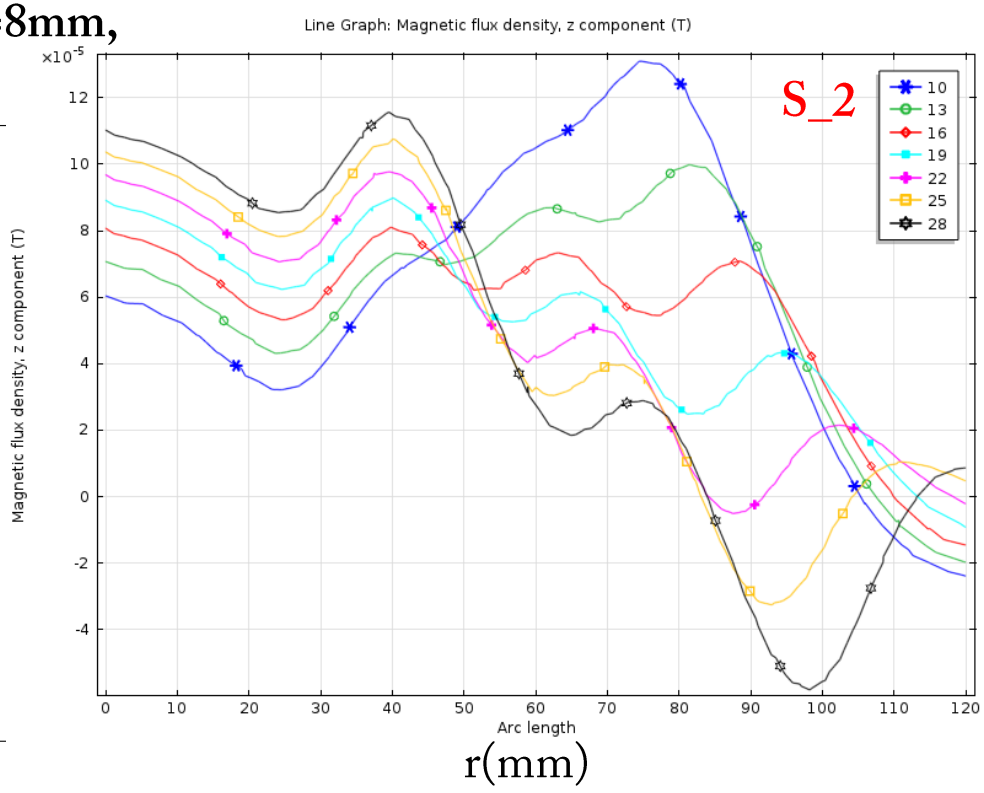
Multi-layer surface coil

Magnetic field

- Parametric sweep : S_2 (10,3,28), W_2=8mm, R_{IN2}=30mm, N_2=3, d=10mm



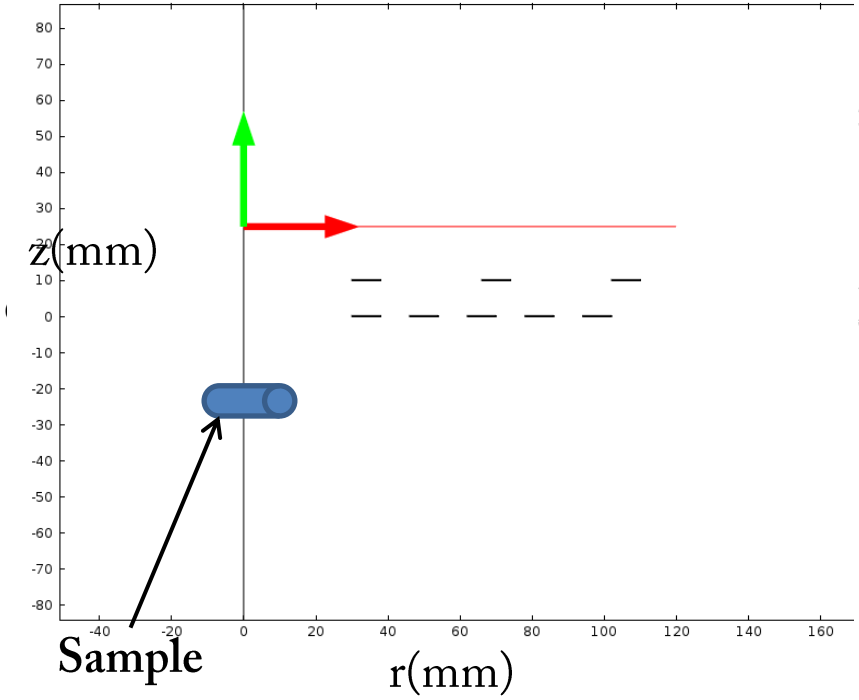
- Cut line 2D z=25mm and r =0 to 120mm



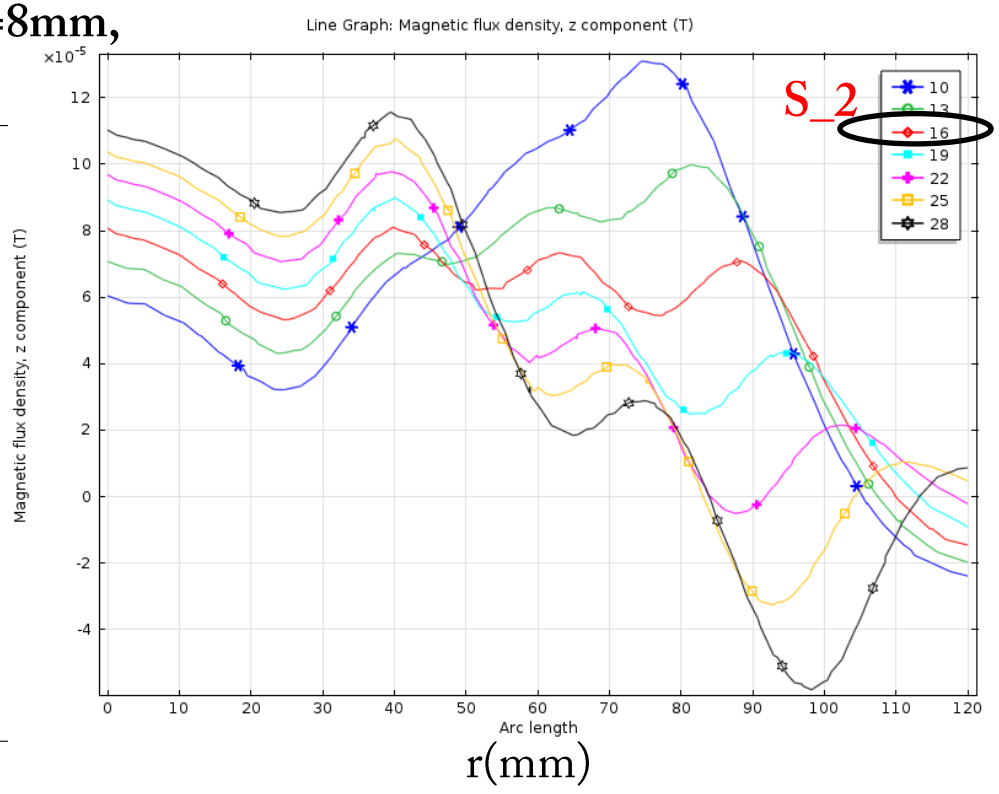
Multi-layer surface coil

Magnetic field

- Parametric sweep : S_2 (10,3,28), W_2=8mm, R_{IN2}=30mm, N_2=3, d=10mm



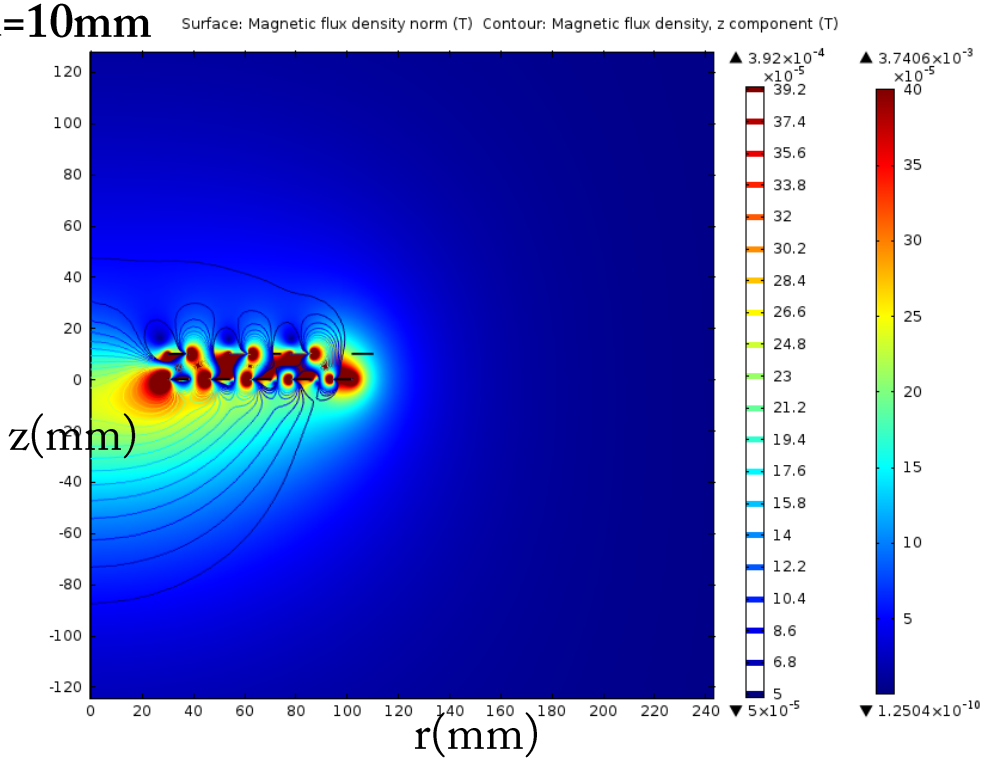
- Cut line 2D z=25mm and r =0 to 120mm



Multi-layer surface coil

Magnetic field

- S_2 =16mm, W_2=8mm, R_{IN2}=30mm, N_2=3, d=10mm



Coil length = 3.9 m

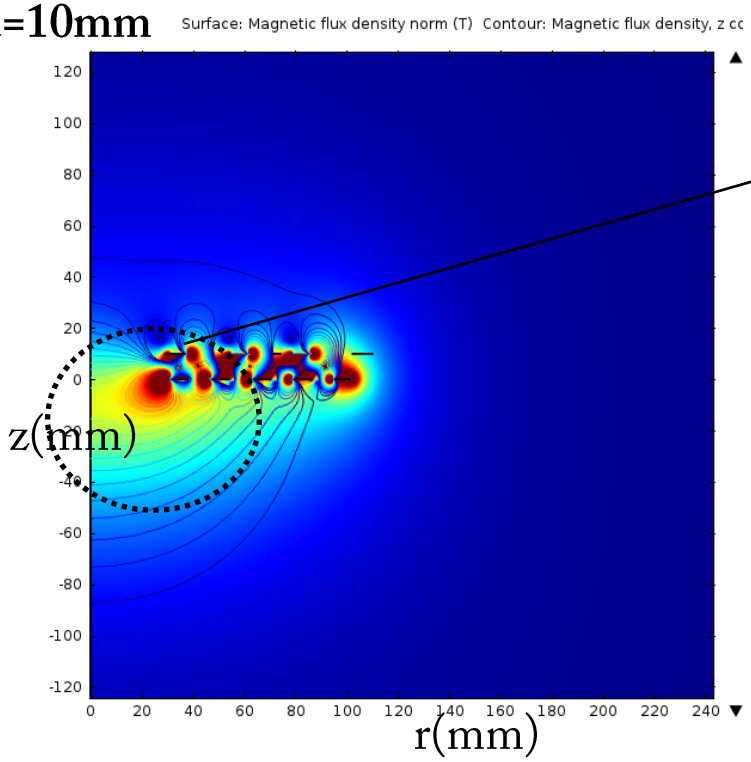
<

$\lambda/20$=4.5m

Multi-layer surface coil

Magnetic field

- S_2 =16mm, W_2=8mm, R_{IN2}=30mm, N_2=3, d=10mm



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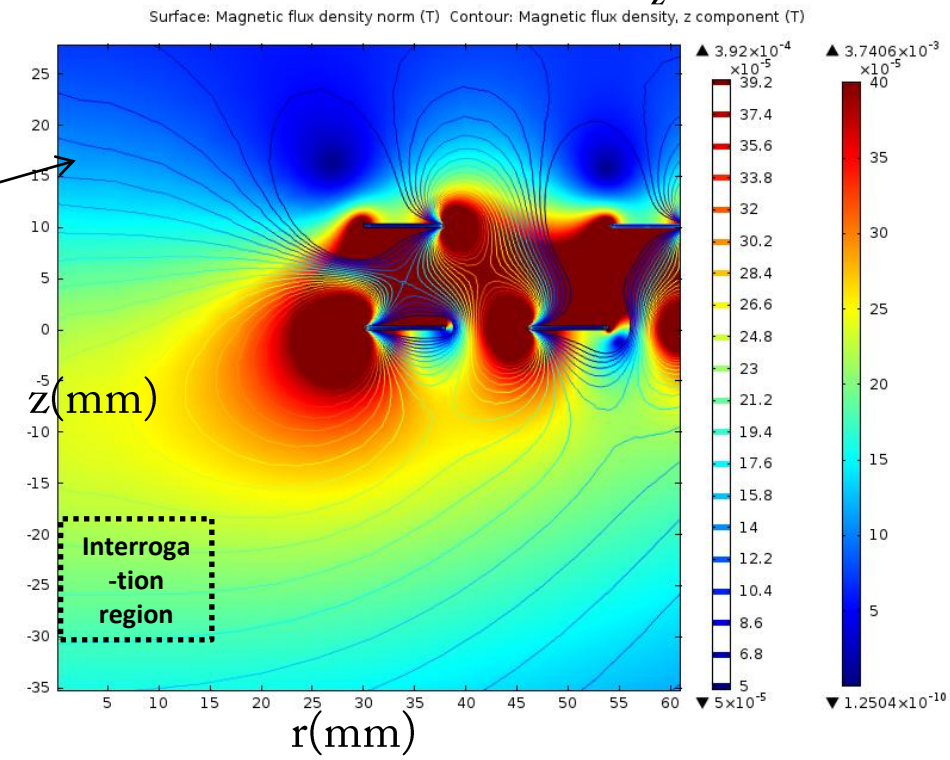
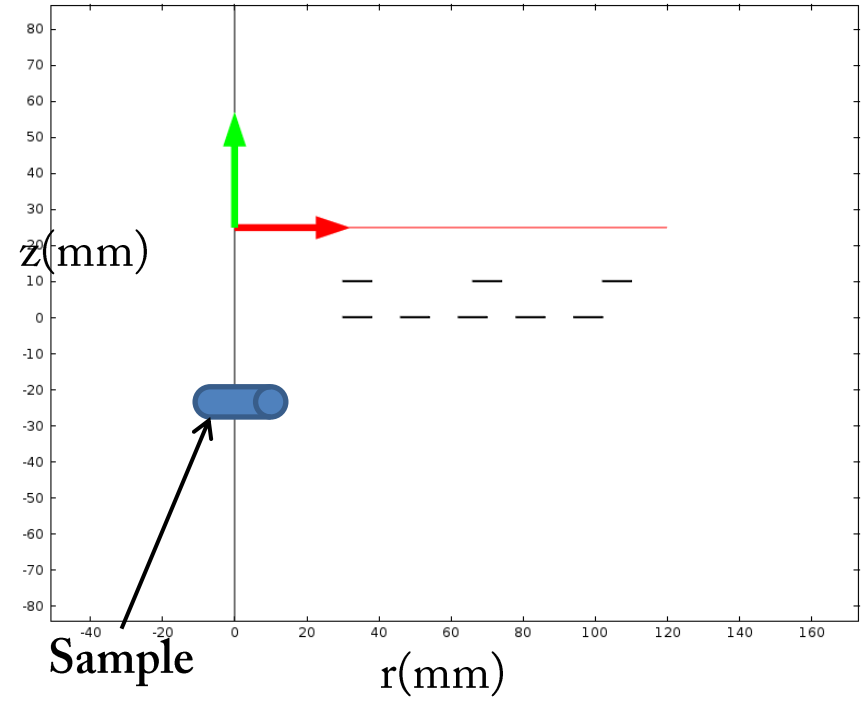
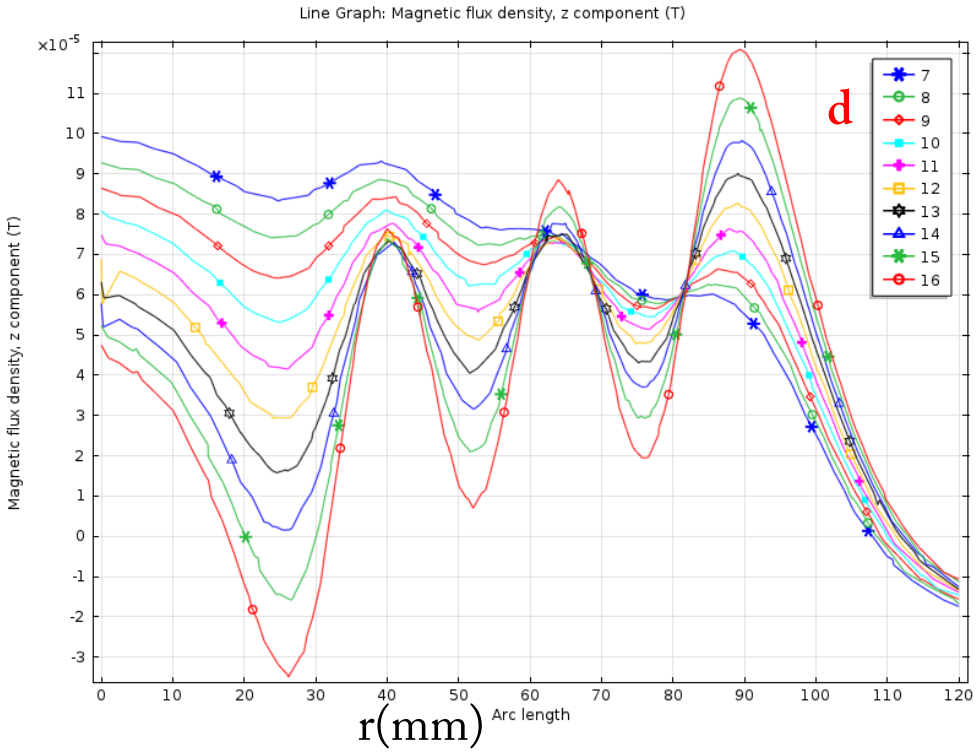


Multi-layer surface coil

Magnetic field

- Parametric sweep : d = (7,1,16), W_2=8mm, R_{IN2}=30mm, N_2=3, S_2=16mm
- Cut line 2D z=25mm and r =0 to 120mm



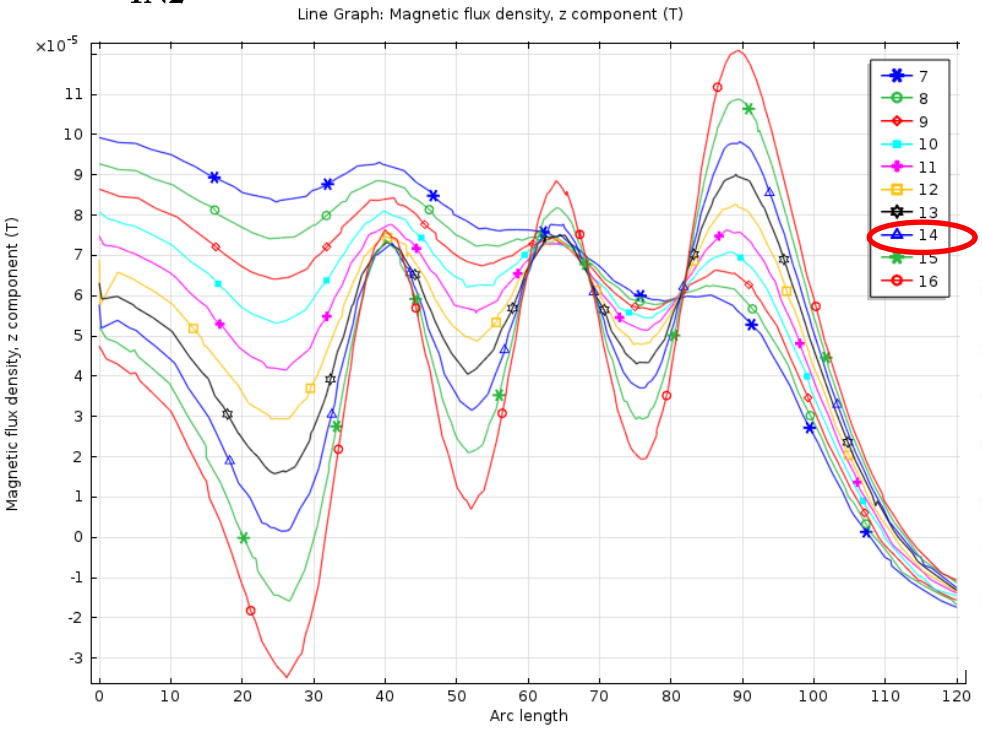


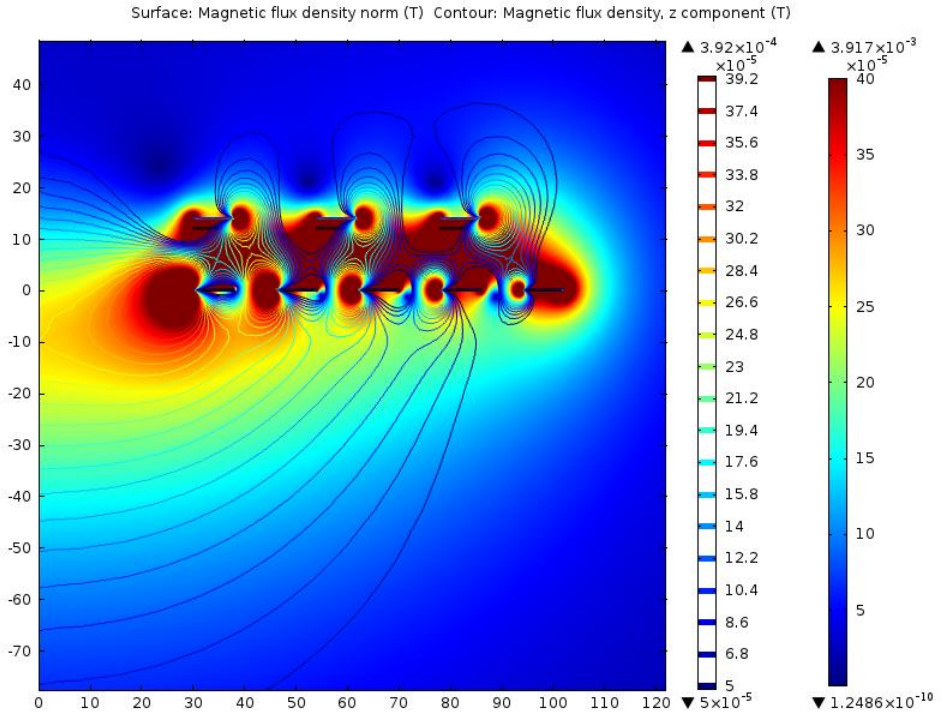
Multi-layer surface coil

Magnetic field

- Parametric sweep : d = (7,1,16), W_2=8mm, R_{IN2}=30mm, N_2=3, S_2=16mm

d = 14 mm ➡ $Q = 528$





Summary

- Geometry optimization of a single-layer surface coil

  ↓ Compromise

  ✦ Quality factor and homogeneity of the magnetic field

- Geometry optimization of a multi-layer surface coil

  ✦ Self shielded coil

  ↓

  Immunity to interfering noise sources

Question ?