Improved Magnetic Sensor for Oil and Natural Gas Well Logging

Marion Okoth, Elizabeth Clarkin, Matthew Mulloy

Motivation and Objectives

Motivation: Reduction of high ringing in magnetic sensor

Project Objectives:

- Produce a low magnetic field sensor with high signal to noise ratio
- Reduce or eliminate unwanted resonances
- Redesign measurement setup to include uniform external magnetic field
- Automation of signal processing

Requirements

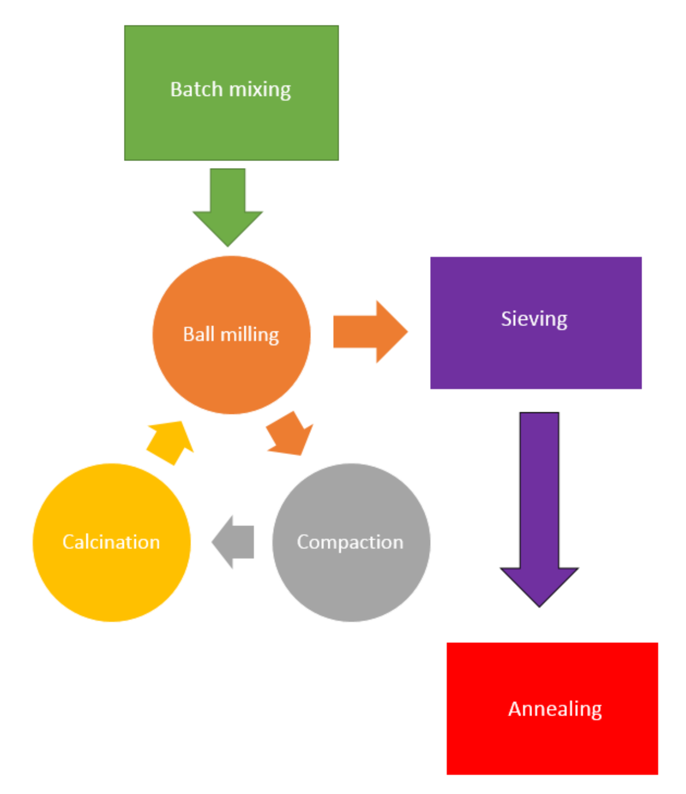
Functional

- Soft magnetic core
- Rod-like geometry
- Reduce unwanted resonances
- Low hysteresis losses
- Uniform magnetic field of 400 G encompassing length of ferrite core

Non-Functional

- Must be one of the materials currently being explored by the client
- Preparation at Ames Lab or the Microelectronic Research Center (MRC)

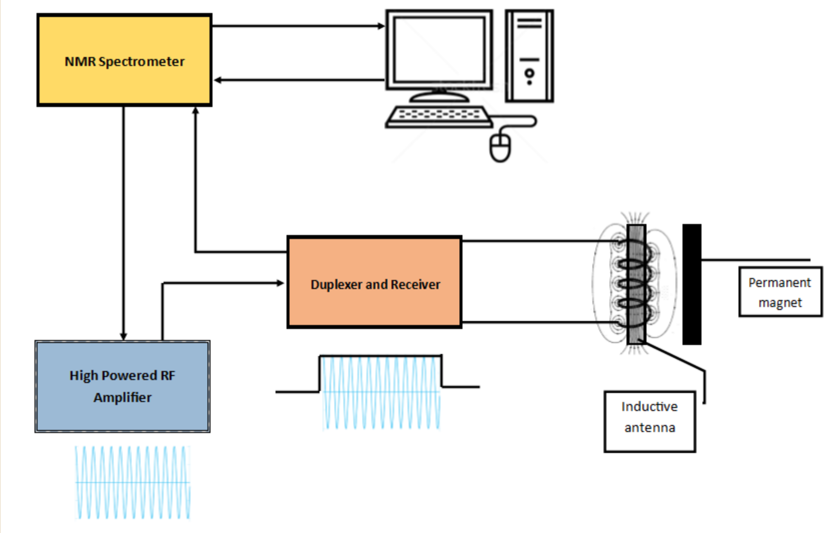
Sample preparation



- First sample is NiZnFerrite+epoxy
- Sample to epoxy ratio 25:75
- Calcination at 1050 - 1100 ºC.
- Two phase microstructure with annealing

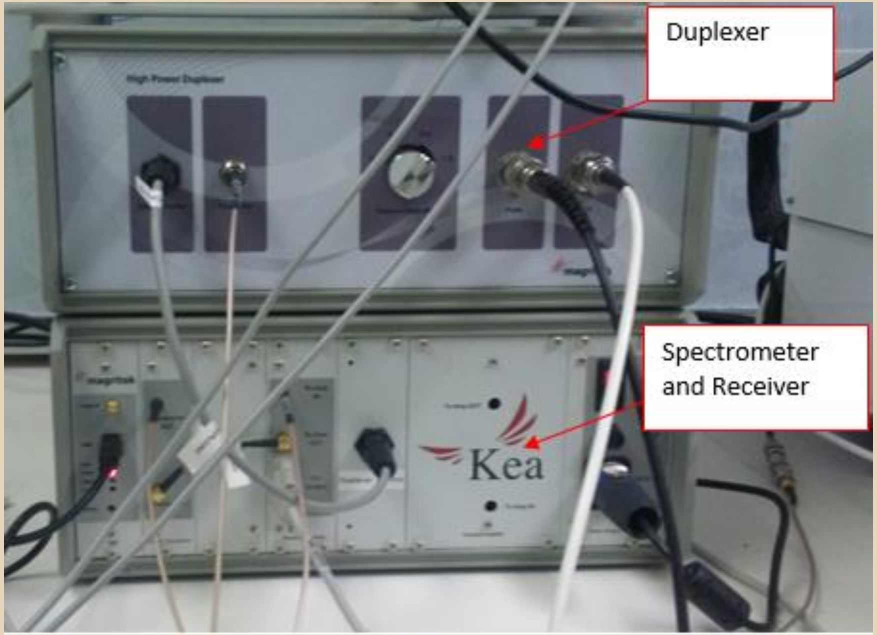
Measurement setup

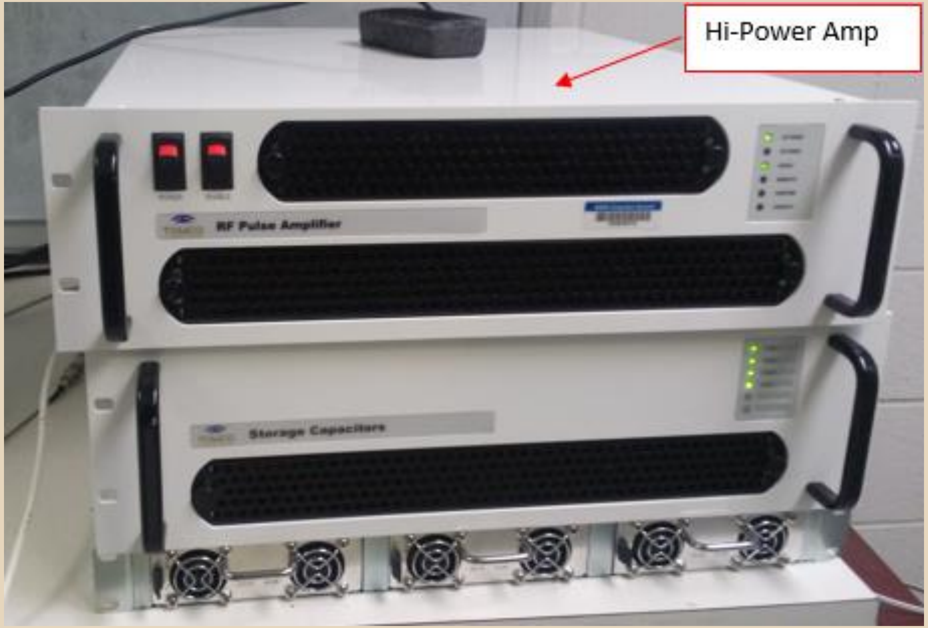
- User defines pulse frequency
- Sent to NMR spectrometer
- Routed to the high power RF amplifier
- Sent to duplexer which filter’s out unwanted signals
- Sent to inductive antenna
- Response sent to receiver
- Routed to the NMR spectrometer



N52 Permanent magnet.

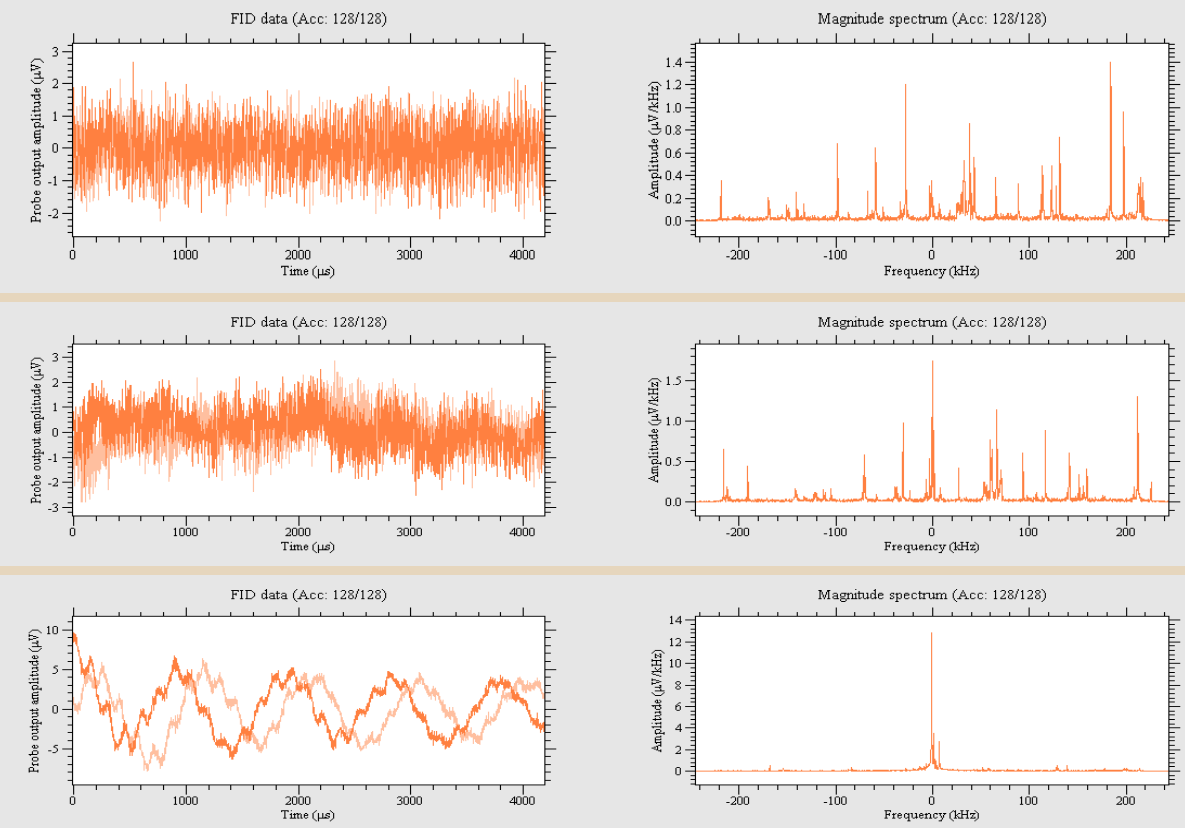
Actual measurement setup





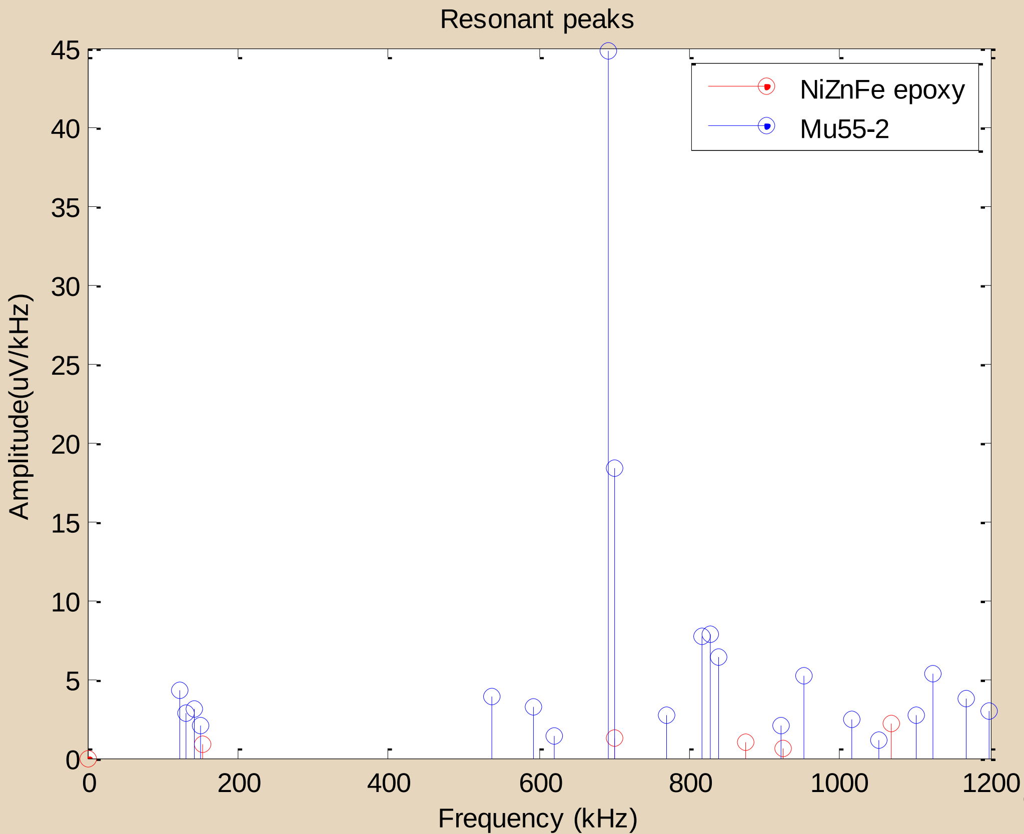
Resonant peaks identification

- Identify all possible peaks from 0.1 MHz to 1.2 MHz
- Find the spectral bandwidth
- Reciprocity between spectral bandwidth and the damping of oscillations
- Time domain signals which die out quickly most likely to be noise
- Develop software that can find spectral bandwidth of multiple data files

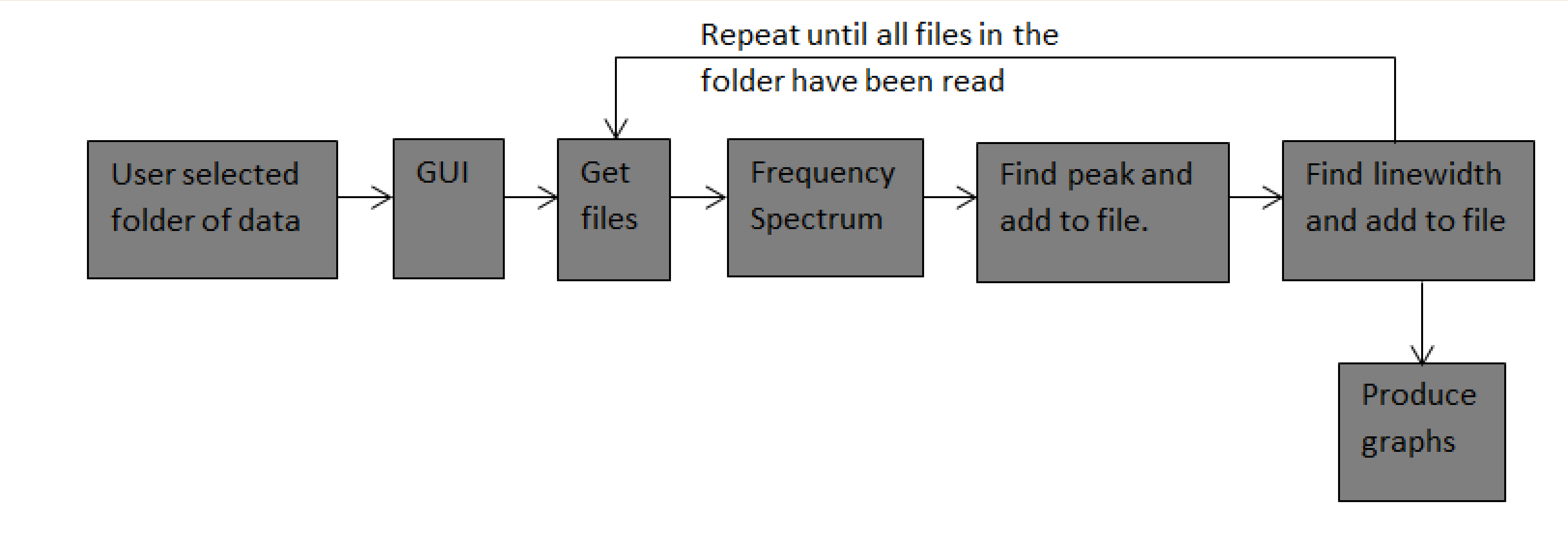


Sample comparison.

- NiZnFerrite+epoxy has fewer peaks
- The Mu55-2 has more peaks and higher amplitude peaks
- Need to test all the other samples and see how they compare



GUI system



Repeat until all files in the folder have been read
User selected folder of data
GUI
Get files
Frequency Spectrum
Find peak and add to file.
Find linewidth and add to file
Produce graphs

The approach

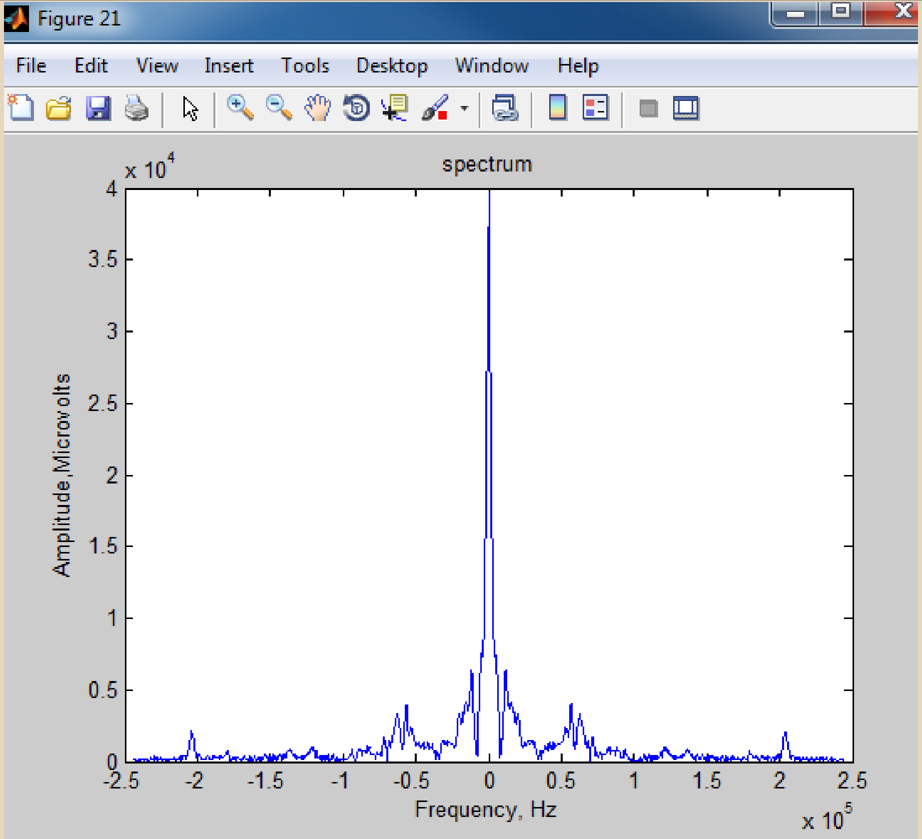
The signal processing relies on three functions

Function Name	Function Purpose
fouriertransform	Transforms the data to the frequency spectrum.
peakdetect	Creates and array of all the peaks present in the data and finds the one closest to the pulse frequency
linewidth	For each file it takes the peak returned by peak detect and finds the point at which that peak is at half its maximum. It then determines the width of the peak at that point.

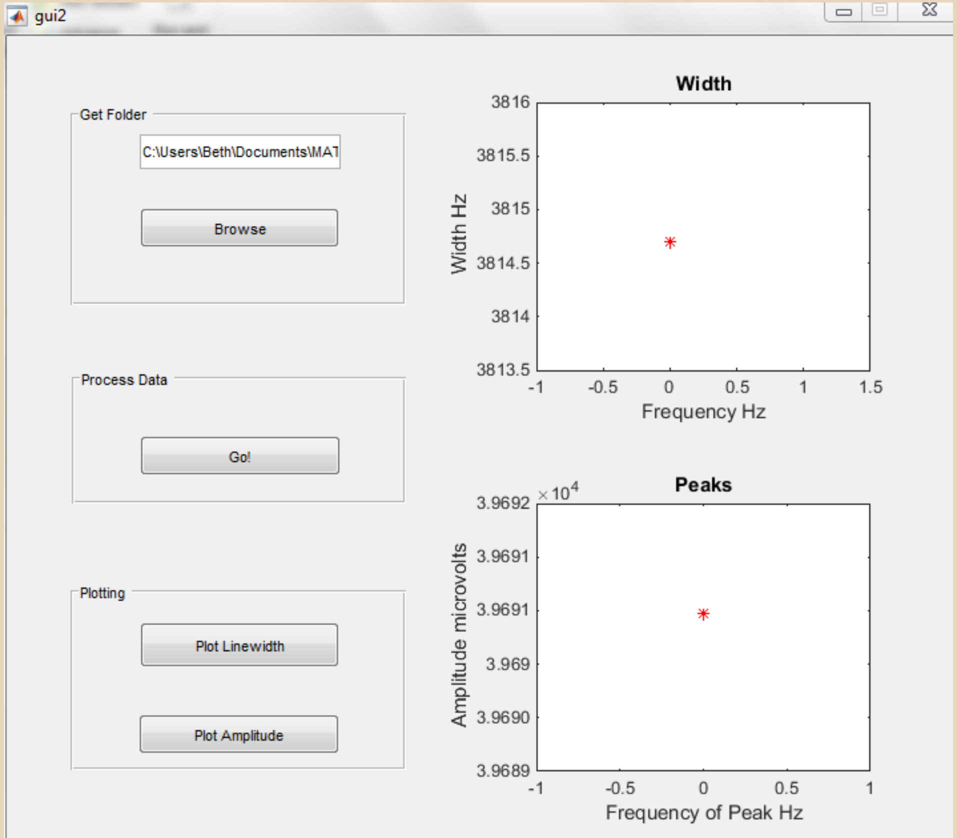
How the processing works

- Frequency spectrum->FFT function
- Peak Detection looks for point greater than both its neighbors
- Half-Width maximum->go to peak and move left until half the peak value is achieved. Multiply by 2

Find signal spectrum



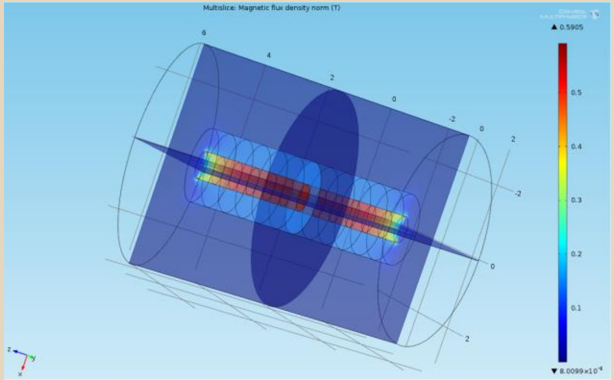
The GUI


gui2
Get Folder
C:\Users\Beth\Documents\MAT
Browse
Process Data
Go!
Plotting
Plot Linewidth
Plot Amplitude
Width
Width Hz
3816
3815.5
3815
3814.5
3814
3813.5
-1
-0.5
0
0.5
1
1.5
Frequency Hz
Peaks
×10^4
Amplitude microvolts
3.9692
3.9691
3.9691
3.969
3.9690
3.9689
-1
-0.5
0
0.5
1
Frequency of Peak Hz

Code demo

Uniform permanent magnetic field

- Induces external static magnetic field
- Magnetizes material in the core
- Low field (400 Gauss) allows the probe to have wide detection range including both oil and water resources
- External field geometries were simulated using COMSOL



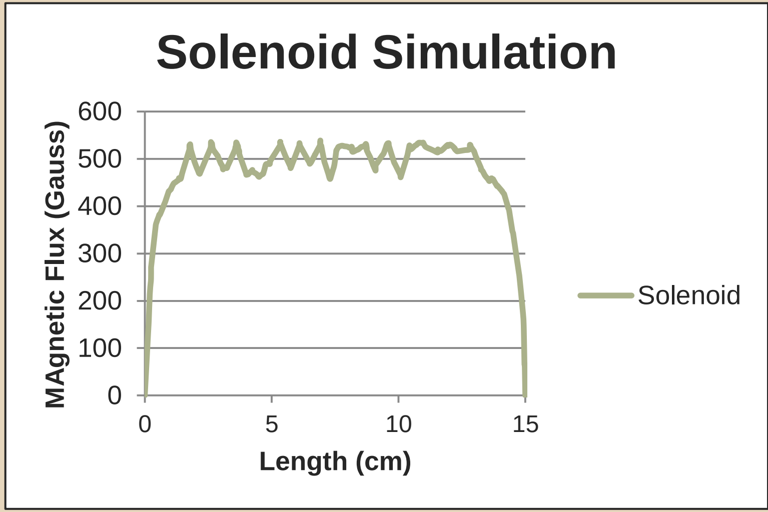
Solenoid solution

- Used solenoid equation: $B = \frac{\mu I N}{L}$
- B = Magnetic flux density, μ = Permeability I = Current, N = Number of turns, L = Length of coil

- Solenoid Specifications:
- I = 3.1A, N = 1550, L = 15, B = 402.543G
- Trial with 19 gauge wire, N =109 , I = 0.5 A, B = 8 G

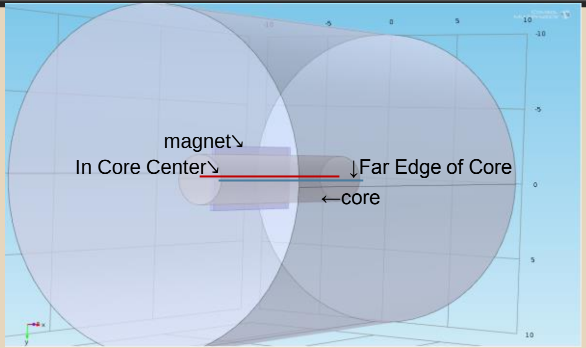
- 40 gauge laminated copper wire will be used for final build

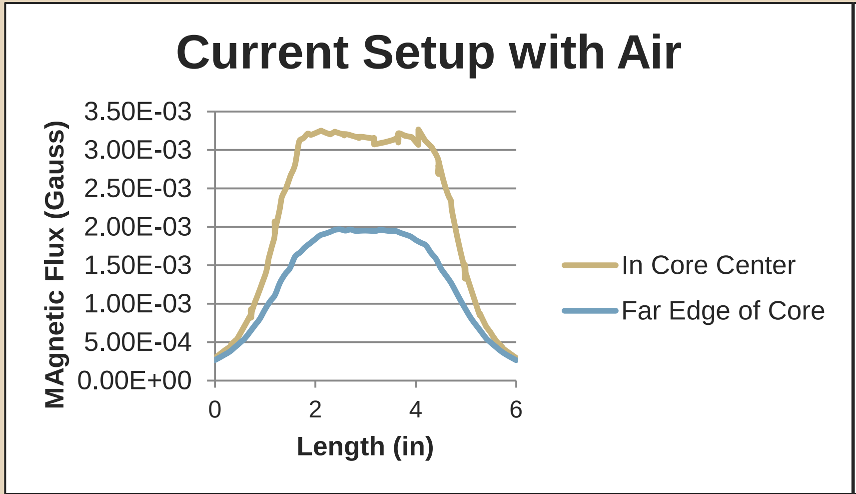
- Simulations run with UNS C10100 Copper, $\mu_r = 6.8$

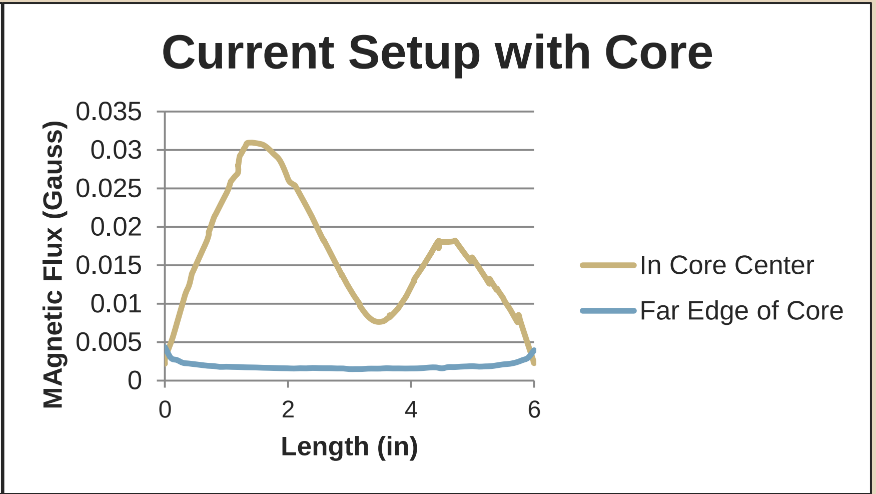


Current setup

- Permanent magnet block: 1/8 in. by 3/4 in. by 3/2 in.
- Magnet 1/4 in. away form core material
- Magnetic field defined radially



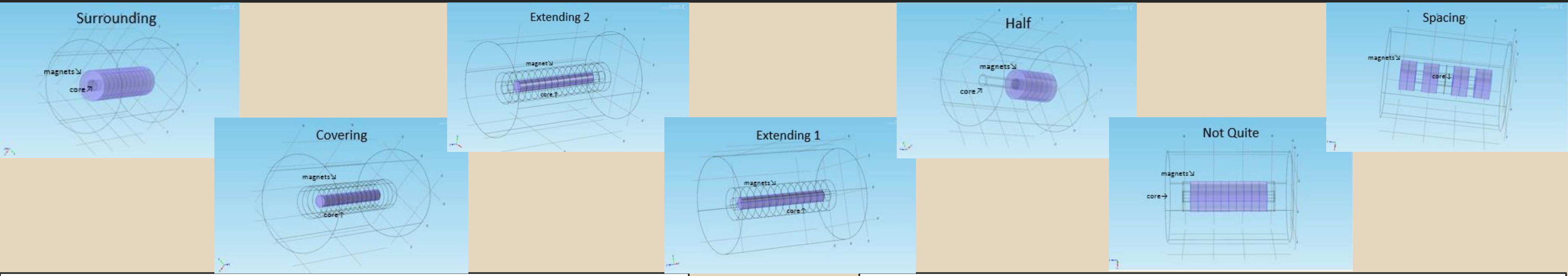


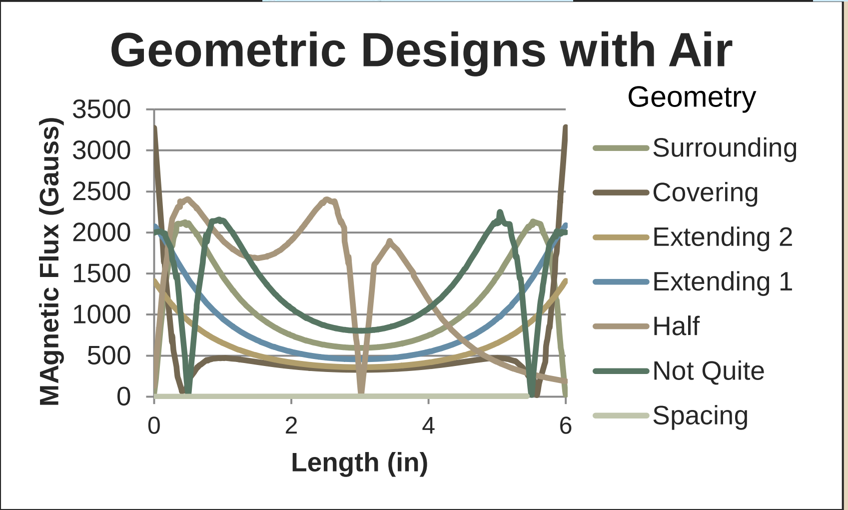


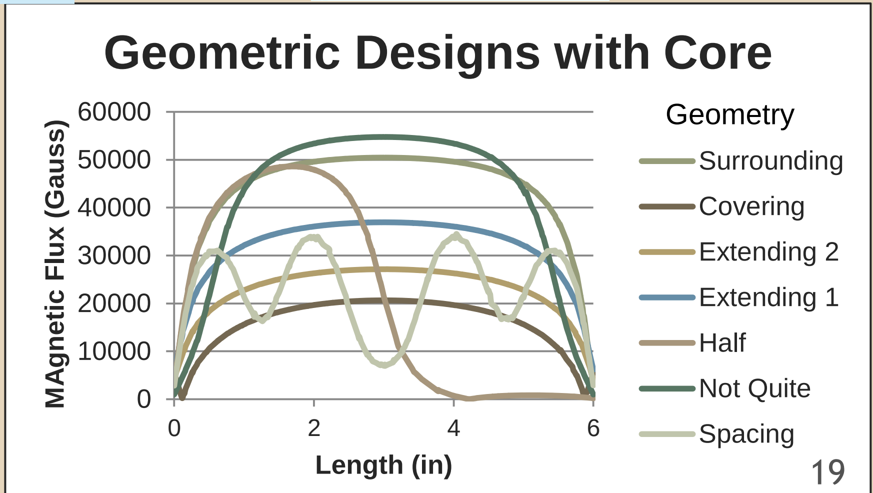
Basics Of Permanent Magnet Simulation

- Permanent Magnet: NdFeB, $\mu_r = 1.5$
- $B = \mu_r \mu_0 * B_{rmax}$
- Residual induction B_{rmax} = 13,200 Gauss
- Soft core: $Mg_{97}ZnGd_2$[solid, treated at 793K], $\mu_r = 1500$
- Magnetic flux measured axially
- Magnetic flux density plotted in Gauss
- Simulation defined in inches to reflect actual geometry of permanent magnets
- Magnets chosen to keep costs reasonable

Geometry

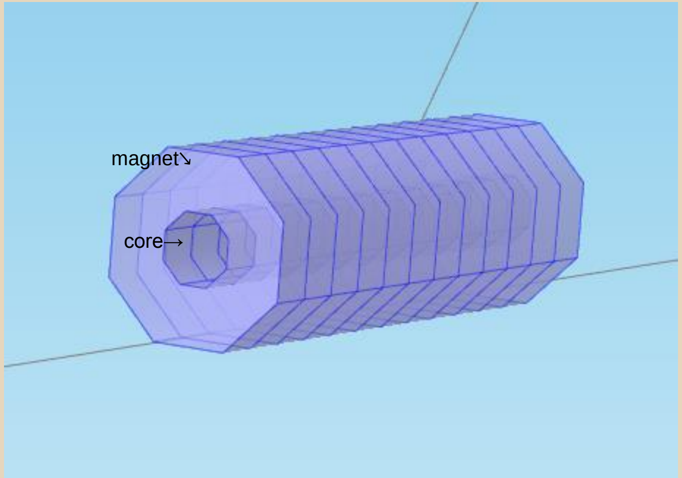

Surrounding
magnets
core
Covering
magnets
core
Extending 2
magnet
core
Extending 1
magnets
core
Half
magnets
core
Not Quite
magnets
core
Spacing
magnets
core


Geometric Designs with Air
MAgnetic Flux (Gauss)
3500
3000
2500
2000
1500
1000
500
0
0
2
4
6
Length (in)
Geometry
Surrounding
Covering
Extending 2
Extending 1
Half
Not Quite
Spacing

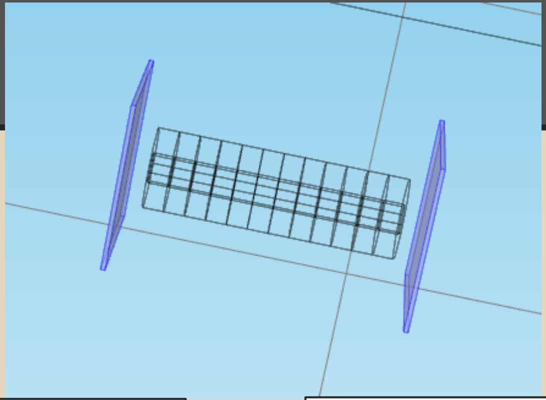

Geometric Designs with Core
MAgnetic Flux (Gauss)
60000
50000
40000
30000
20000
10000
0
0
2
4
6
Length (in)
Geometry
Surrounding
Covering
Extending 2
Extending 1
Half
Not Quite
Spacing

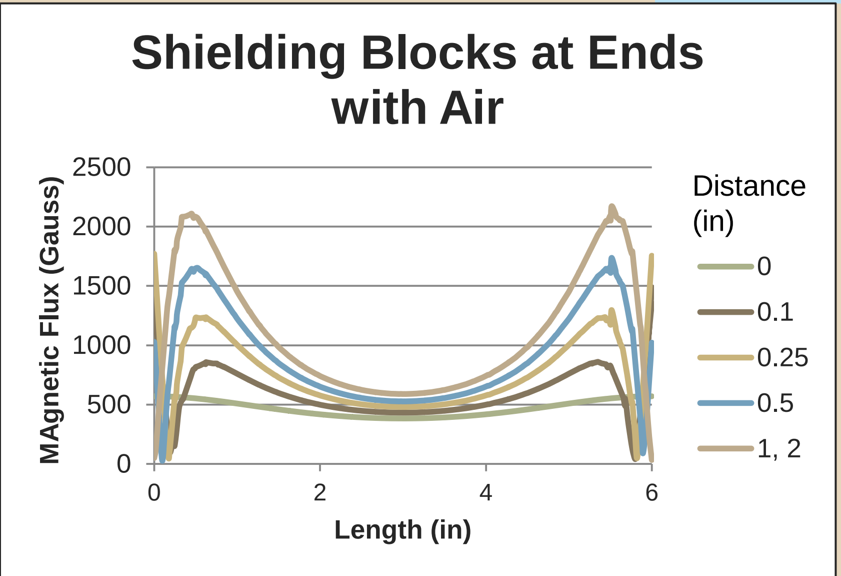
Shielding

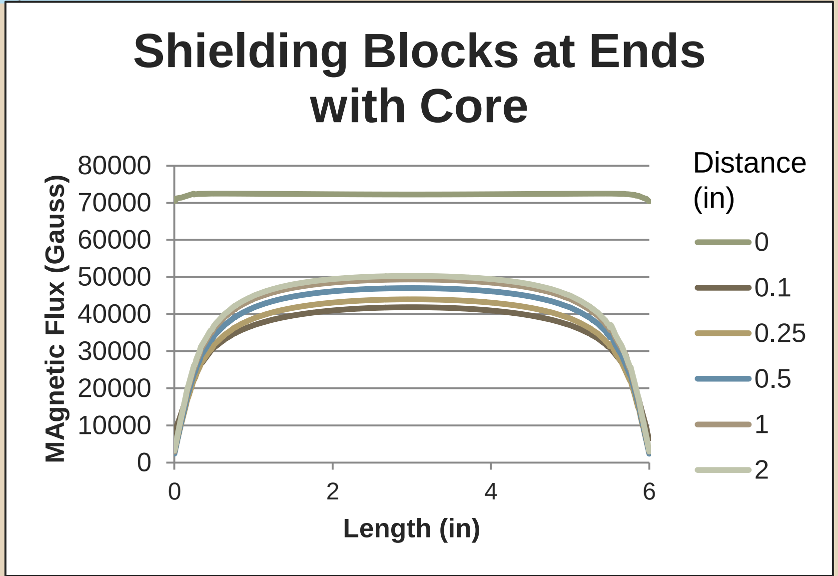
- Shielding idea from errors in surrounding geometry interacting with magnetic flux
- Material: Udimet400
- $\mu_r = 80{,}000$
- 60 % nickel
- 1/10 in. thick
- All use the Surrounding geometry



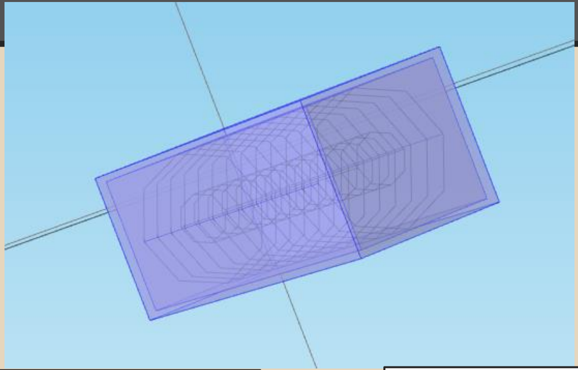
Blocks

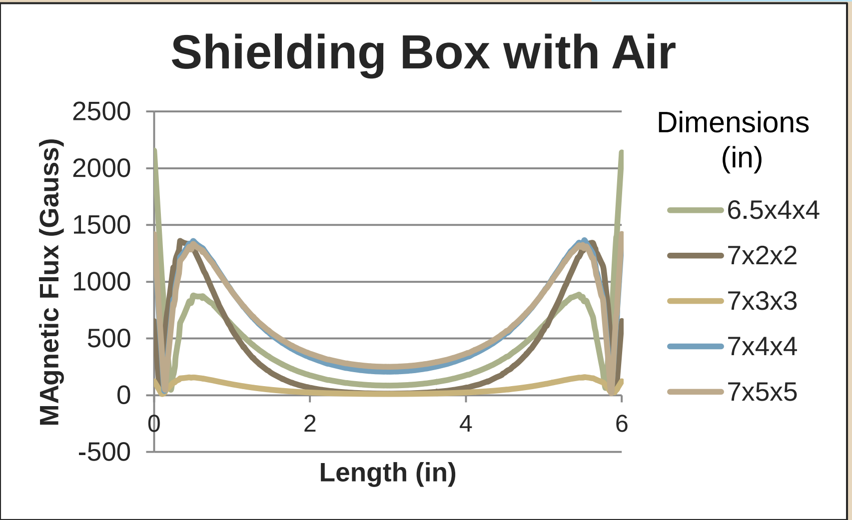



Shielding Blocks at Ends with Air
MAgnetic Flux (Gauss)
2500
2000
1500
1000
500
0
0
2
4
6
Length (in)
Distance (in)
0
0.1
0.25
0.5
1, 2

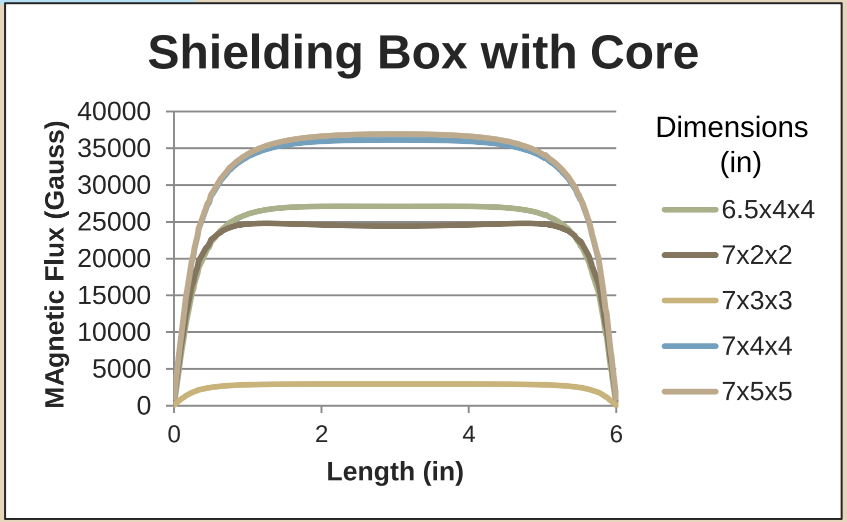

Shielding Blocks at Ends with Core
MAgnetic Flux (Gauss)
80000
70000
60000
50000
40000
30000
20000
10000
0
0
2
4
6
Length (in)
Distance (in)
0
0.1
0.25
0.5
1
2

Box



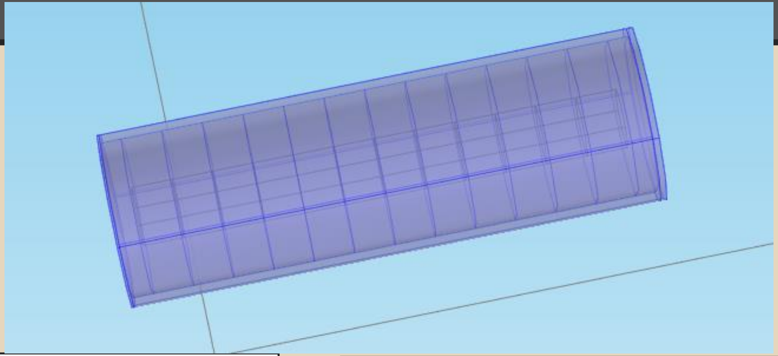


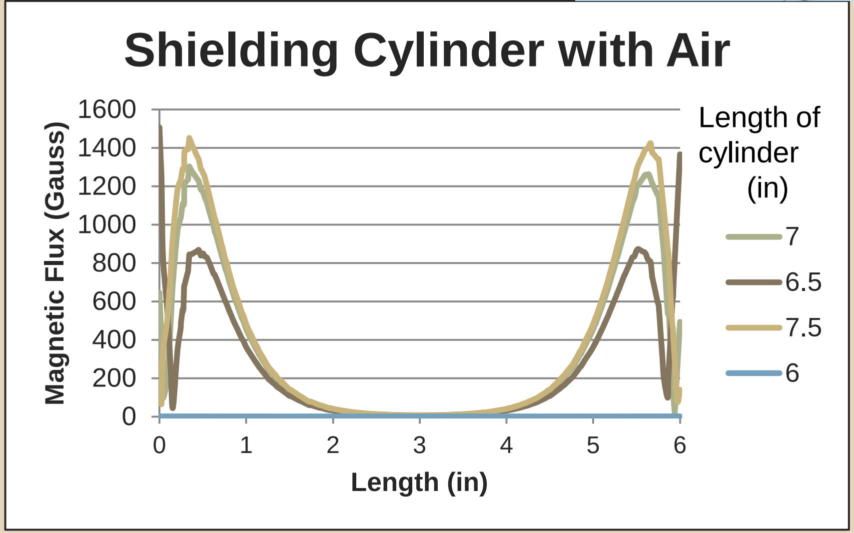
Shielding Box with Air
MAgnetic Flux (Gauss)
2500
2000
1500
1000
500
0
-500
0
2
4
6
Length (in)
Dimensions (in)
6.5x4x4
7x2x2
7x3x3
7x4x4
7x5x5



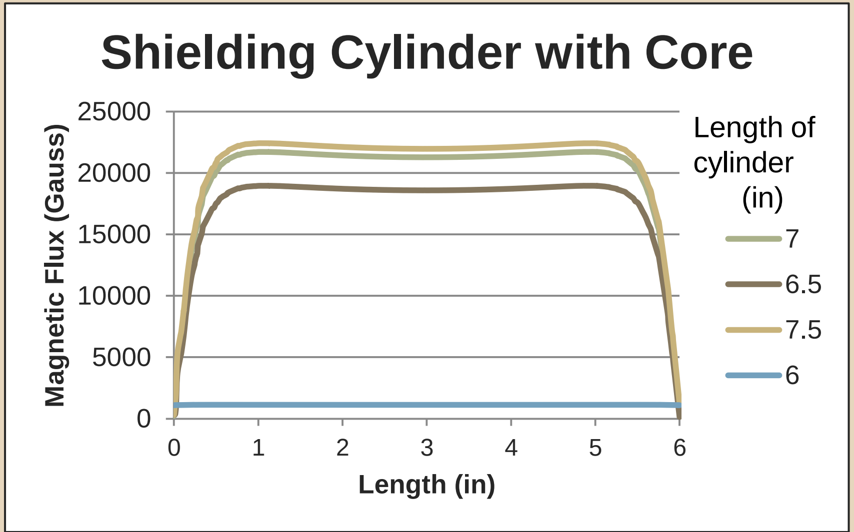
Shielding Box with Core
MAgnetic Flux (Gauss)
40000
35000
30000
25000
20000
15000
10000
5000
0
0
2
4
6
Length (in)
Dimensions (in)
6.5x4x4
7x2x2
7x3x3
7x4x4
7x5x5

Cylinder





Shielding Cylinder with Air
Magnetic Flux (Gauss)
1600
1400
1200
1000
800
600
400
200
0
0
1
2
3
4
5
6
Length (in)
Length of cylinder (in)
7
6.5
7.5
6



Shielding Cylinder with Core
Magnetic Flux (Gauss)
25000
20000
15000
10000
5000
0
0
1
2
3
4
5
6
Length (in)
Length of cylinder (in)
7
6.5
7.5
6

Deliverables

May 2015

- Compare resonant frequencies of our sample and Mu55
- Prepare MATLAB GUI
- COMSOL simulations using permanent magnets

December 2015

- Magnetic sensor with fewest number of resonant peaks
- Prepare GUI machine interface
- Construct uniform magnetic field generator

What remains

- Measurements of all other client samples to identify amplitudes and frequencies
- Fix the frequency shifting of the spectrum
- Test linewidth and peak detect
- Determine whether it is possible to interface with inbuilt software. If so do so
- Construction of Solenoid and permanent magnet generator

Thank you

Questions?