EE66a Lab si3g19

Eddy Current Screening

3.1 Apparatus

Simple example of eddy current screening, consisting of a copper (non-magnetic) tube inside a solenoid with a search coil on a moveable central support.

Second tube with axial slit → demonstrating when eddy current path is broken

Variable frequency supply → power function generator in series with variable resistor, to assist solenoid current adjustment.

Circuit current: 100mA → avoid distortion of sinusoidal waveform

- Why do you think the current will vary with frequency if the applied voltage remains the same?
  Current varies with frequency
  As self-inductance increases, frequency increases, the potential difference drops across the coil

Dimensions

a) Solenoid

Length = 280 mm
Approximate mean diameter = 110 mm
Number of turns = 664

b) Copper Tube

Outside diameter (2a) = 88.5 mm
Inside diameter (2b) = 82.5 mm
Wall thickness (t) = 3 mm
Resistivity (?) = 2.1 10?8 ?-m

3.2 Experimental

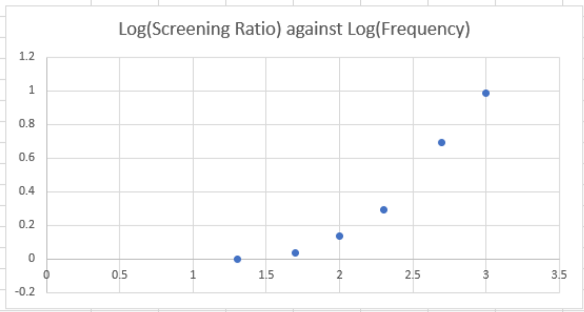
3.2.1

H_0 : field at the centre of the solenoid without the copper tube

H_1 : field with tube in position

Frequency: 20Hz-1000Hz

Frequency (Hz)	V(H1) (mV)	V(H0) (mV)	Screening Ratio H1/H0	Log Frequency	Log Screening Ratio
20	6.685	6.737	0.992281431	1.301029996	-0.003365136
50	15.202	14.008	1.085237007	1.698970004	0.035524595
100	29.562	21.568	1.370641691	2	0.136923938
200	58.037	29.646	1.957667139	2.301029996	0.291738851
500	142.629	29.067	4.906904737	2.698970004	0.690807627
1000	286.924	29.56	9.706495264	3	0.987062447



- Explain how does this voltage is related to the field inside the tube.
  Voltage V is proportional to field
  V=IR
  $B = \frac{\mu_0 I}{2\pi r}$ $E = \frac{-dB}{dt} * \frac{r}{2}$
  - $E = \frac{-dI}{dt} * \frac{\mu_0 n r}{2}$

- Why the screening improves as the frequency increases?
  As frequency increases, the rate of change of voltage across the coil increases. Therefore the rate of change of magnetic field increases and induces more current in the coil.

3.2.2

screeneddy.m

```
ur = 1;
u0 = 4.*pi.*10^-7;
p = 2.1.*10^-8;
f = 10:10:1000;
w = 2.*pi.*f;
d = ((2.*p)./(w.*ur.*u0)).^0.5;
t = 3.*10^-3;
c = t./d;
y = (0.5).*(cosh(2.*c)+cos(2.*c))+(b./(2.*d)).*((sinh(c).*cosh(c))-(sin(c).*cos(c)))+((b./(2.*d)).^2).*(cosh(2.*c)-cos(2.*c));
a = 88.5/2.*10^-3;
b = 82.5/2.*10^-3;
screen_ratio = ((a./b)./y).^(0.5);
plot (f, screen_ratio)
xlabel('Frequency (Hz)')
ylabel('Screening Ratio')
grid on
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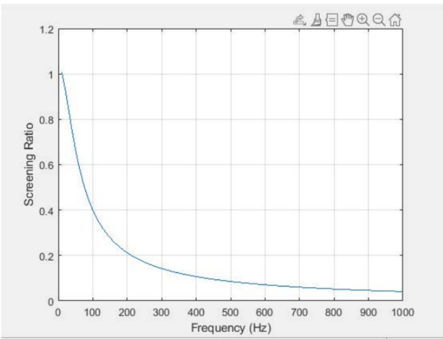


Using the matlab code, I saw that I got similar results. However, t must be remembered the tube is copper not aluminium.

- Compare experimental and theoretical values. Do you expect better of worse agreement if the tube outer and inner radii are reduced by factor of 10?
  Expect my results to fit worse because t<< a. so reduces t by a factor of 10. Reduces difference by a factor of 10. This means that t will be closer to $\delta$and the approximate value will be less accurate.

3.2.3

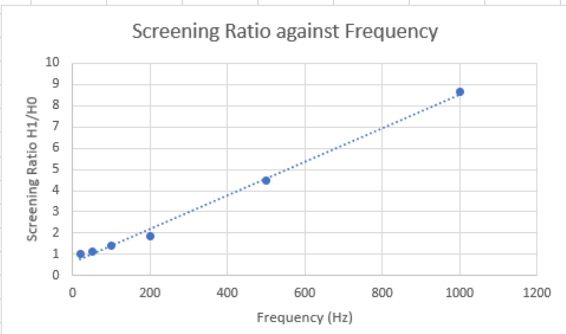
Constant Frequency: 300Hz

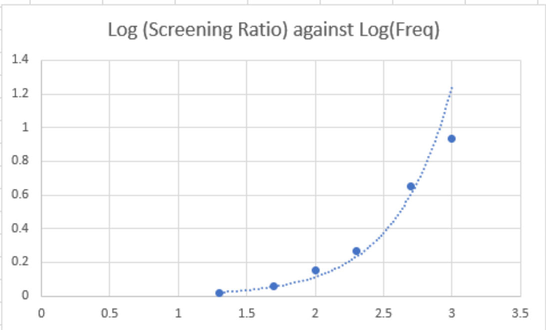
Solenoid in by	V(H1) (mV)	V(H0) (mV)	Screening Ratio H1/H0
100% in	27.5	69.9	0.39341917
75% in	27.4	69.1	0.396526773
50% in	25.4	64.3	0.395023328
25% in	19.4	53	0.366037736

- Explain the dependence of the fields H0, H1 and the screening ratio on the position.
  Screening ratio stays relatively the same
  Somewhat constant, no dependence

3.2.4 Split copper tube

Frequency (Hz)	V(H1) (mV)	V(H0) (mV)	Screening Ratio H1/H0	Log Frequency	Log Screening Ratio
20	6.987	6.737	1.037108505	1.301029996	0.015824196
50	16.003	14.008	1.142418618	1.698970004	0.057825272
100	30.794	21.568	1.427763353	2	0.154656231
200	54.518	29.646	1.838966471	2.301029996	0.264573811
500	130.111	29.067	4.476244538	2.698970004	0.650913804
1000	256.094	29.56	8.6635318	3	0.937694974





Constant Frequency: 300Hz

Solenoid in by	V(H1) (mV)	V(H0) (mV)	Screening Ratio H1/H0
100% in	90.4	69.9	1.293276109
75% in	90	69.1	1.302460203
50% in	87.6	64.3	1.362363919
25% in	76.4	53	1.441509434

- As expected, the screening is very bad. Why?
  Screening is very poor as there is a gap in the solenoid. The eddy currents which were previously free to flow around the complete tube are now unable to as the path is broken by the slit
  There would be another magnetic field created in the slit.
- What happens near the end of the tube?
  The field strength decreases

3.2.5 Cut copper tube

Frequency (Hz)	Solenoid in by	V(H1) (mV)	V(H0) (mV)	Screening Ratio H1/H0
50Hz	100% in	14.313	69.9	0.204763948
	75% in	14.049	69.1	0.203314038
	50% in	13.93	64.3	0.216640747
	25% in	11.662	53	0.220037736
200Hz	100% in	30.178	69.9	0.431731044
	75% in	29.736	69.1	0.430332851
	50% in	27.005	64.3	0.419984448
	25% in	23.077	53	0.435415094

3.3 Theoretical consideration

$$\delta = (\frac{2\rho}{\omega\mu_r\mu_0})^{1/2}$$

$$\frac{H_1}{H_0} = \sqrt{\frac{a/b}{Y}}$$

$$c = \frac{t}{\delta}$$

$$Y = \frac{1}{2}(\cosh(2c) + \cos(2c)) + \frac{b}{2\delta}(\sinh(c)\cosh(c) - \sin(c)\cos(c)) + \left(\frac{b}{2\delta}\right)^2 (\cosh(2c) - \cos(2c))$$