Resonator Modeling

DM Radio Collaboration Meeting

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Motivation

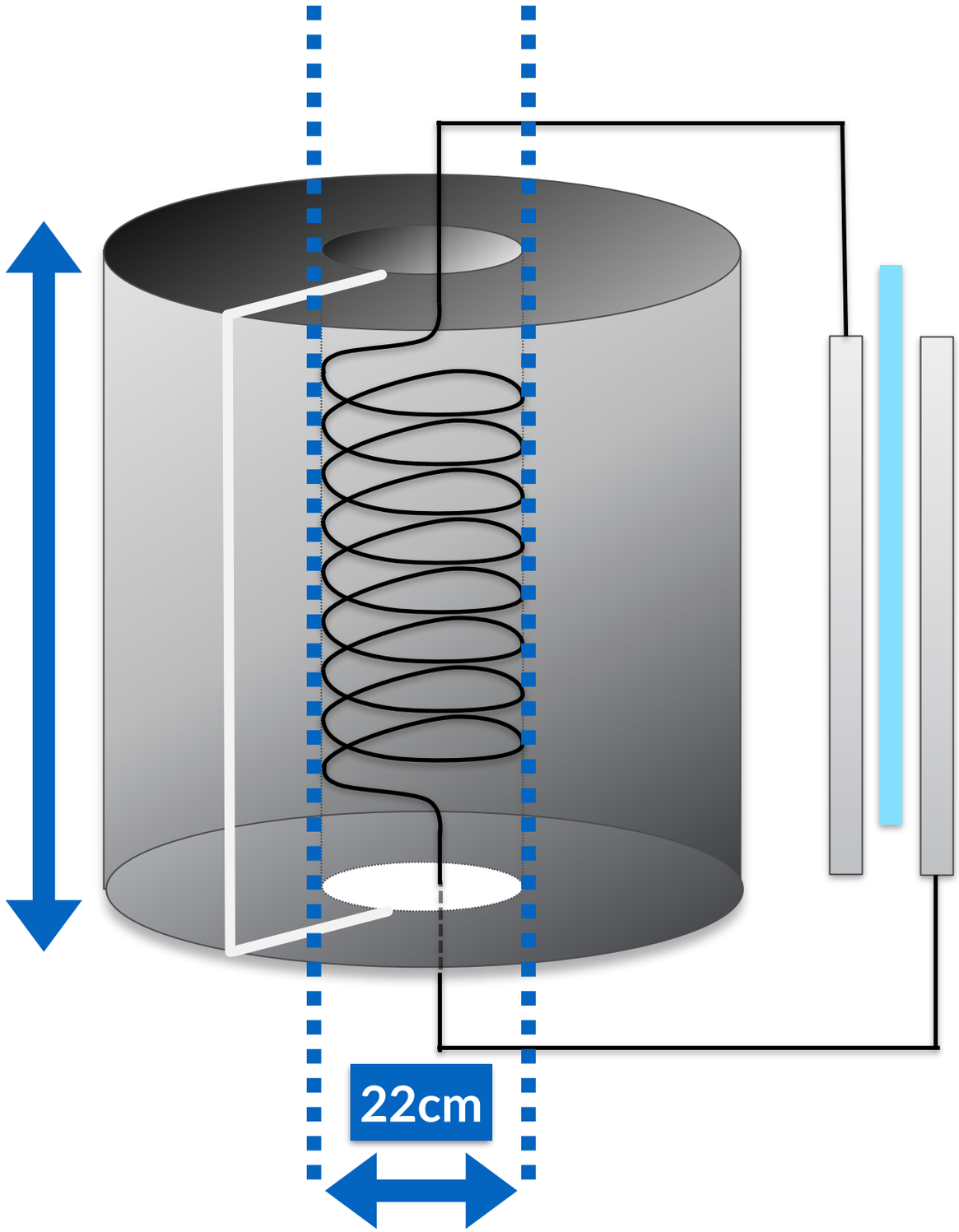
- 50L (& M^3) is a resonant search with a tunable circuit.
- Resonator Q impacts sensitivity — must optimise.

$$\mathrm{FOM} \propto \frac{c_{\mathrm{PU}} B_0 V^{5/6} Q^{1/4}}{\eta^{1/4} T^{1/4}}$$

Preliminary Constraints

- Requirement: Tunable from ~5 kHz to 5 MHz.
- Requirement: High Q (~10^6).
- Capacitance has to be above parasitic capacitance ~10pF.
- Single layer of inductor turns.

Strawman Model



44cm solenoid height

C_p ~ 1 pF

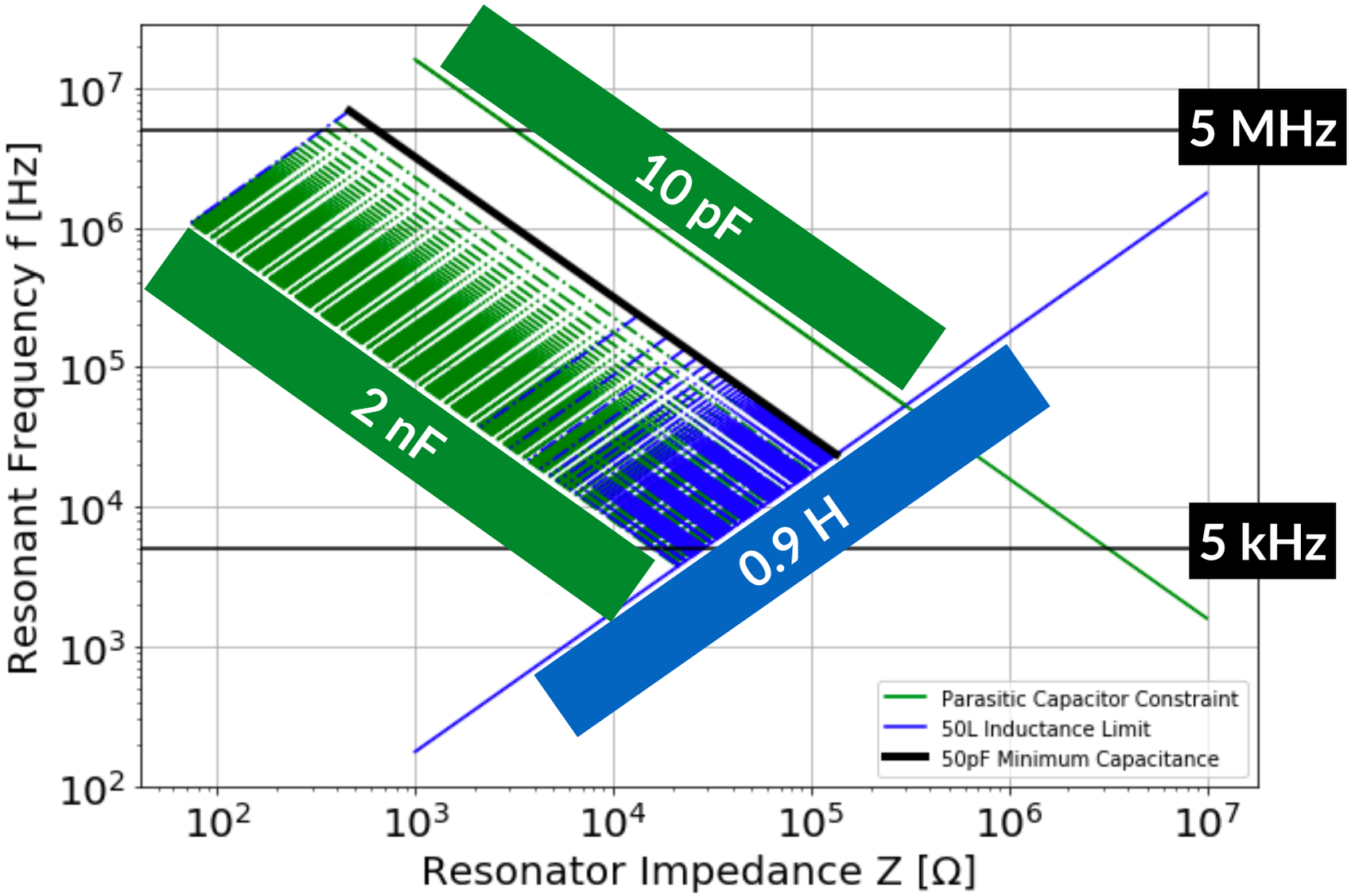
L = 10μH – 0.9 H

11 cm x 11 cm plate
0.5mm gap → C = 200 pF

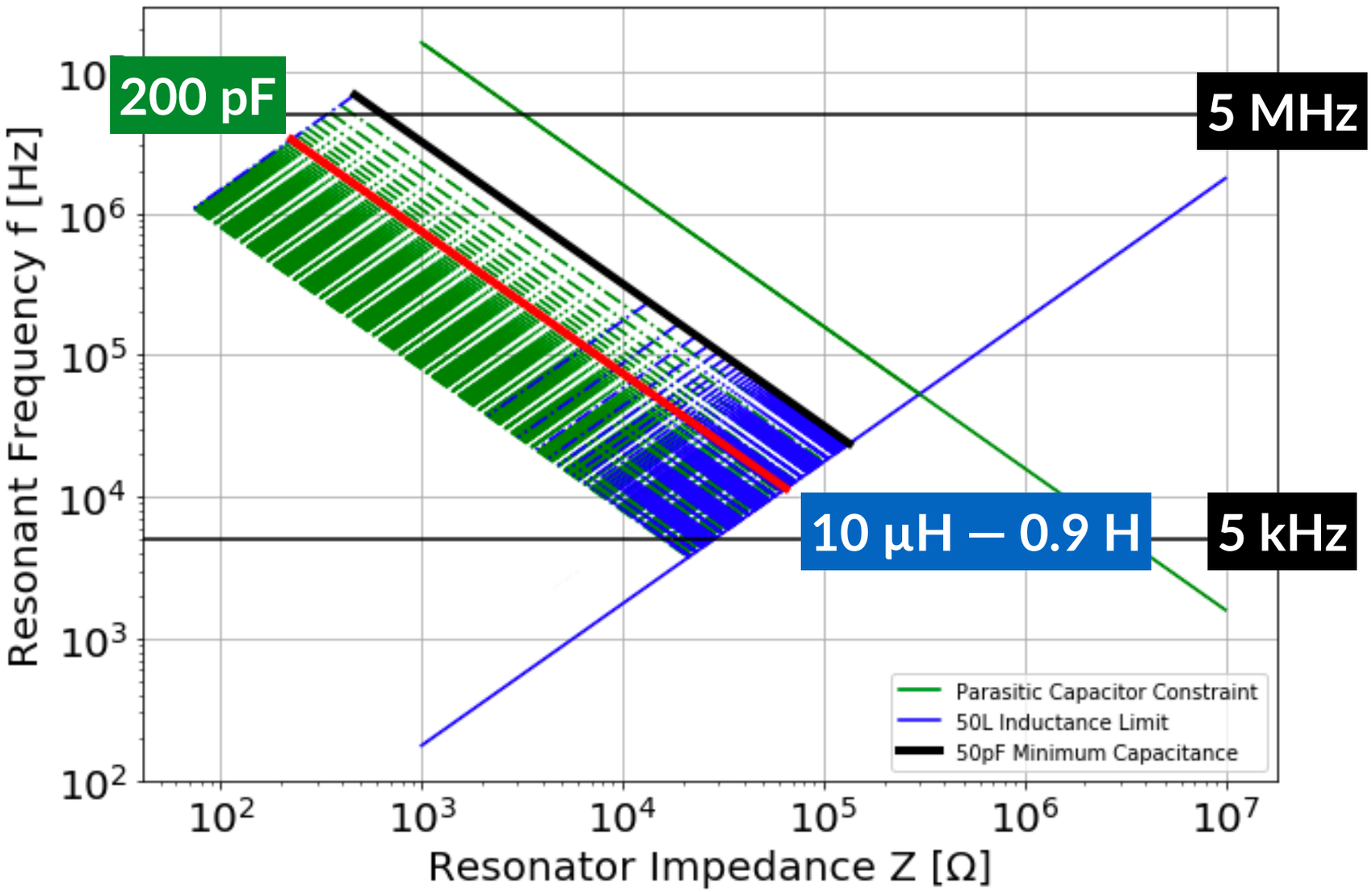
33 cm x 33 cm plate
0.5mm gap → C = 2 nF

22cm

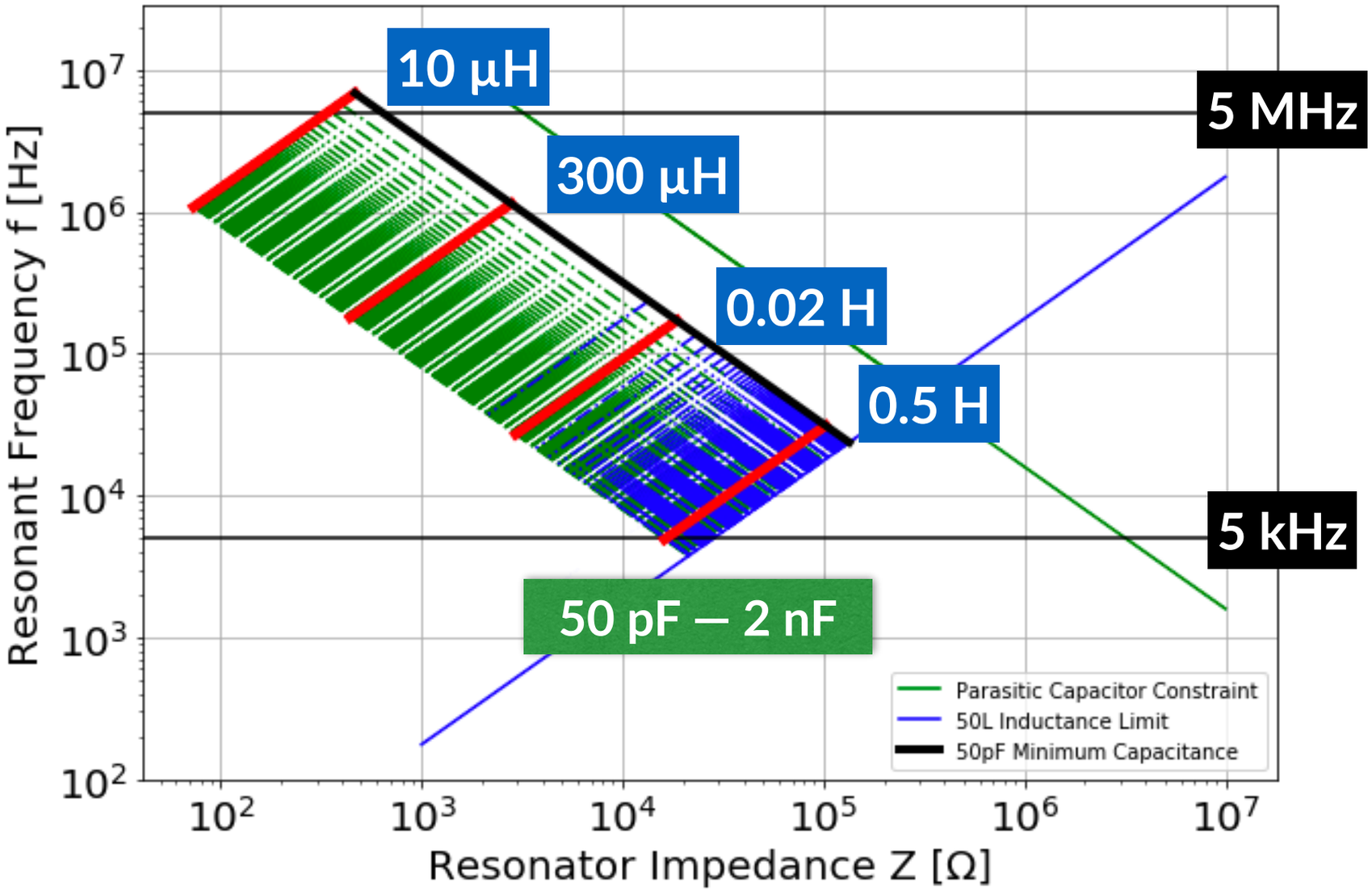
Accessible Range



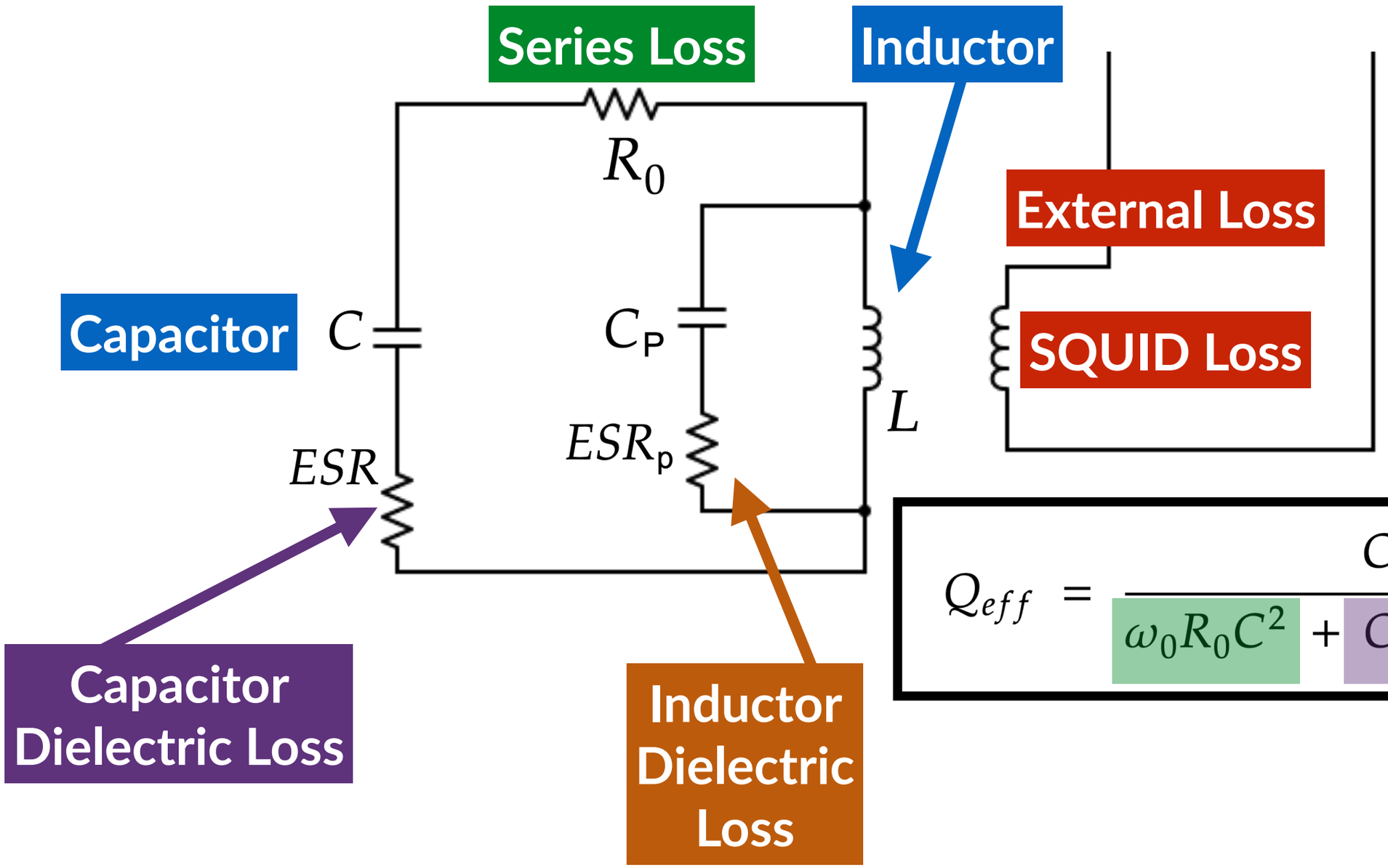
Inductive Tuning



Capacitive Tuning



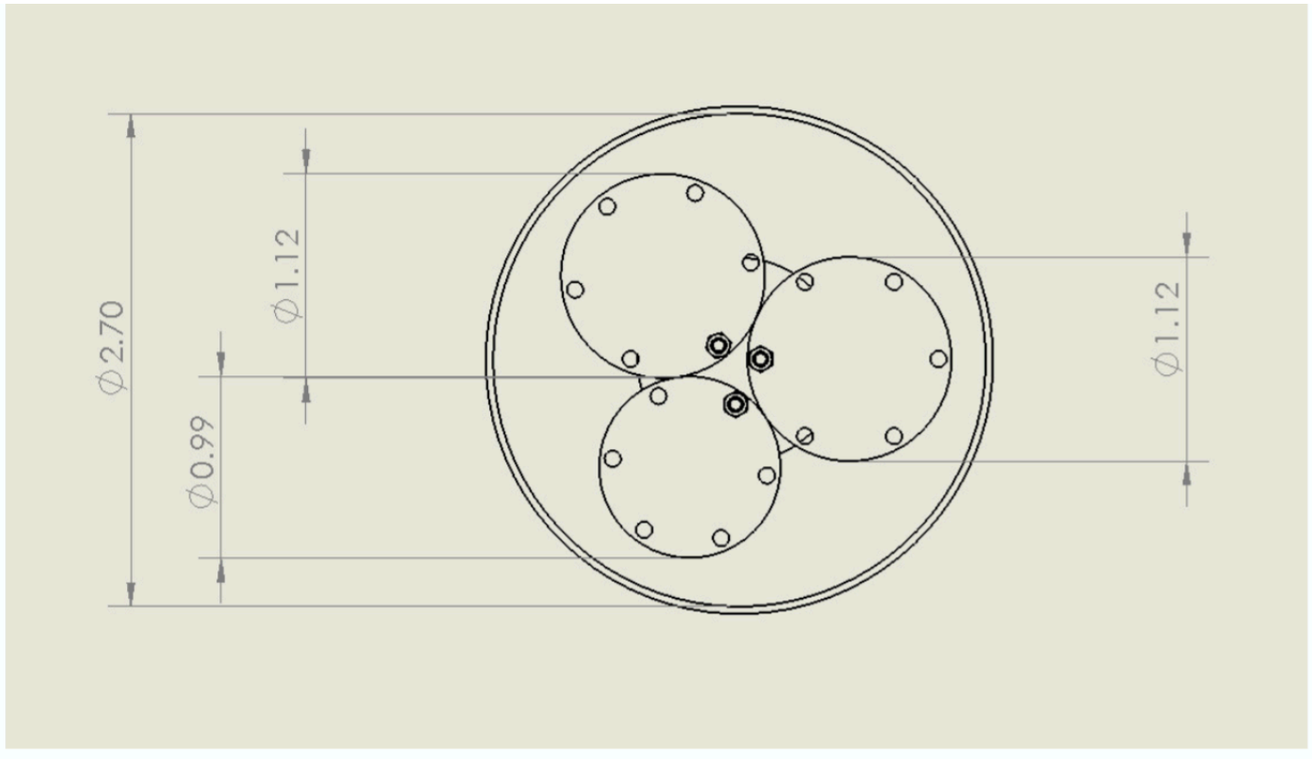
Circuit Model

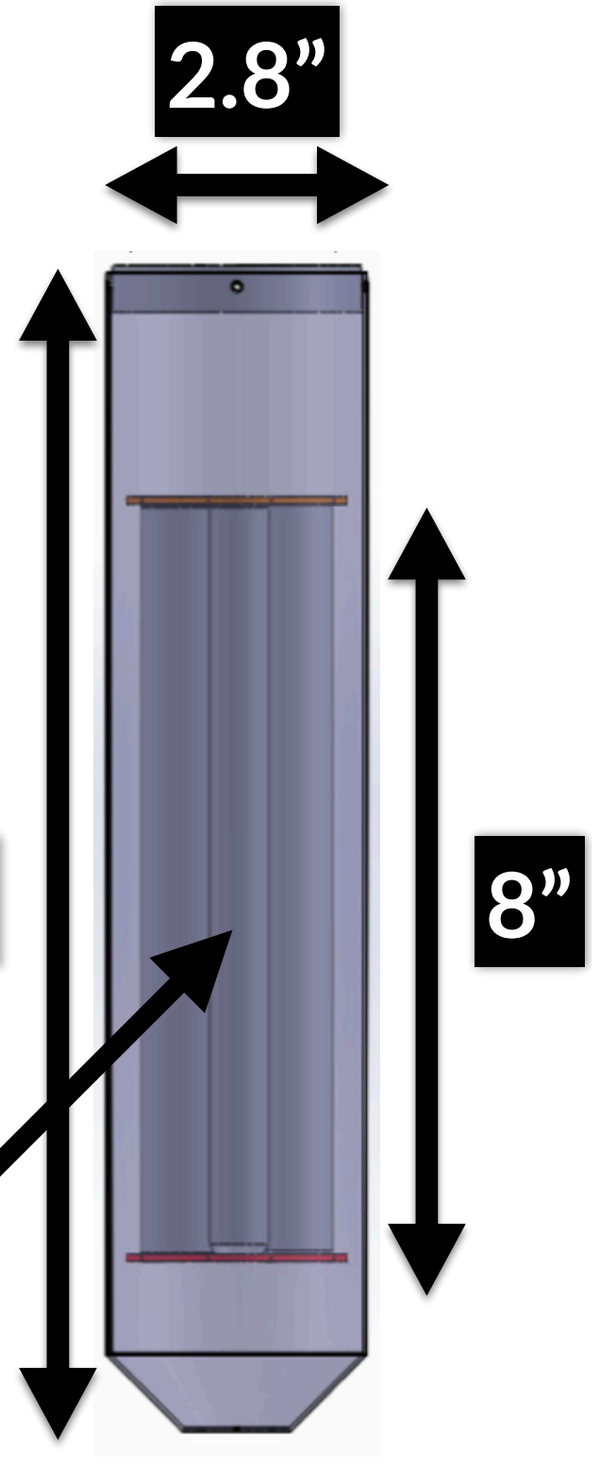


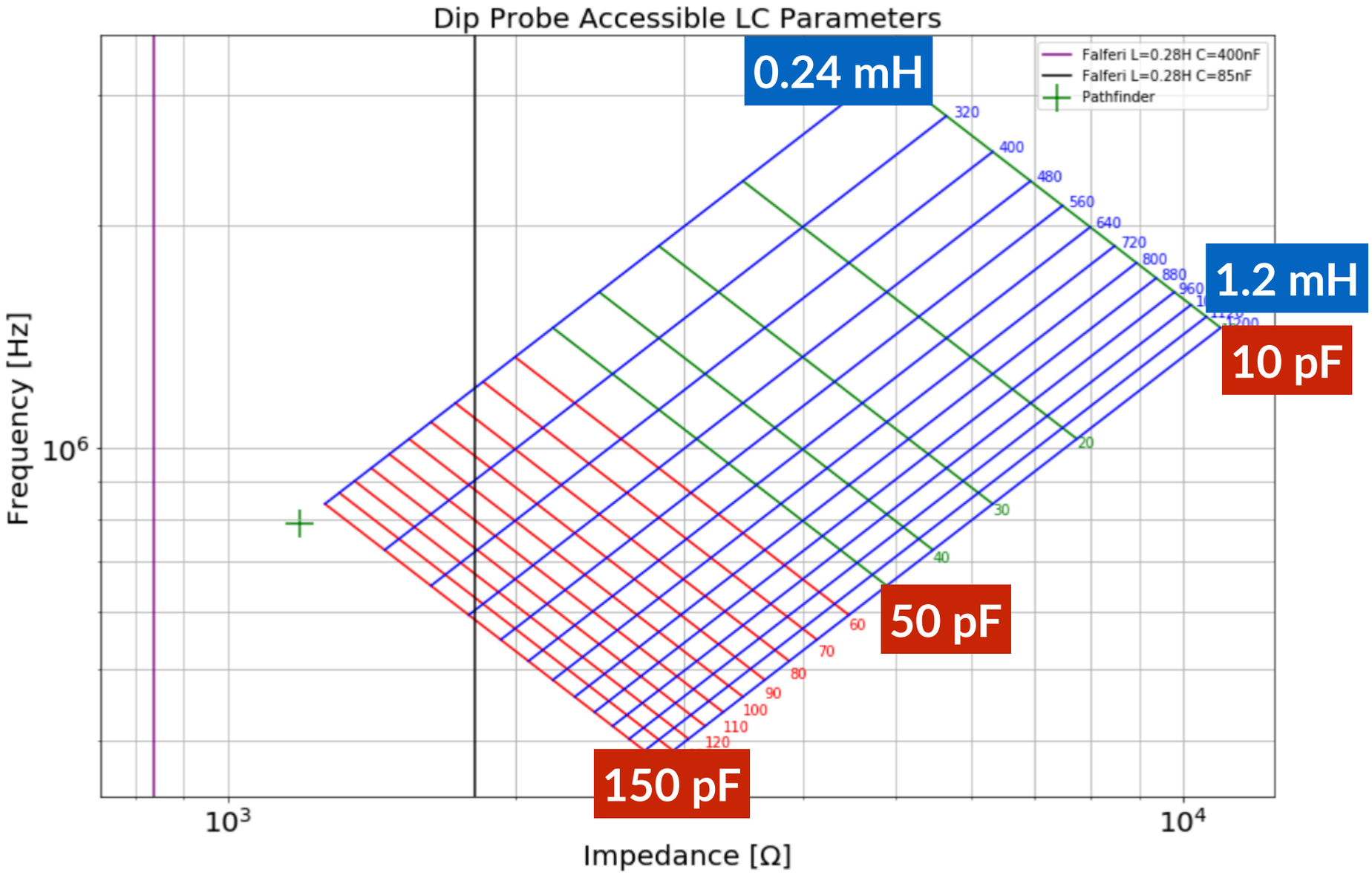
$$Q_{eff} = \frac{C + C_p}{\omega_0 R_0 C^2 + C \tan\delta + C_p \tan\delta_I}$$

Dip Probe Campaign

- Need materials data (tan δ at MHz frequencies).
- Requires a dedicated testing campaign → dip probe.
- With materials data, can also use probe to test if loss model accurately predicts Q.


ϕ2.70
ϕ1.12
ϕ0.99
ϕ1.12


2.8”
11”
8”
Nb tubes
contain L,C, SQUID


Dip Probe Accessible LC Parameters
0.24 mH
1.2 mH
10 pF
50 pF
150 pF
Falferi L=0.28H C=400nF
Falferi L=0.28H C=85nF
Pathfinder
320
400
480
560
640
720
800
880
960
20
30
40
60
70
80
90
100
110
120
10^6
10^3
10^4
Frequency [Hz]
Impedance [Ω]

- Dip probe can access relevant parameter space.
- Can measure tan δ to 10^{-6} level (assuming dip probe resonator Q of 50,000).

A (**Premature**) Q Estimate

- **Assuming** R_0 negligible, $\tan \delta = 10^{-6}$, $\tan \delta_l = 10^{-4}$
- $C_p \sim 1$ pF (from literature), L = 1.7 mH, C = 1.5 nF
- f = 100 kHz, Q = 940,000

Assumptions *inspired* by Falferi et al. Review of Scientific Instruments 65, 2916 (1994)

Grandi et al. IEEE Transactions on Industry Applications 35, 1162 (1999)

Next Steps

- Assemble dip probe.
- Get material data/refine loss model.
- Future: Refine strawman, connect to sheath modeling, consider aspects such as tuning.