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Calculating Impedance of a Common Mode Choke In High Frequency Regime

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Common Mode Choke

- Electromagnetic Interference (EMI) filter
- Filter out EMI noise
- Power inverters, converters

https://www.quora.com/What-is-the-difference-between-a-common-mode-choke-and-transformer

https://www.lairdtech.com/products/cc2824j502r-10-auto

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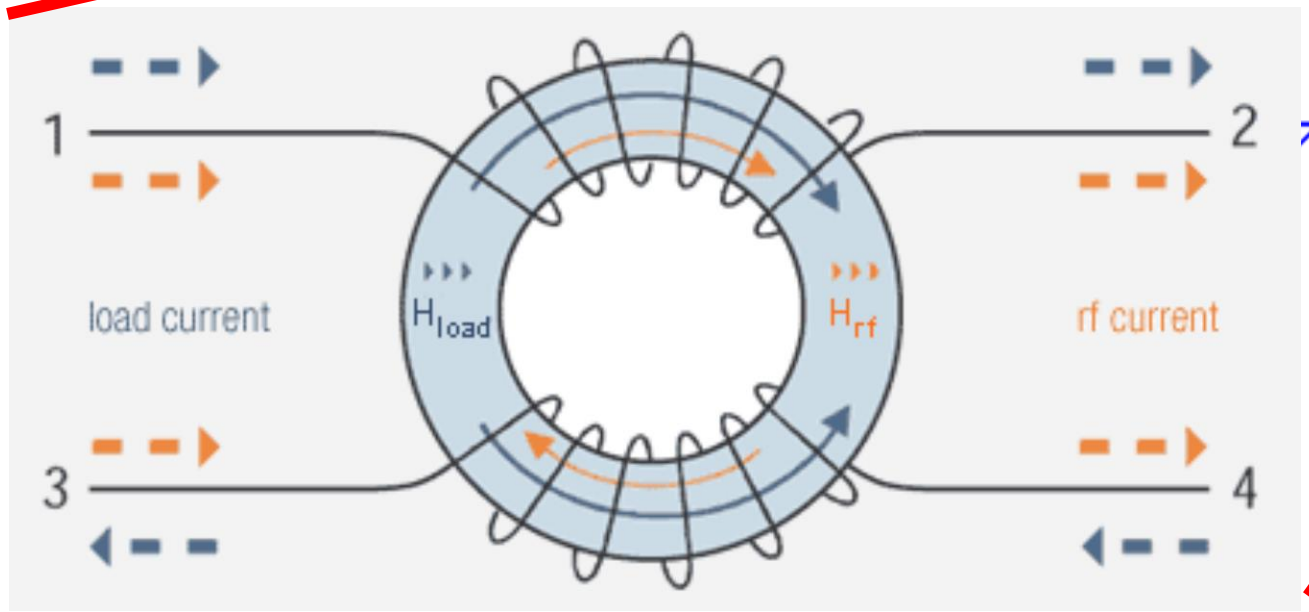
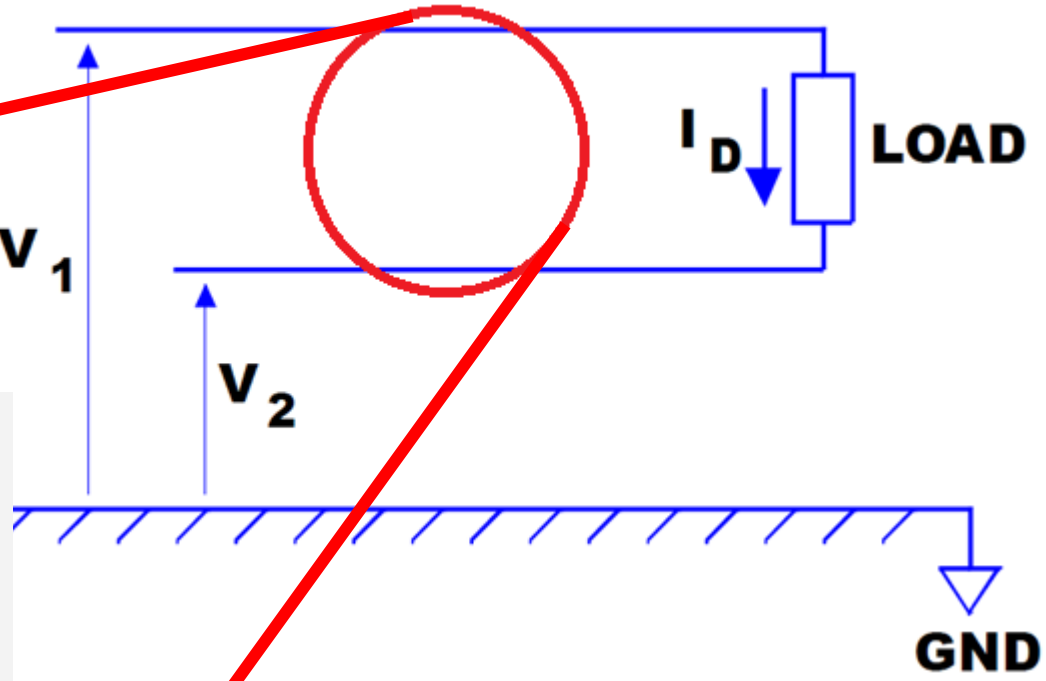
Common Mode Choke

- EMI filter





http://www.vacuumschmelze.com/en/research-innovation/application-know-how/common-mode-chokes.html

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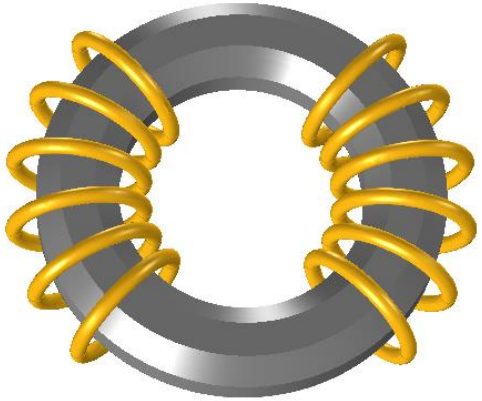
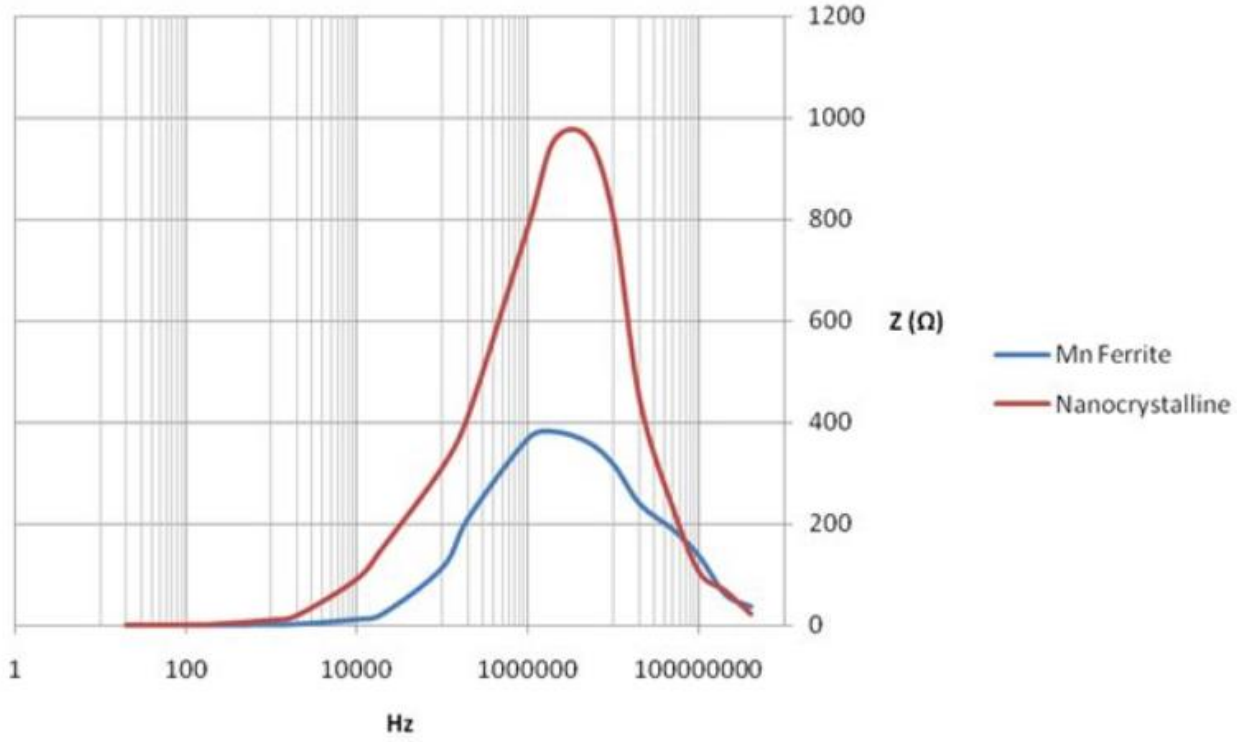
Motivation

- Self-resonance
- Inductive → Capacitive
- Key indicator for performance
- Simulate impedance behavior in high-frequency regime





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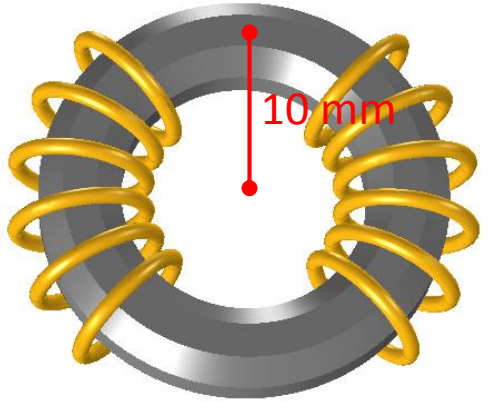
Model

- Considerations:
- (1) Magnetic material
- (2) Inter-winding (paracitic) capacitance
- (3) Common Mode



- mm scale
- Octagonal cross-section

- Two-Step approach:
- (1) Electrostatic model → inter-winding capacitance
- (2) Time harmonic electromagnetic simulation → impedance

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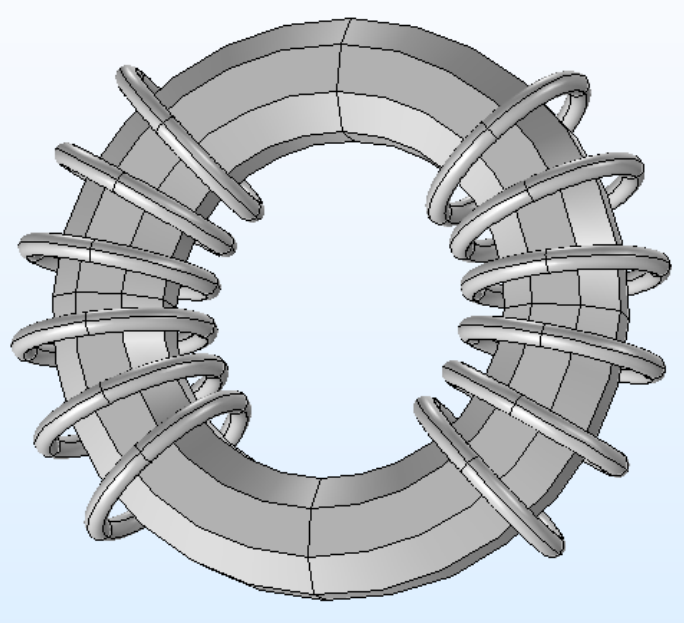
Electrostatics

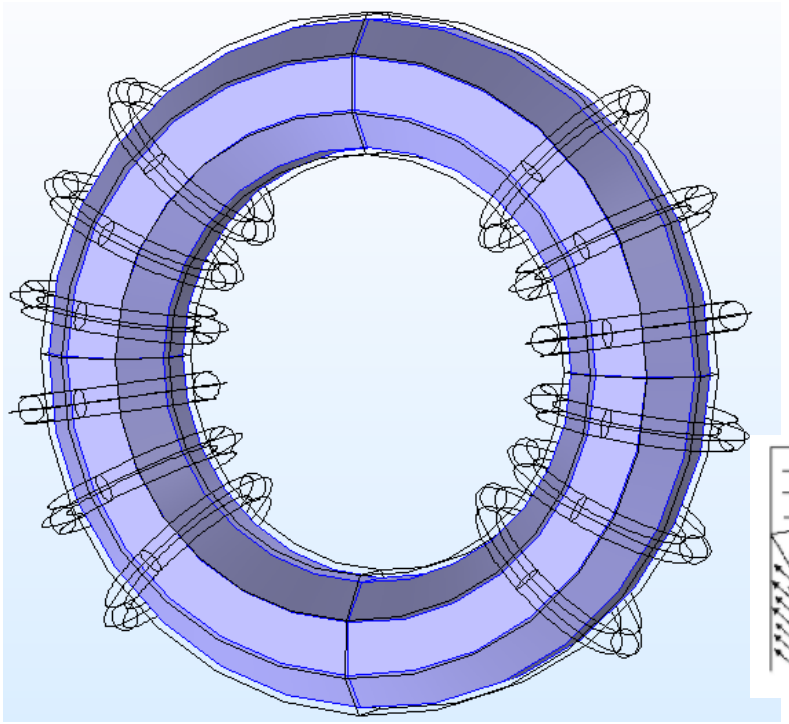
- Mutual capacitance

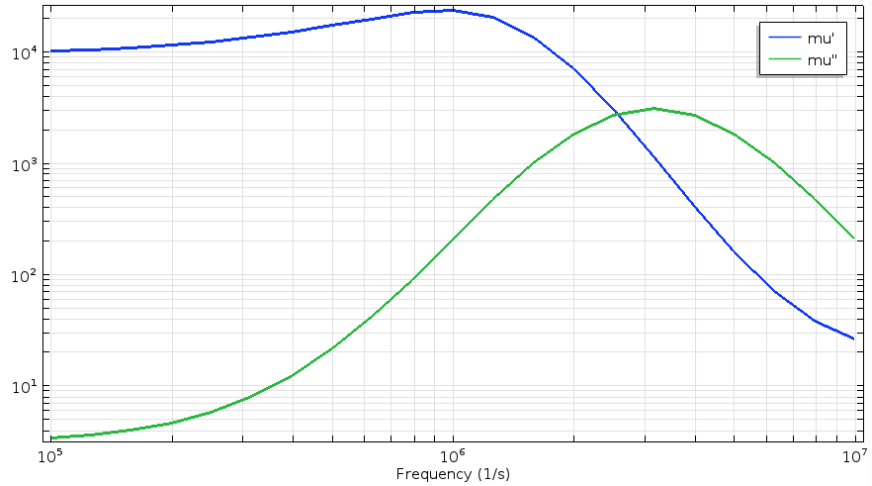


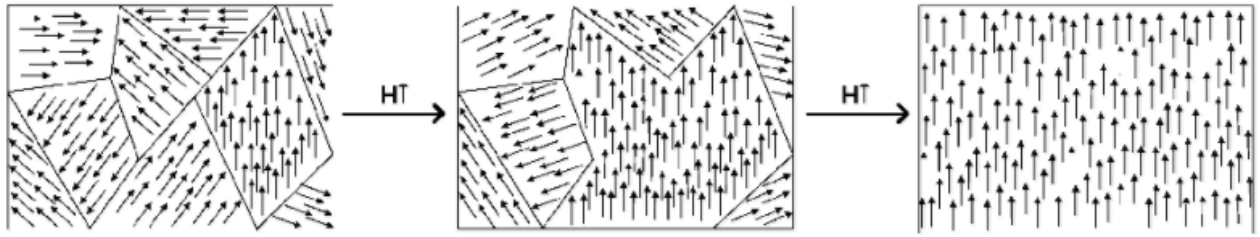
馬克仕威爾至互感: 馬克仕威爾電容 (pF)											
0.48557	0.35709	0.032122	0.016541	0.011266	0.011432	0.0079020	0.0044302	0.0038294	0.0035496	0.0035206	0.0051186
0.35709	0.34684	0.34569	0.026594	0.013147	0.011272	0.0044326	0.0026380	0.0023666	0.0022710	0.0023307	0.0035218
0.032122	0.34569	0.33691	0.34512	0.026591	0.016541	0.0038286	0.0023649	0.0021827	0.0021525	0.0022709	0.0035505
0.016541	0.026594	0.34512	0.33699	0.34575	0.032152	0.0035522	0.0022715	0.0021546	0.0021823	0.0023661	0.0038297
0.011266	0.013147	0.026591	0.34575	0.34674	0.35717	0.0035215	0.0023300	0.0022719	0.0023649	0.0026378	0.0044314
0.011432	0.011272	0.016541	0.032152	0.35717	0.48557	0.0051207	0.0035211	0.0035526	0.0038282	0.0044320	0.0079038
0.0079020	0.0044326	0.0038285	0.0035521	0.0035213	0.0051207	0.48555	0.35721	0.032134	0.016538	0.011269	0.011435
0.0044301	0.0026380	0.0023649	0.0022714	0.0023300	0.0035212	0.35721	0.34685	0.34564	0.026589	0.013144	0.011268
0.0038294	0.0023666	0.0021827	0.0021546	0.0022719	0.0035527	0.032134	0.34564	0.33699	0.34517	0.026597	0.016548
0.0035497	0.0022710	0.0021525	0.0021823	0.0023649	0.0038283	0.016538	0.026589	0.34517	0.33680	0.34564	0.032138
0.0035207	0.0023307	0.0022709	0.0023661	0.0026379	0.0044320	0.011269	0.013144	0.026596	0.34564	0.34684	0.35725
0.0051188	0.0035217	0.0035504	0.0038297	0.0044314	0.0079038	0.011435	0.011268	0.016548	0.032138	0.35725	0.48560

Impedance Calculation

- Magnetic Fields + Electrical Circuit
- Ferrite Material

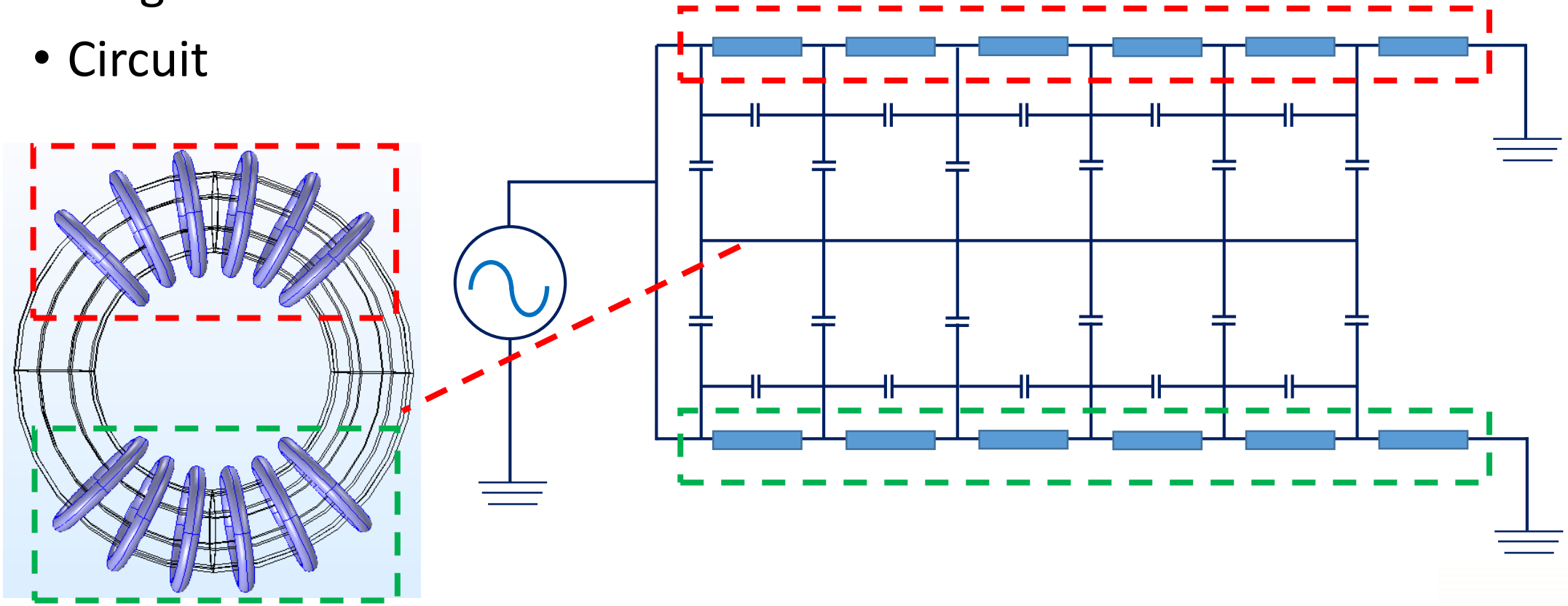






Impedance Calculation

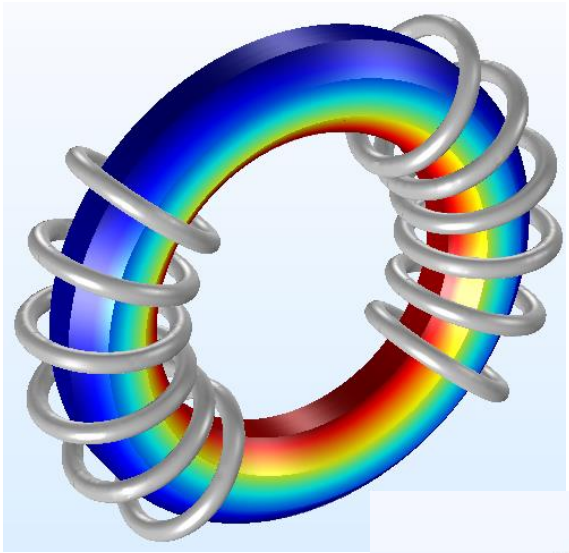
- Magnetic Fields + Electrical Circuit
- Circuit

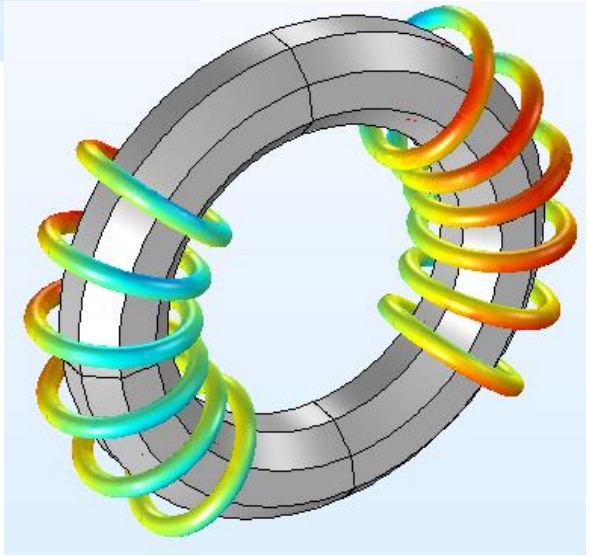


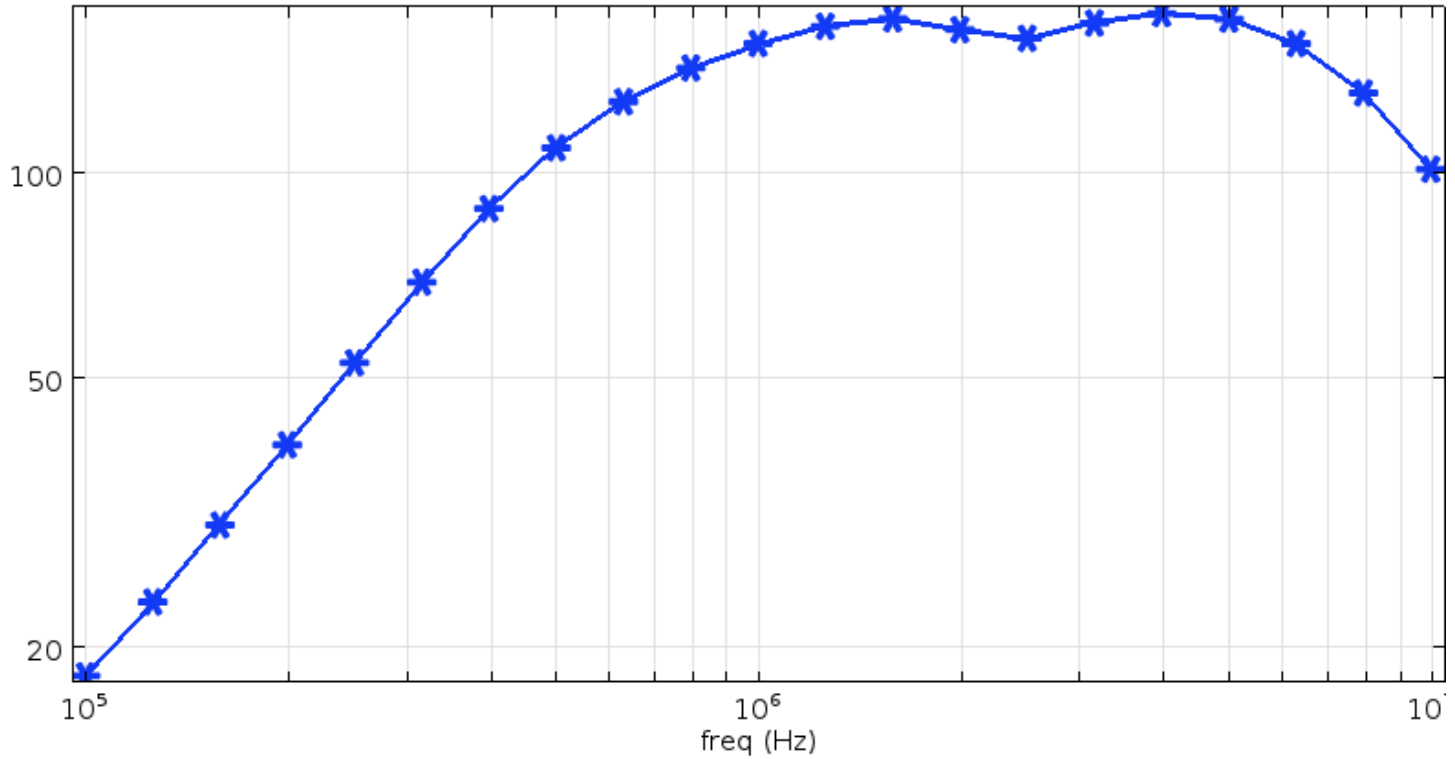
M. Kovačić, et al, *IEEE Transactions on Electromagnetic Compatibility*, vol. 57, no. 1, pp. 93-101, Feb. 2015

Results

- Self-resonance







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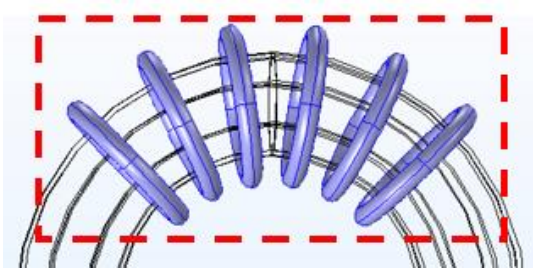
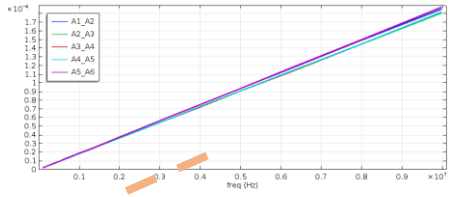
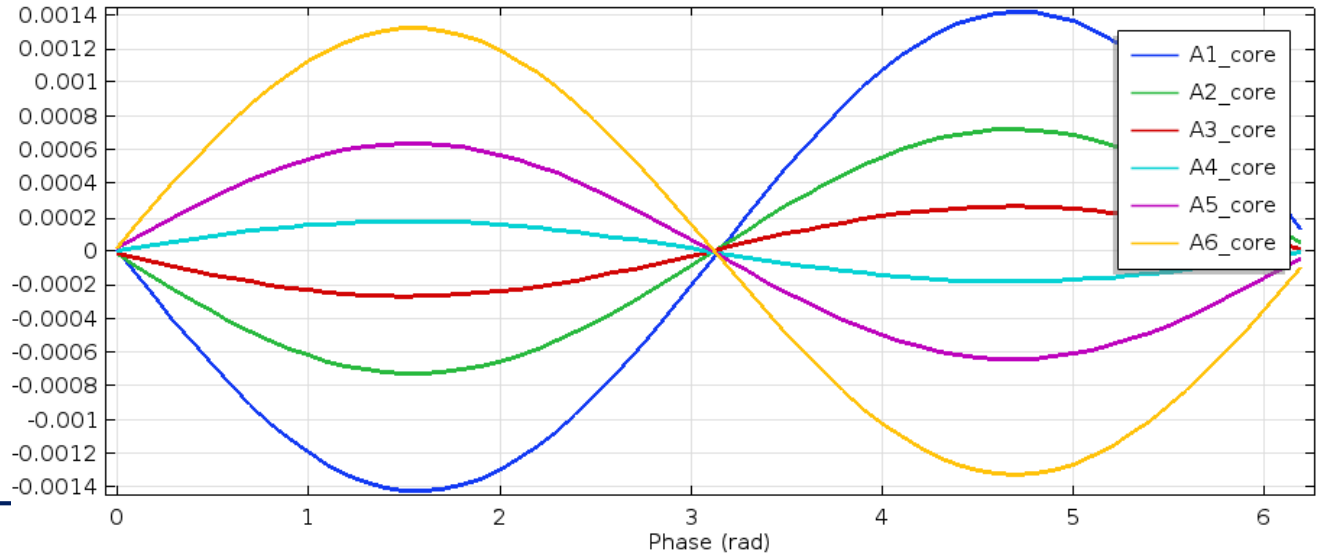
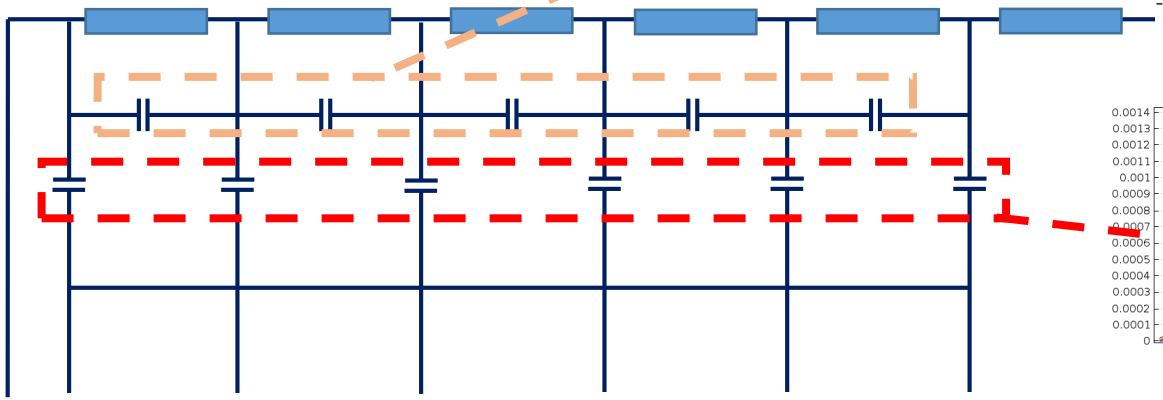
Parasitic capacitance

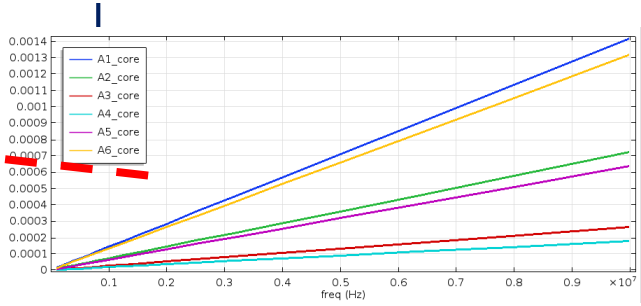
- Overall (Similar to Proximity Effect)











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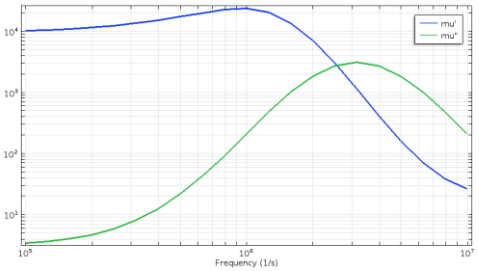
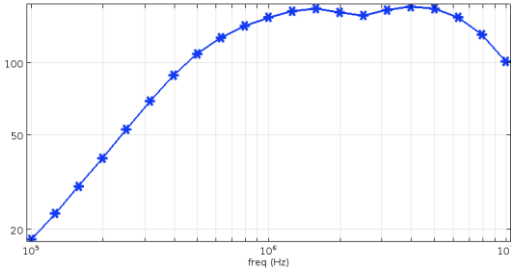
Self-Resonance

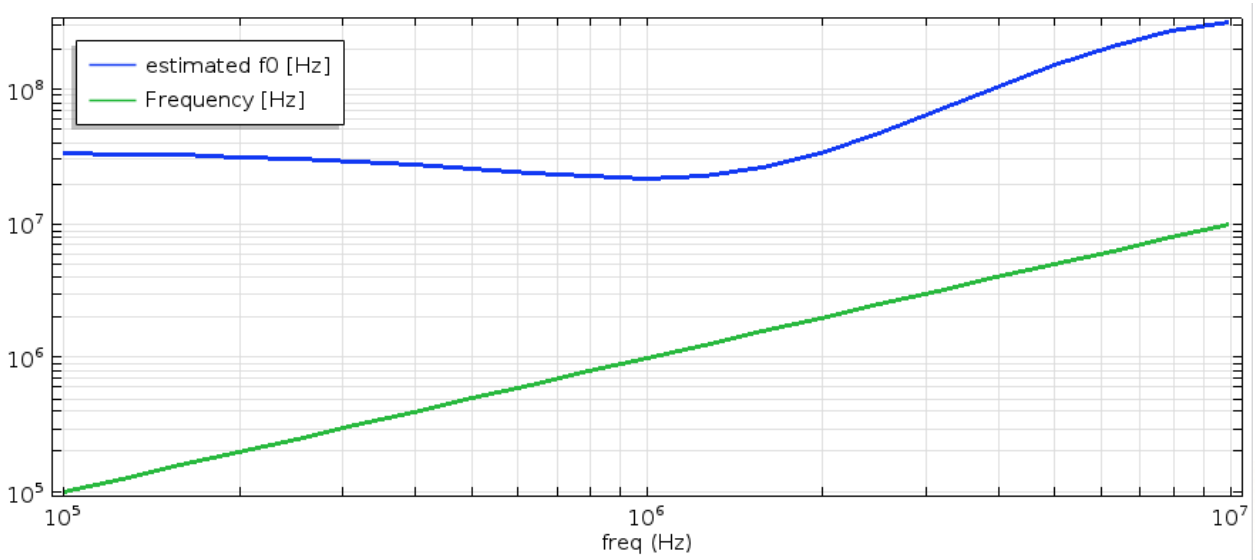
- Material Behavior → Self-resonance?
-

$$L \approx \frac{\mu N^2 A}{2\pi r}$$





- $L \approx \frac{\mu N^2 A}{2\pi r}, \quad f_0 \sim \frac{1}{2\pi\sqrt{LC}}$



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Conclusion

- Two-step FEM approach to study Impedance of Common Mode Choke
- Self-resonance
- Overall Effect Parasitic Capacitance (Similar to Proximity Effect)
- Self-resonance → mainly attributed to material properties

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