Healthcare Re-imagined

Design and Optimization of 4 Element Surface Coil Array

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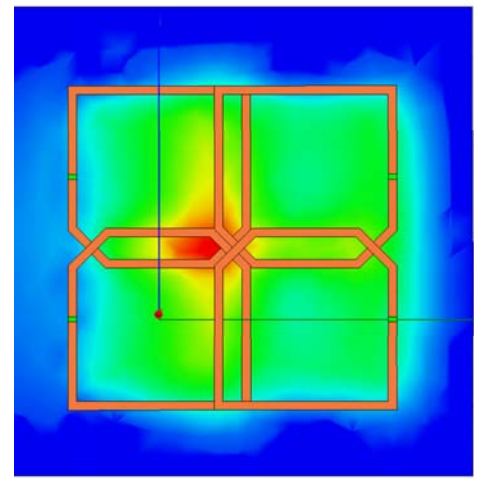
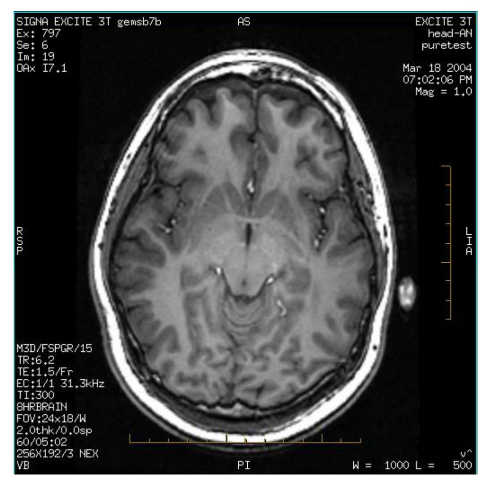


Presented by Shu Li

Application Engineer
Ansoft Corporation



What is MRI?

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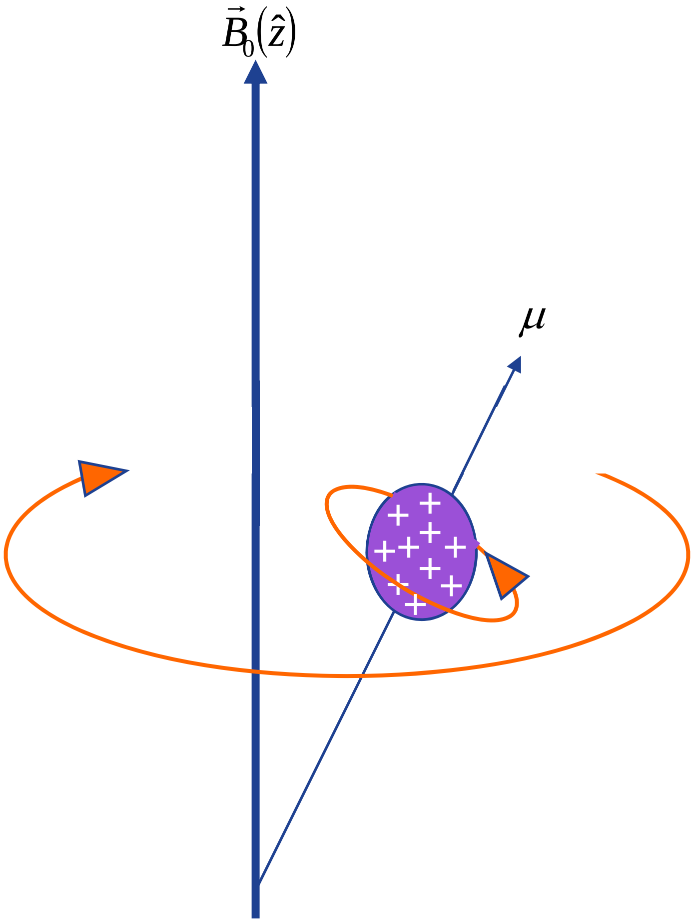
Physical Principles : A spinning proton generates a magnetic moment



$$f = \left(\frac{\gamma}{2\pi}\right) B_0 \;\; where\, \gamma = \frac{4\pi\mu_Z}{h}$$

$$For\ hydrogen, \left(\frac{\gamma}{2\pi}\right) = \frac{42.58MHz}{Tesla}$$

$B_0(T)$	$f\,(MHz)$
1.5	63.87
3.0	127.74
7.0	298.06

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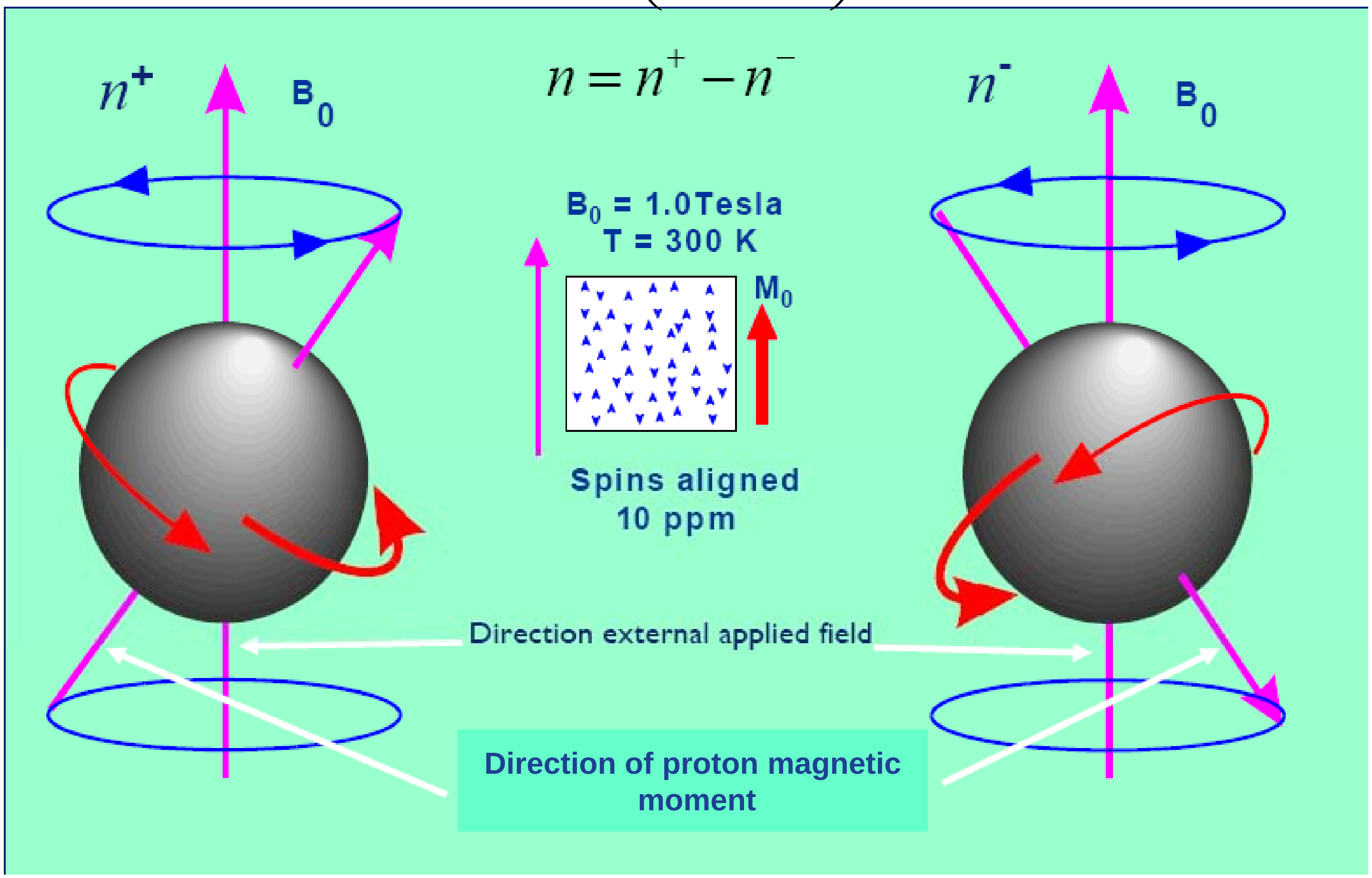
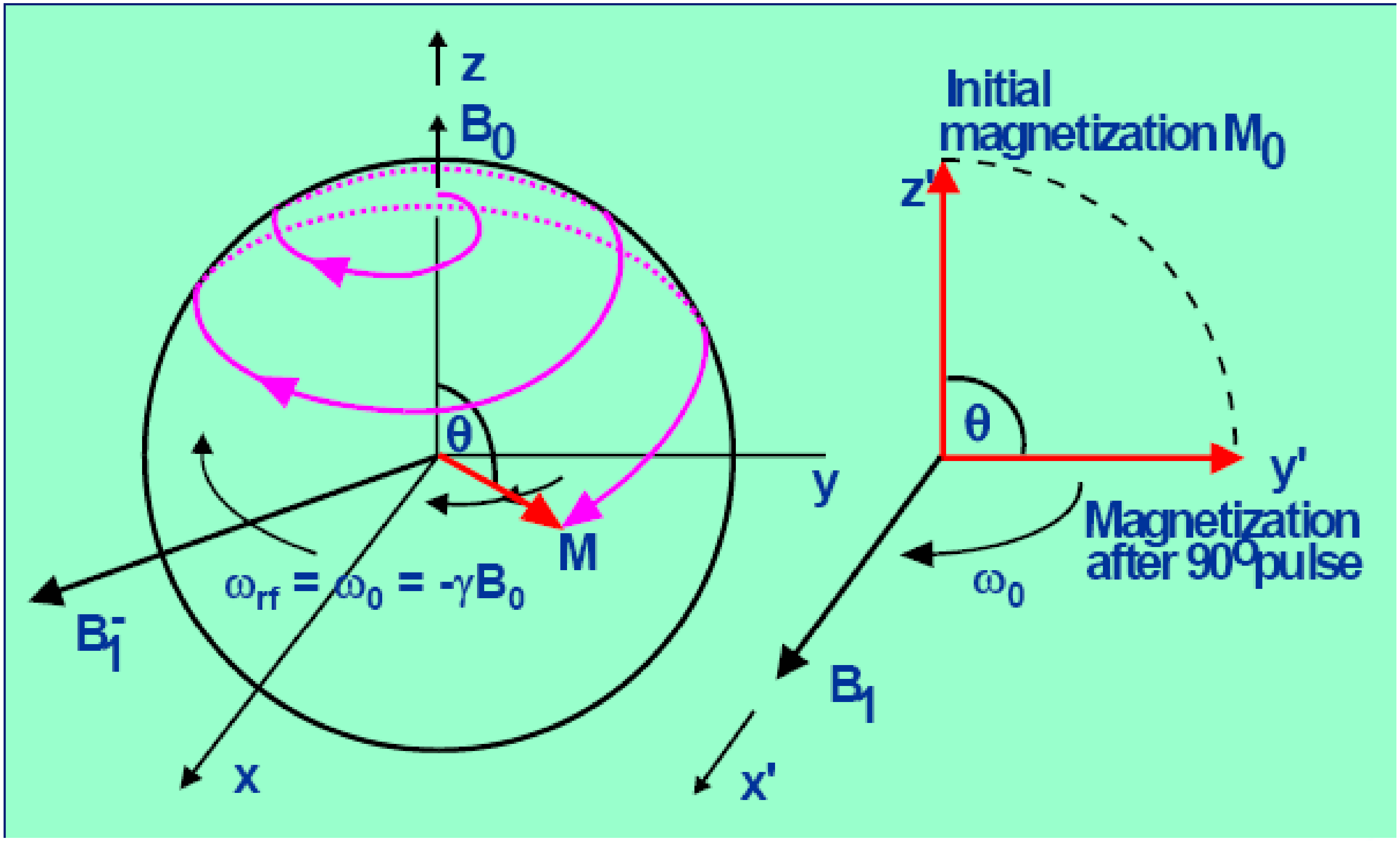
Proton spin alignment

$$f = \left(\frac{\gamma}{2\pi} \right) B_0$$



Excite the spins with an RF field



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When spins fall back, they emit an RF signal

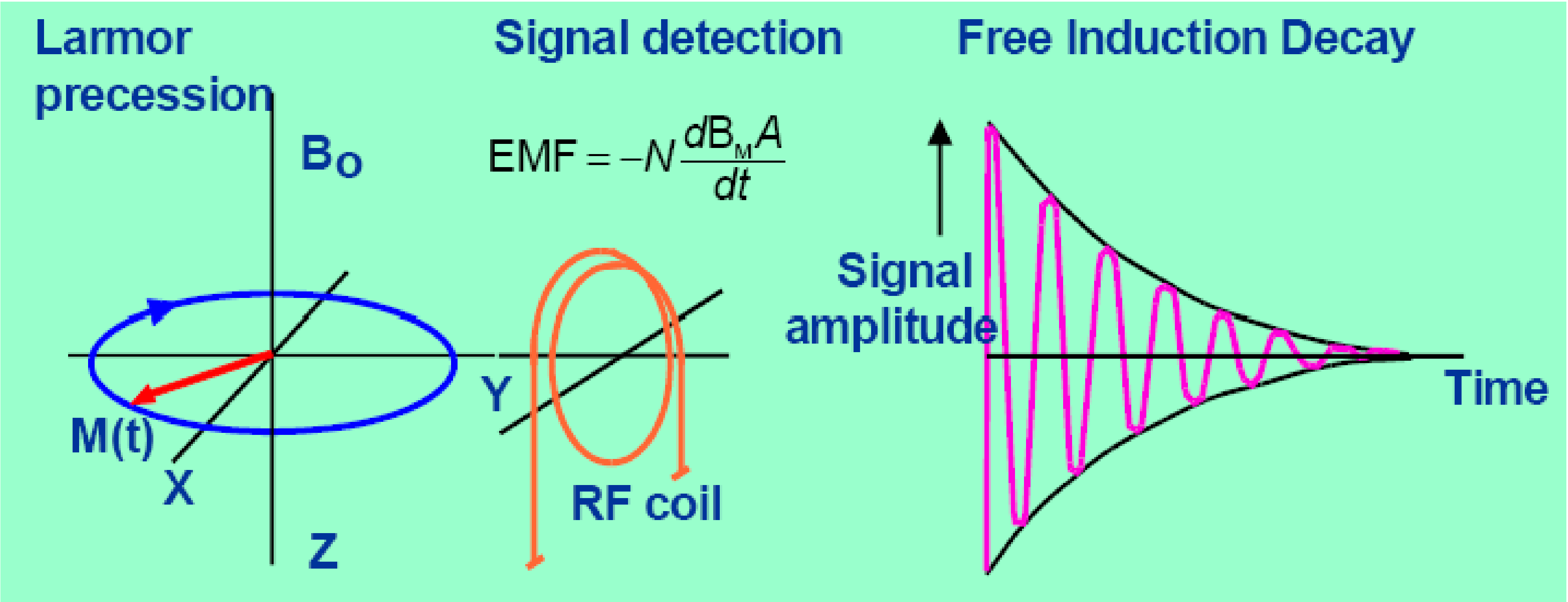
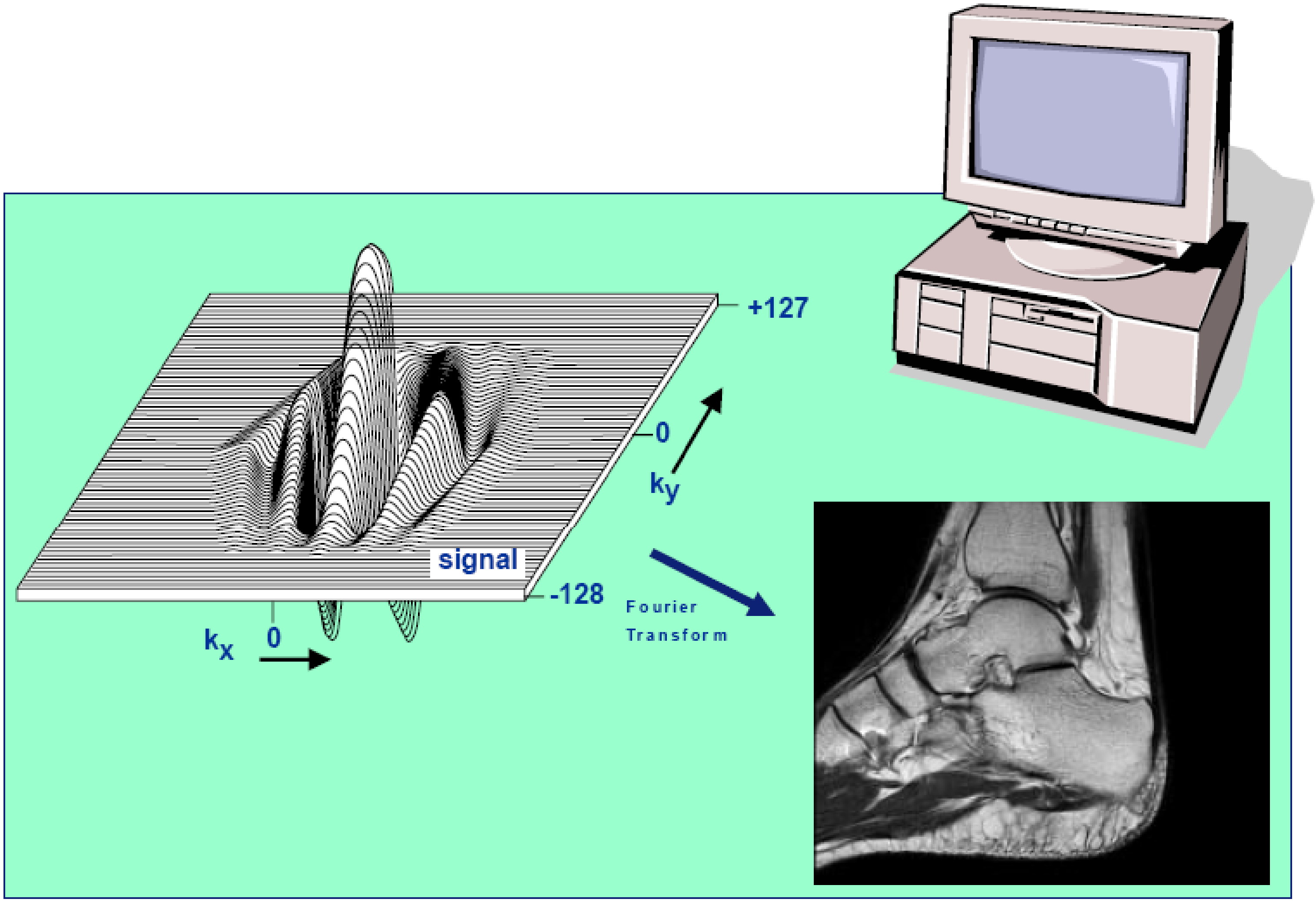


Image Formation



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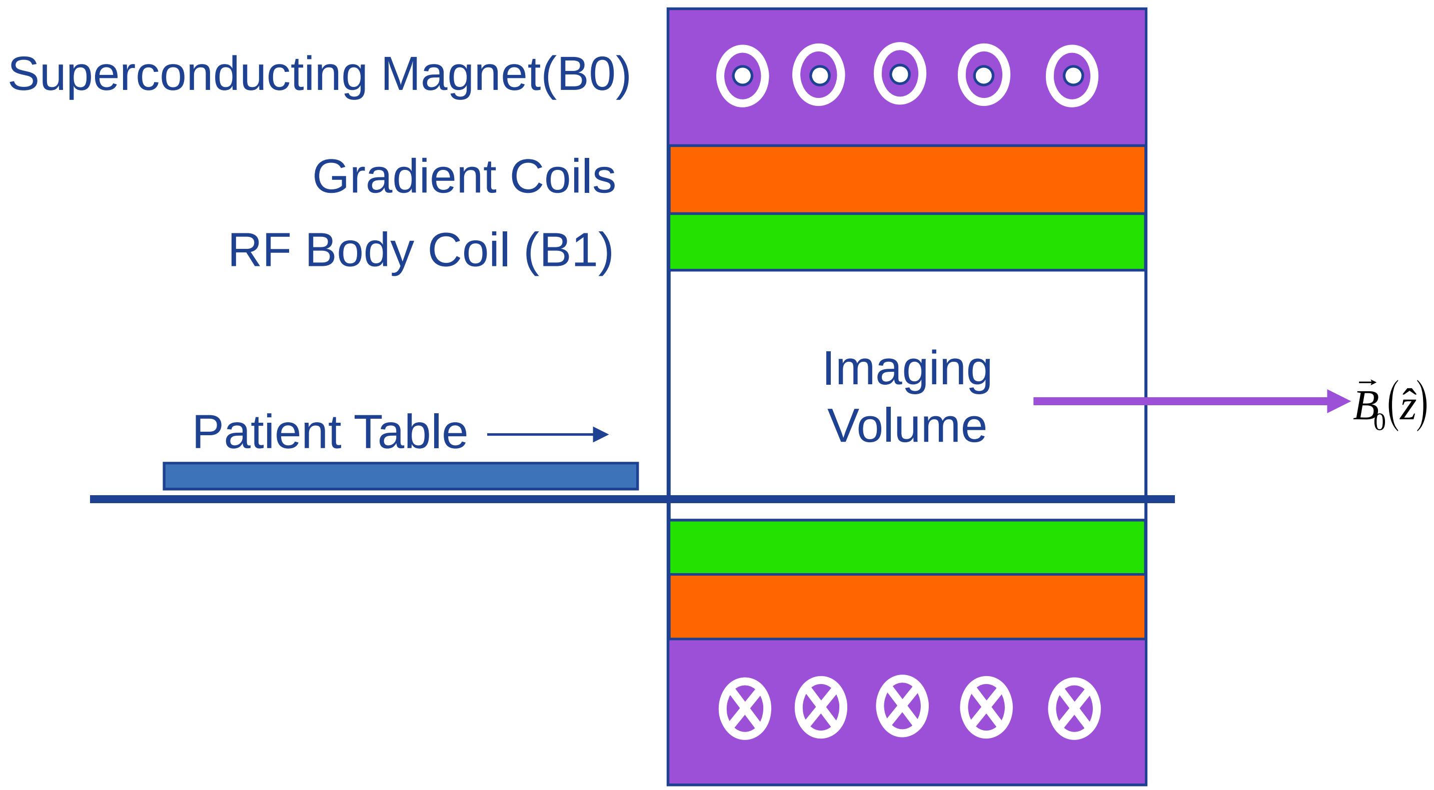
Simplified Cross Section of MR Scanner



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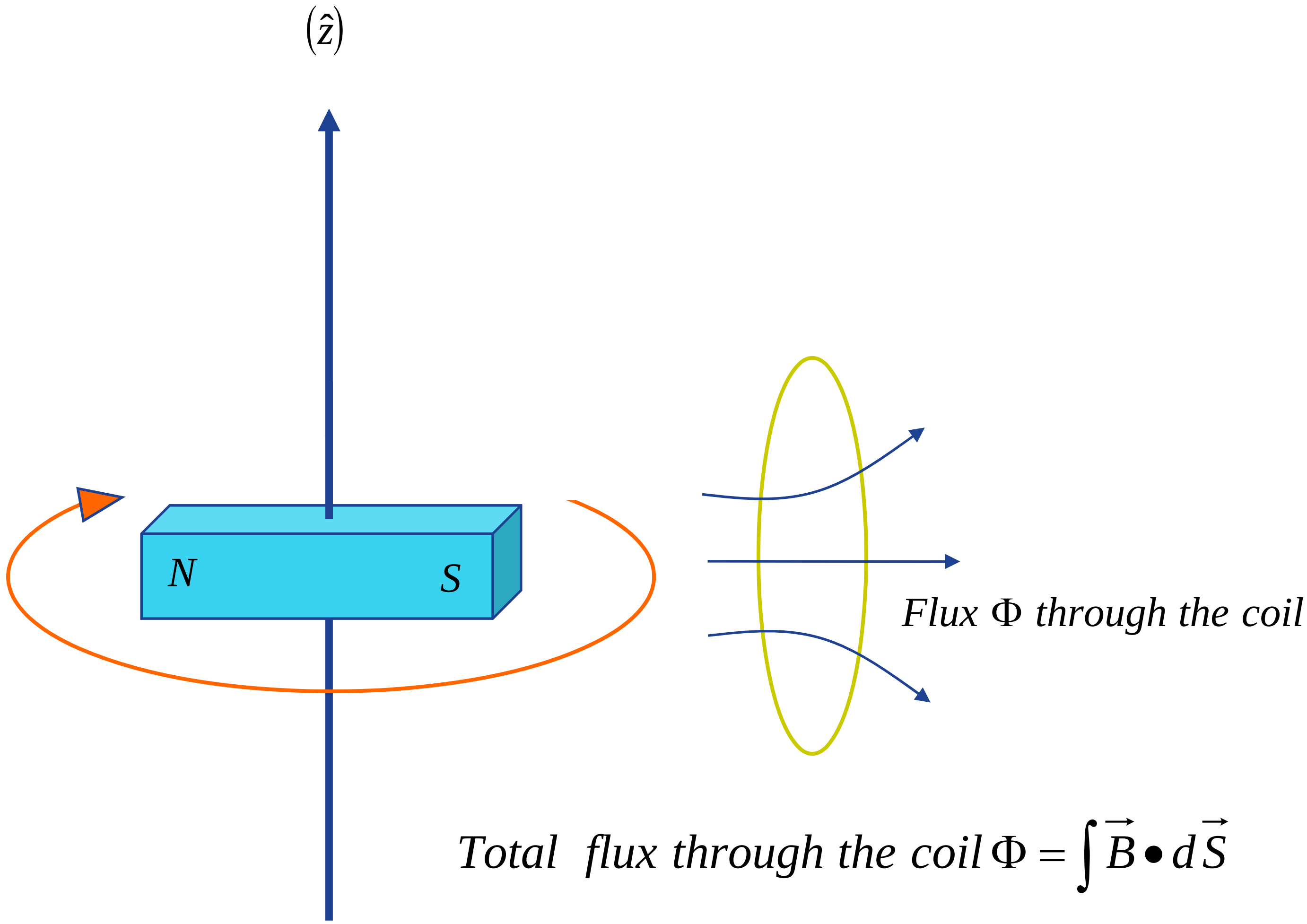
Signal Detection



$$Total\ \ flux\ through\ the\ coil\ \Phi = \int \vec{B} \bullet d\vec{S}$$

$$Induced\,Voltage = -\frac{d\,\Phi}{dt}$$

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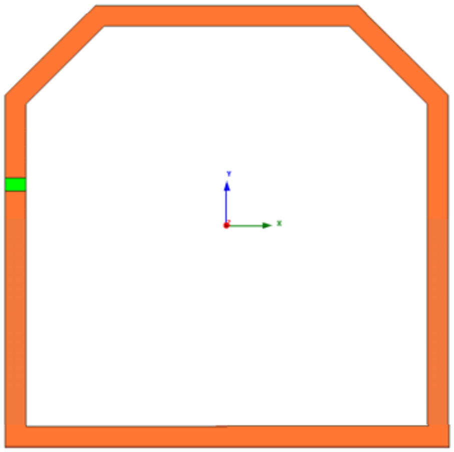
Surface Coils

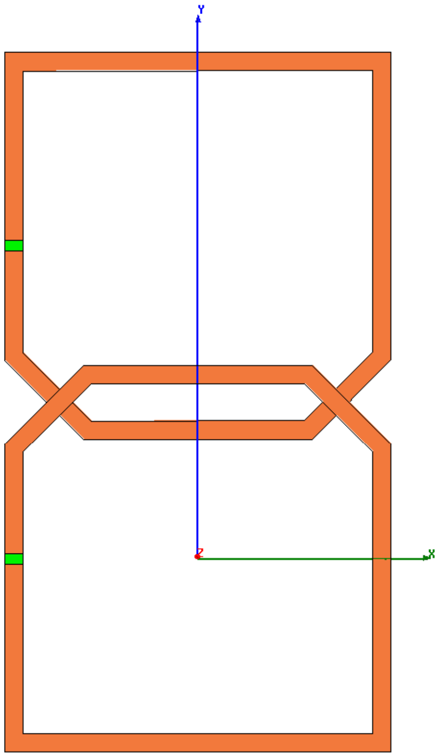
- Local to anatomy of interest
- High SNR over a limited area
- Acceleration
- We'll look at a linear coil array….

The 4 element array

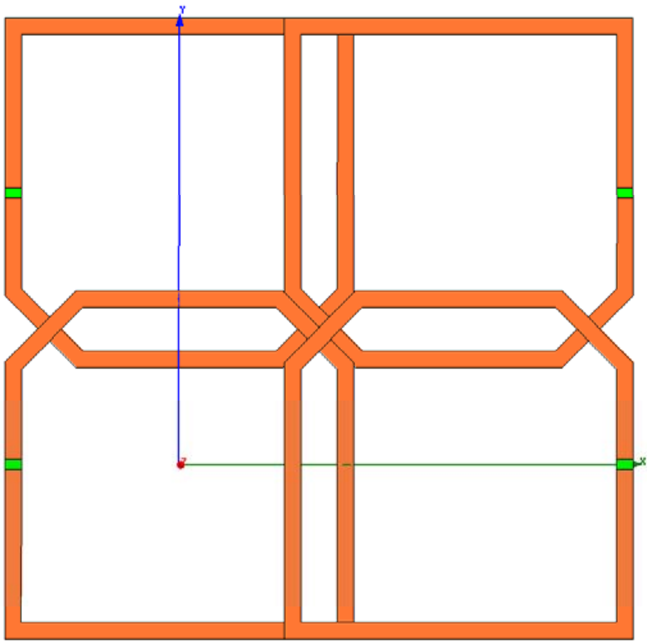
Start with a single loop element



Add a second element

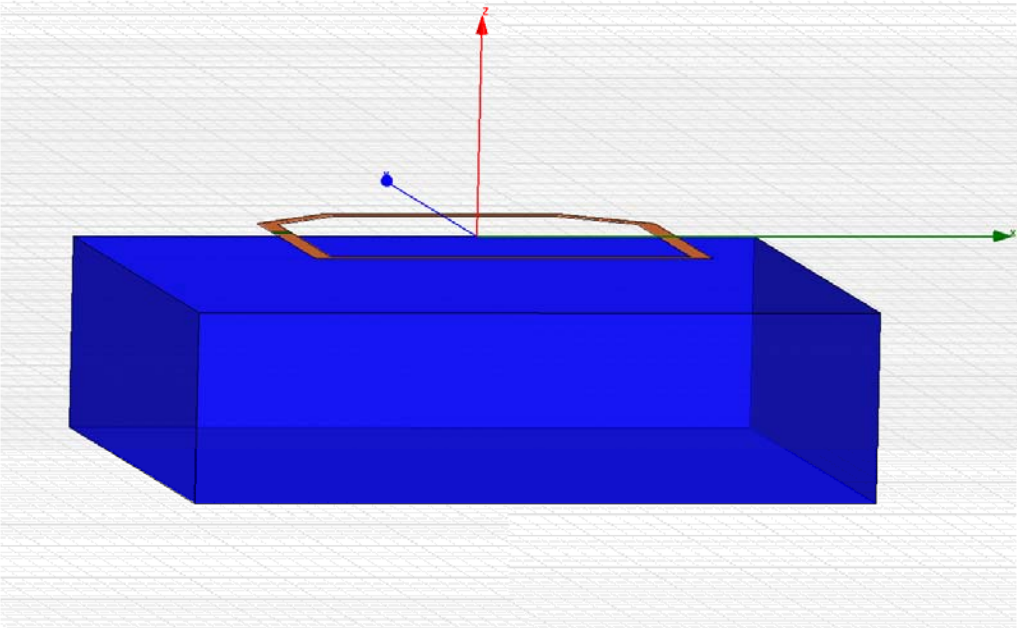


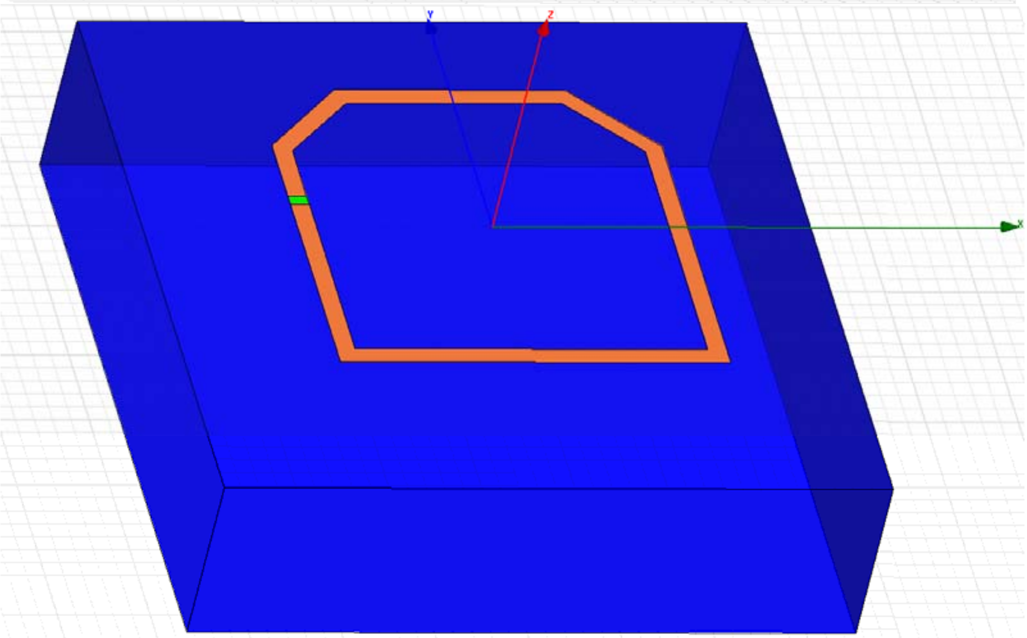
Complete Array

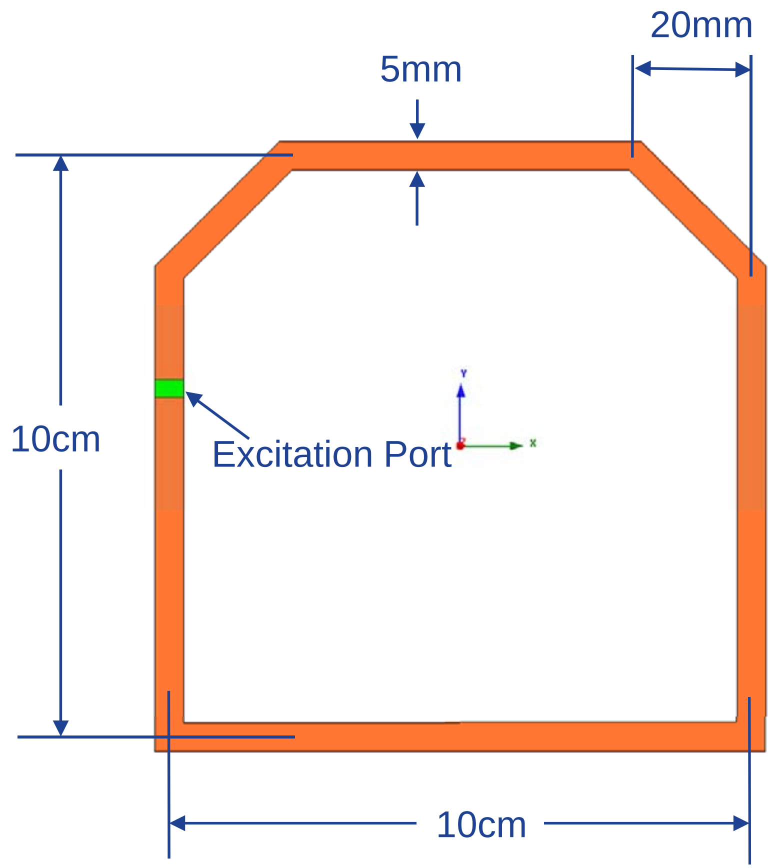


Roemer, Edelstein et. al., “The NMR Phased Array,” Magnetic Resonance in Medicine, vol. 16, pp. 192-225, 1990

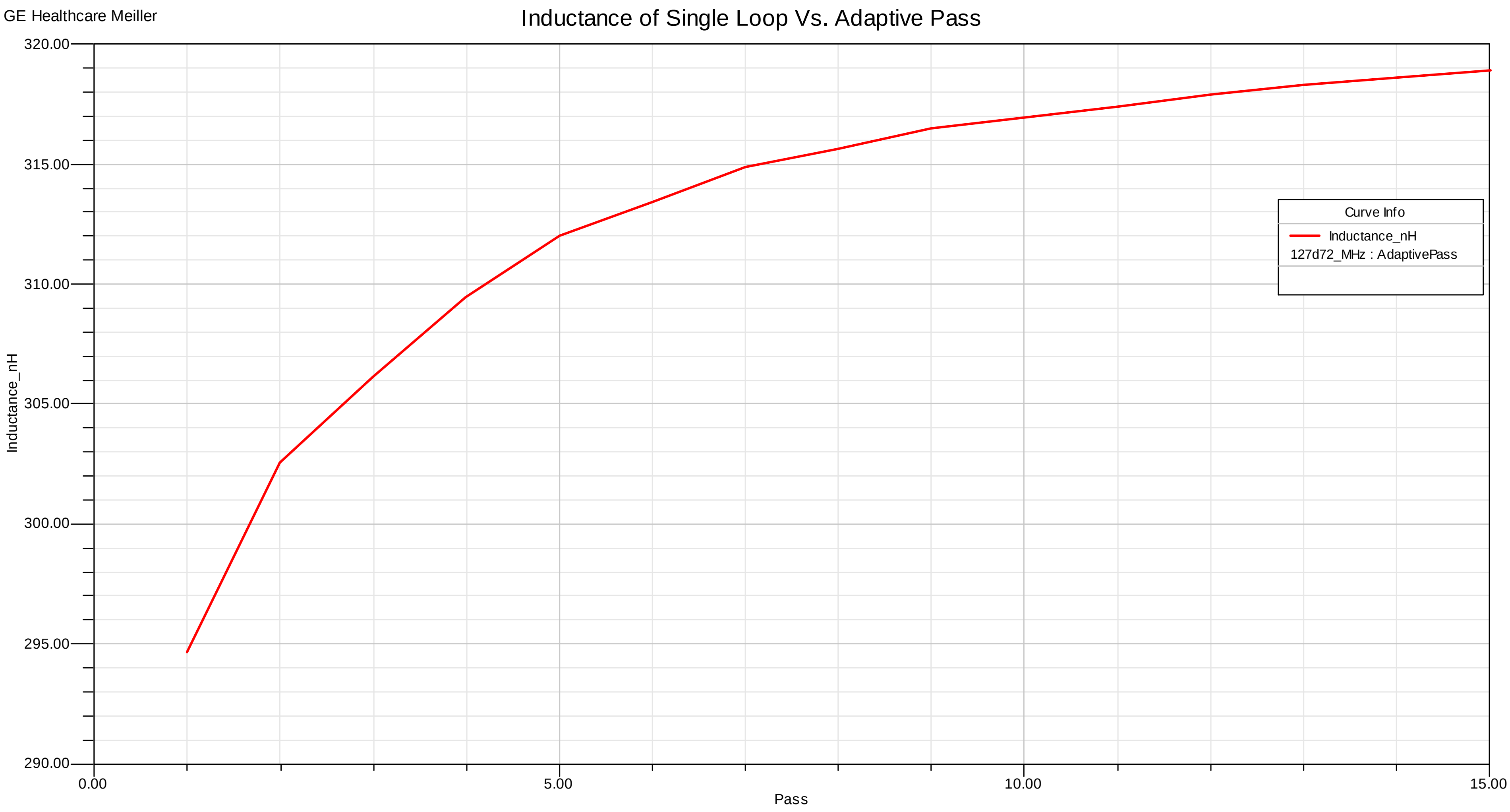
Construct Model of Single Element





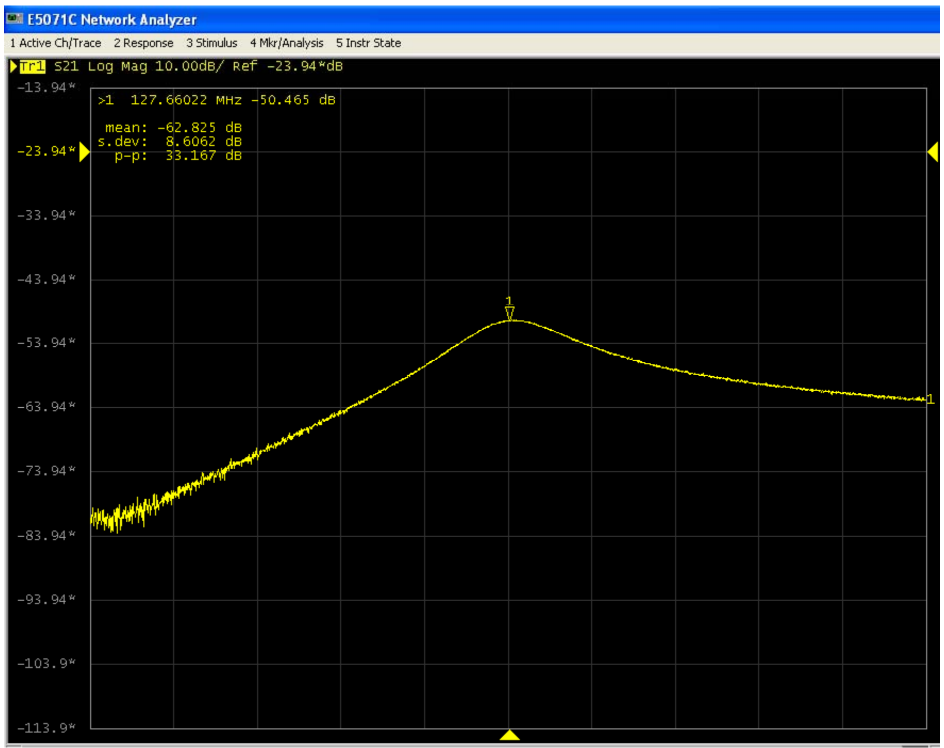


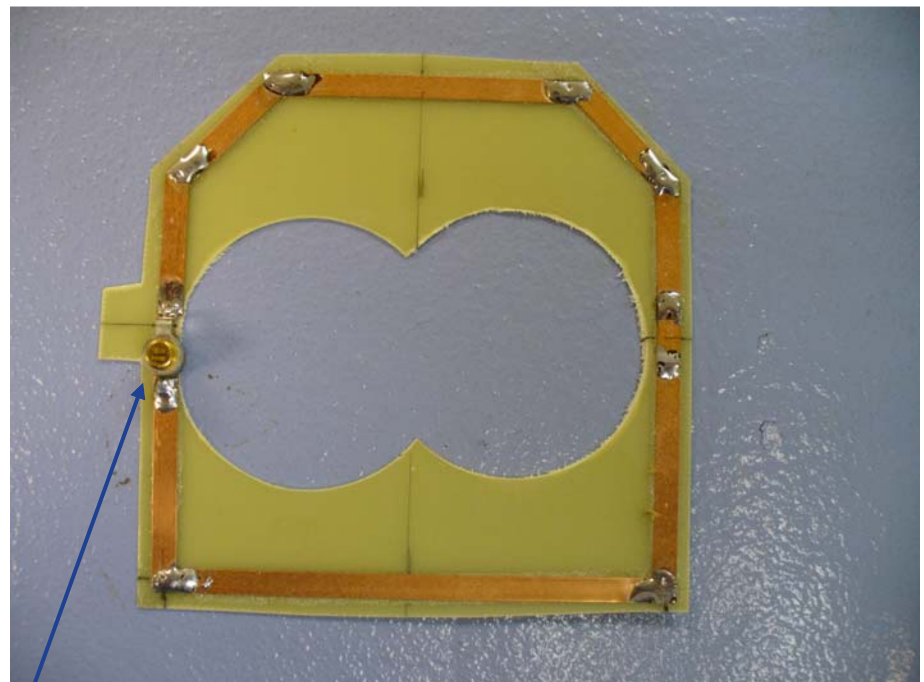
Modeled Inductance of Single Element



Experimental Verification of Inductance

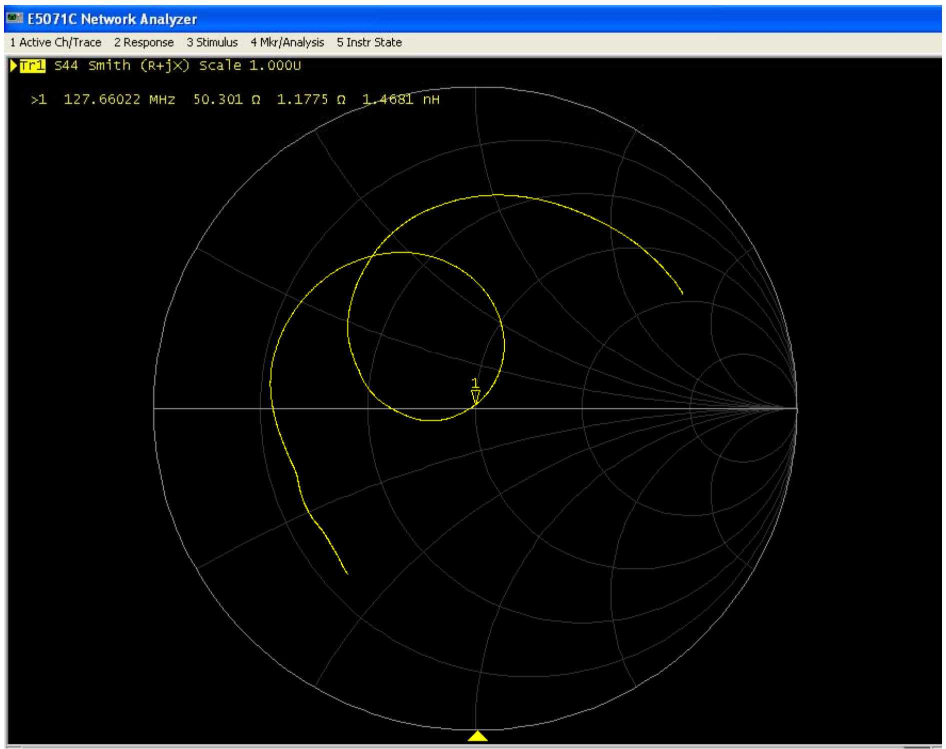
From the model, L=320nH, and to resonate we need $C = \dfrac{1}{\omega^2 L} = 4.86\,pF$

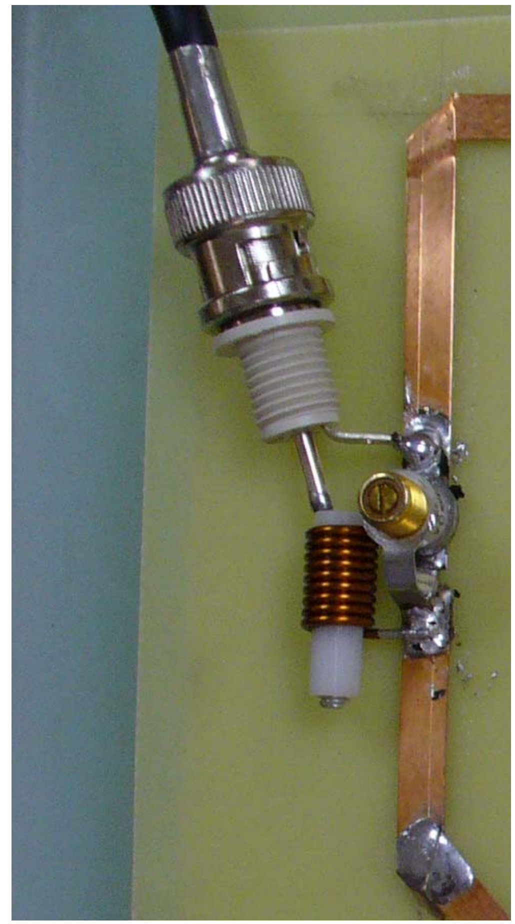




Coil was tuned, then this capacitor removed and measured at 4.78pF

Match to 50 ohms





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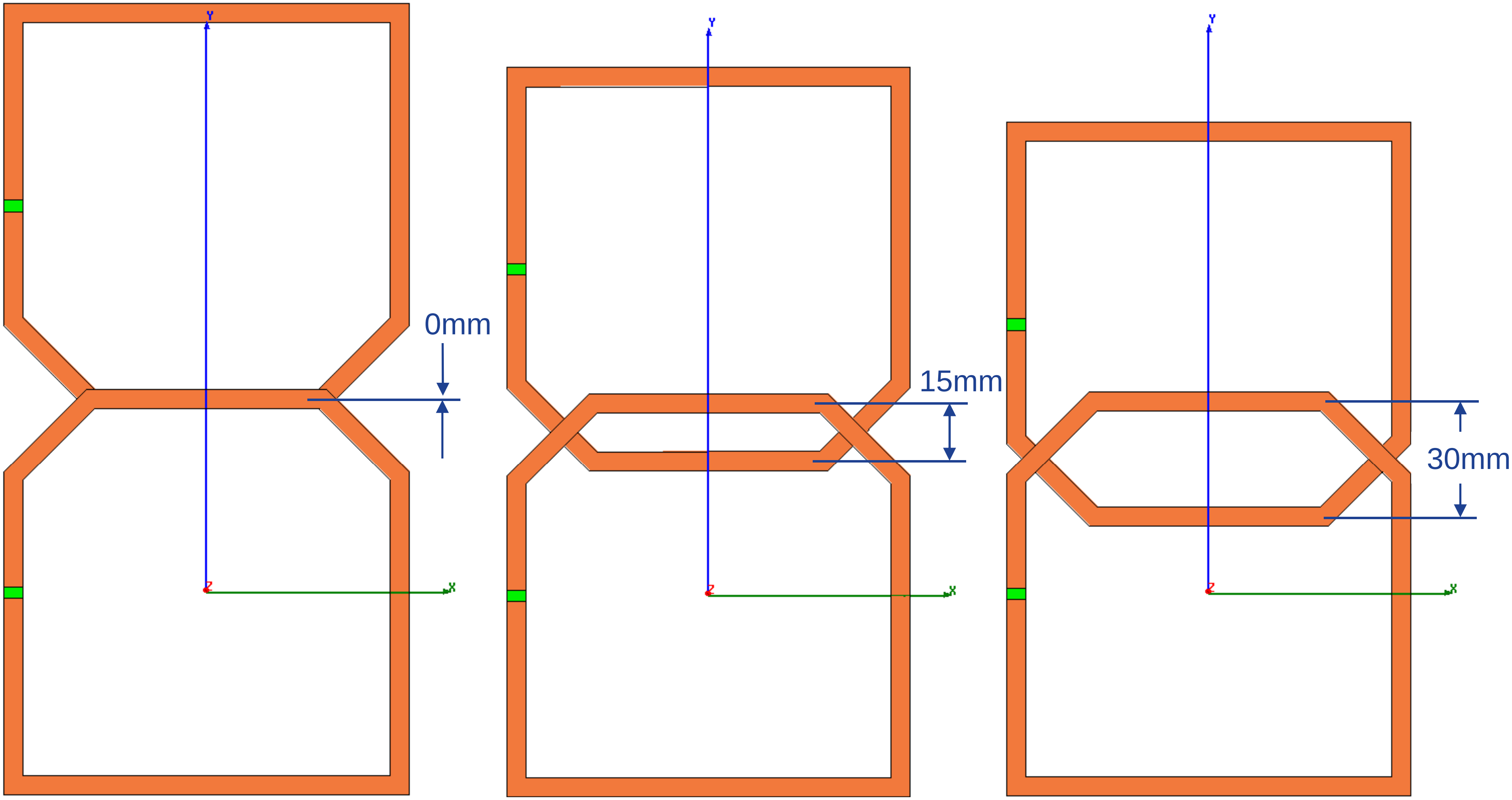
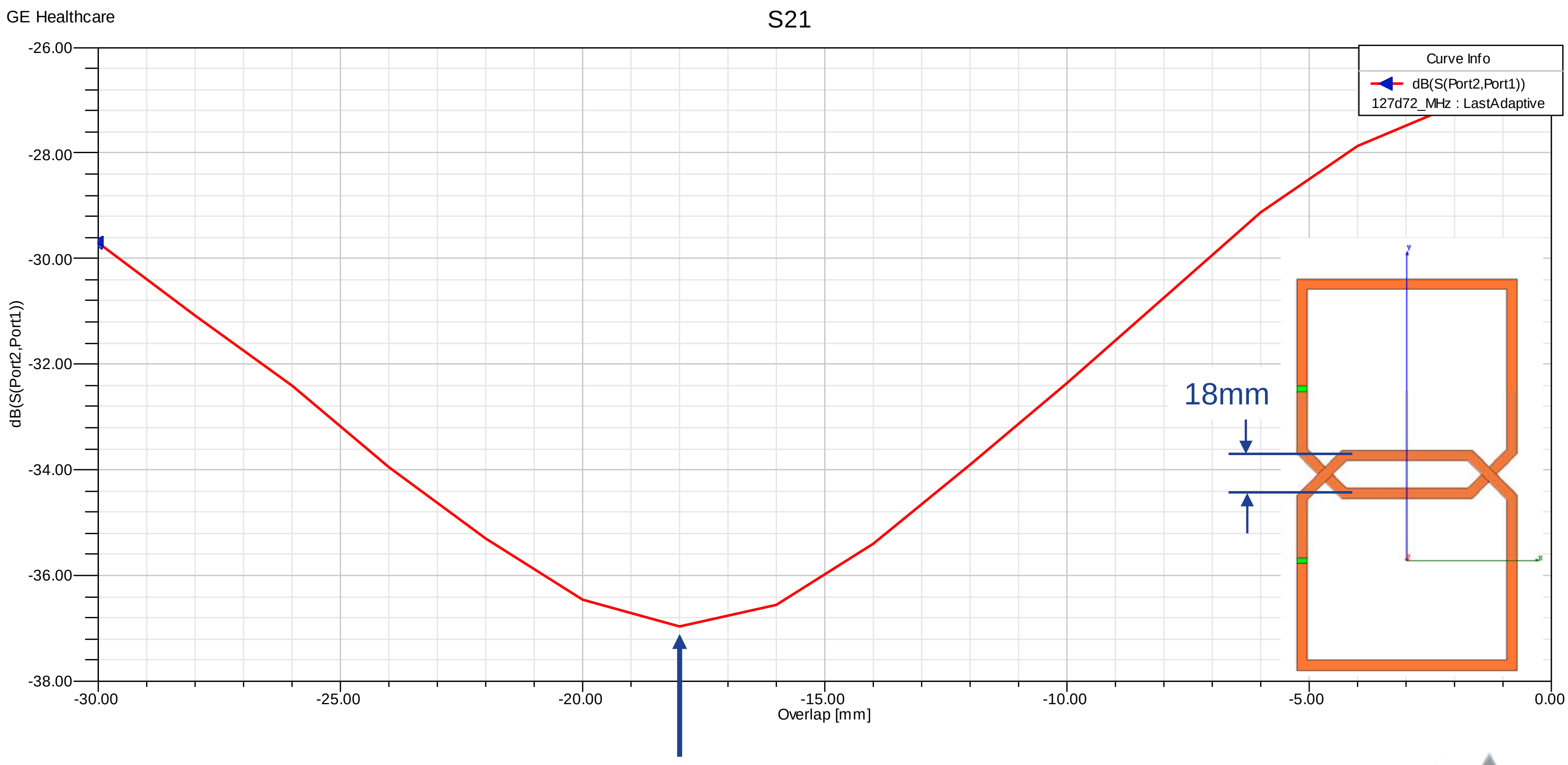
Add Second Element



Geometric Decoupling of 2 Elements

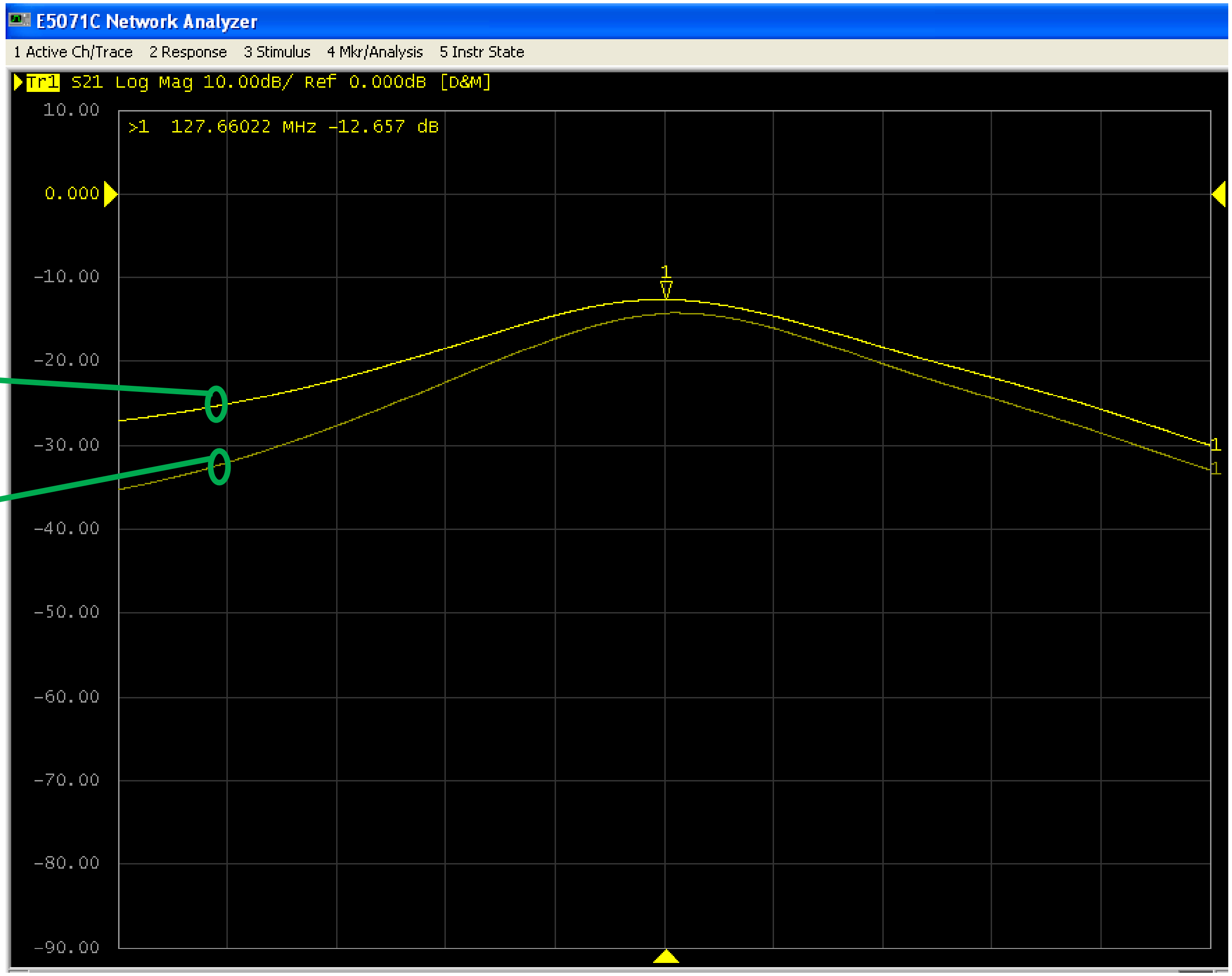


18mm Overlap Minimizes Coupling

Experimental Verification of Geometric Decoupling

Coupling
with Overlap = 15mm

Lowest coupling
with Overlap = 18mm



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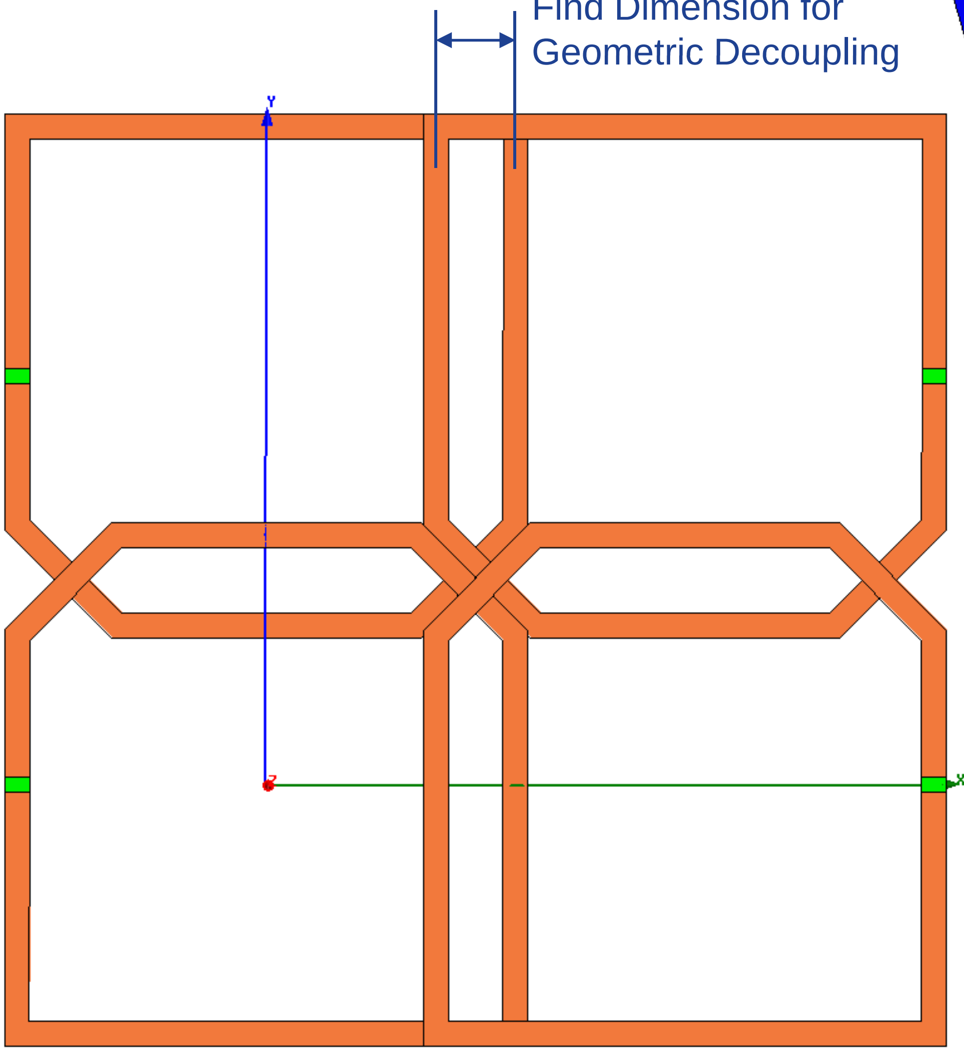
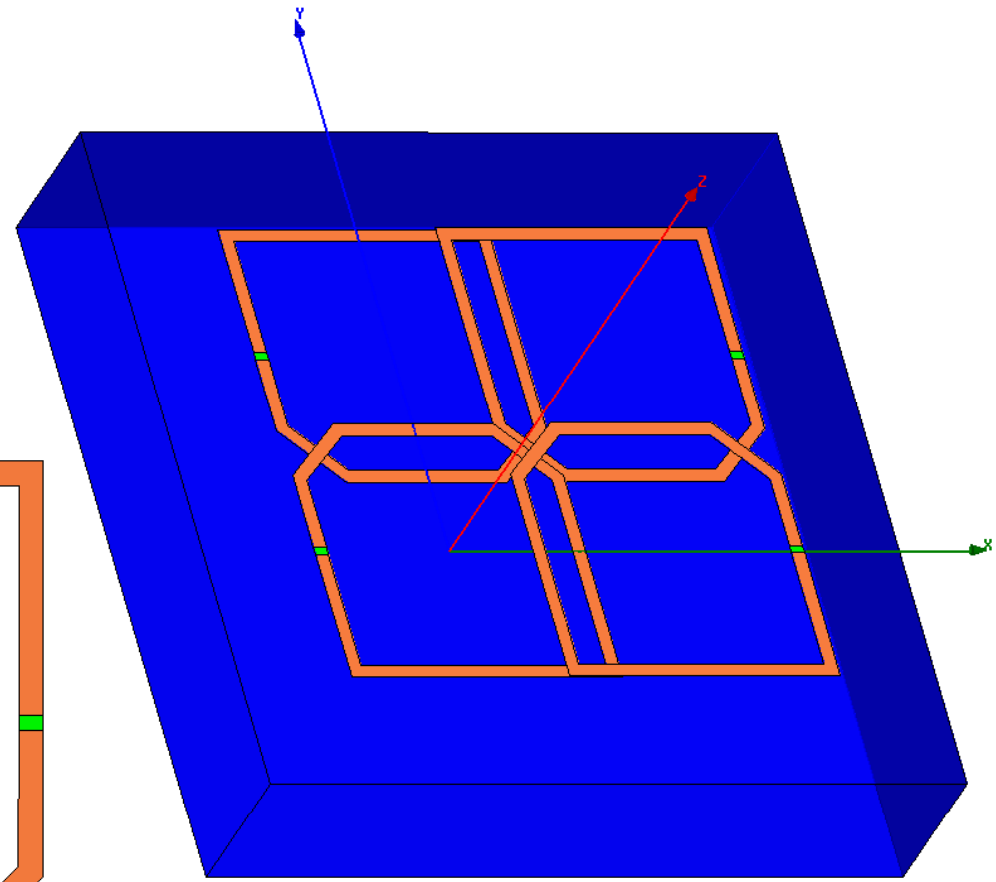
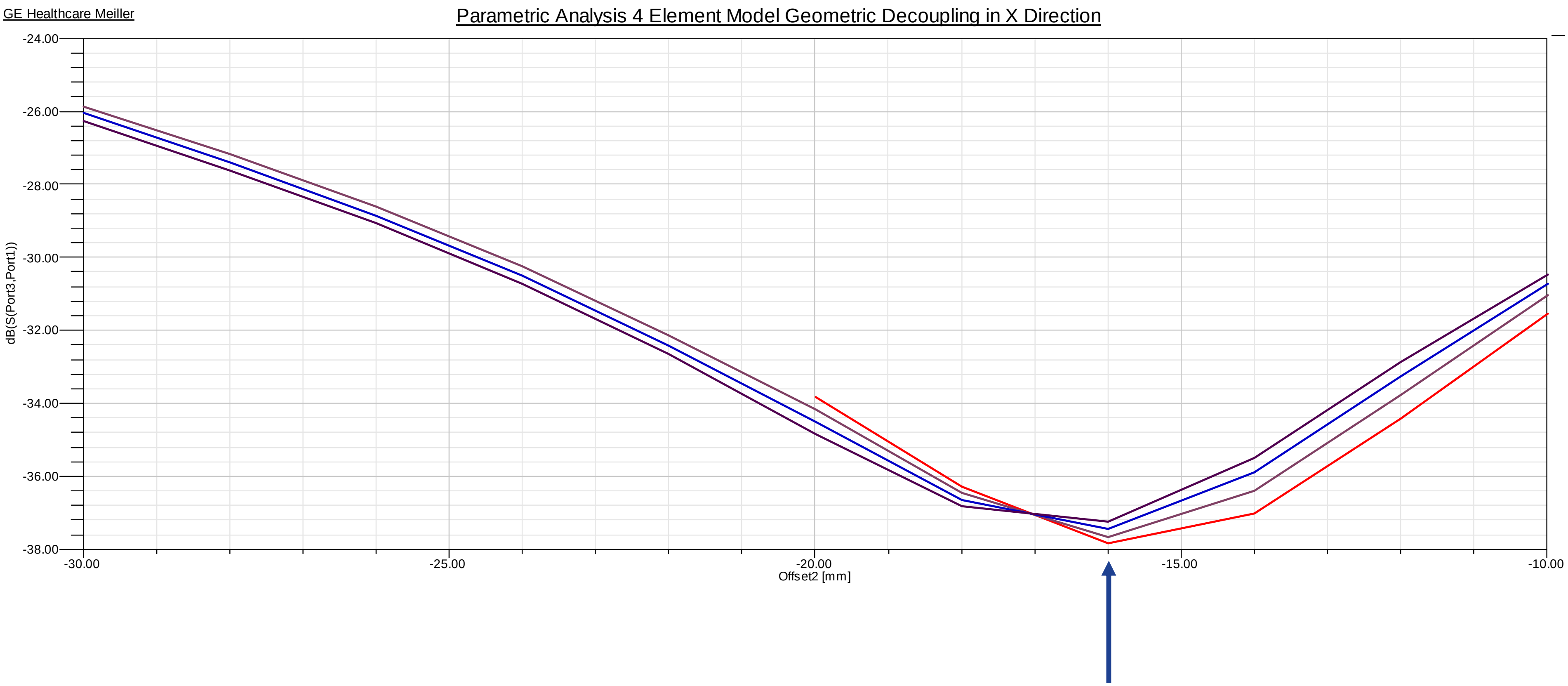
4 Element Array





Parametric Study to Decouple in X Direction



16mm Overlap Minimizes Coupling

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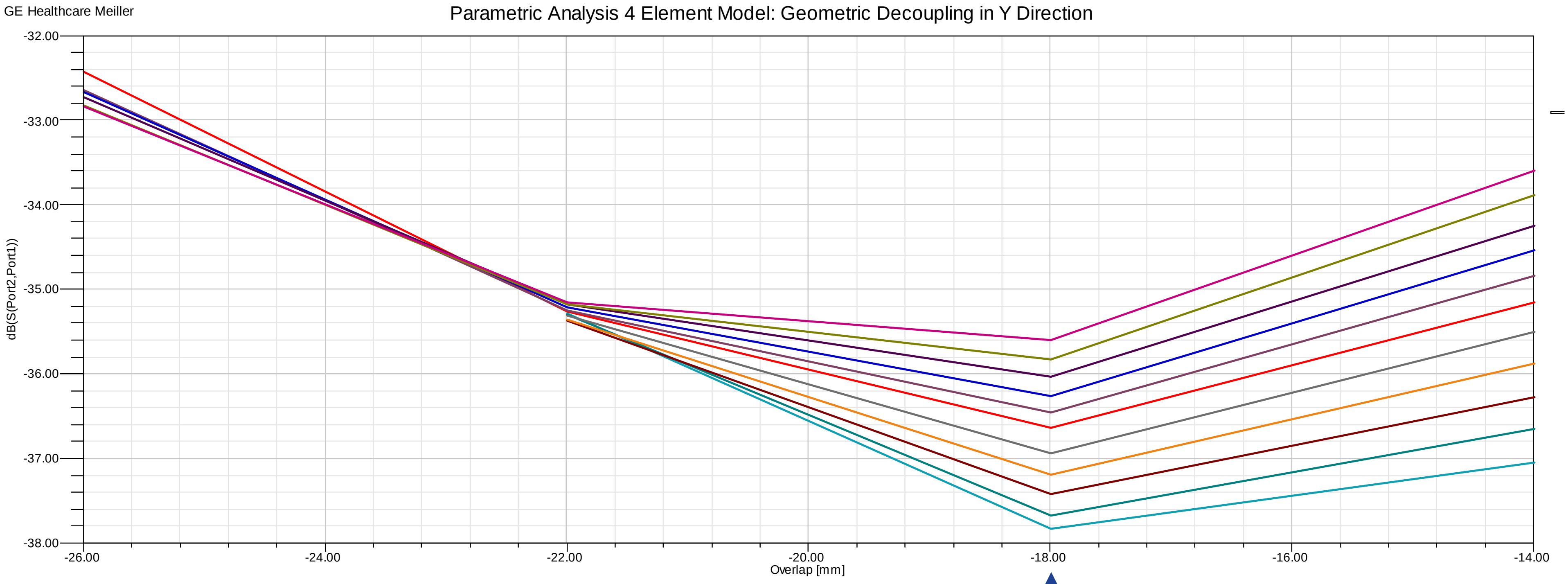
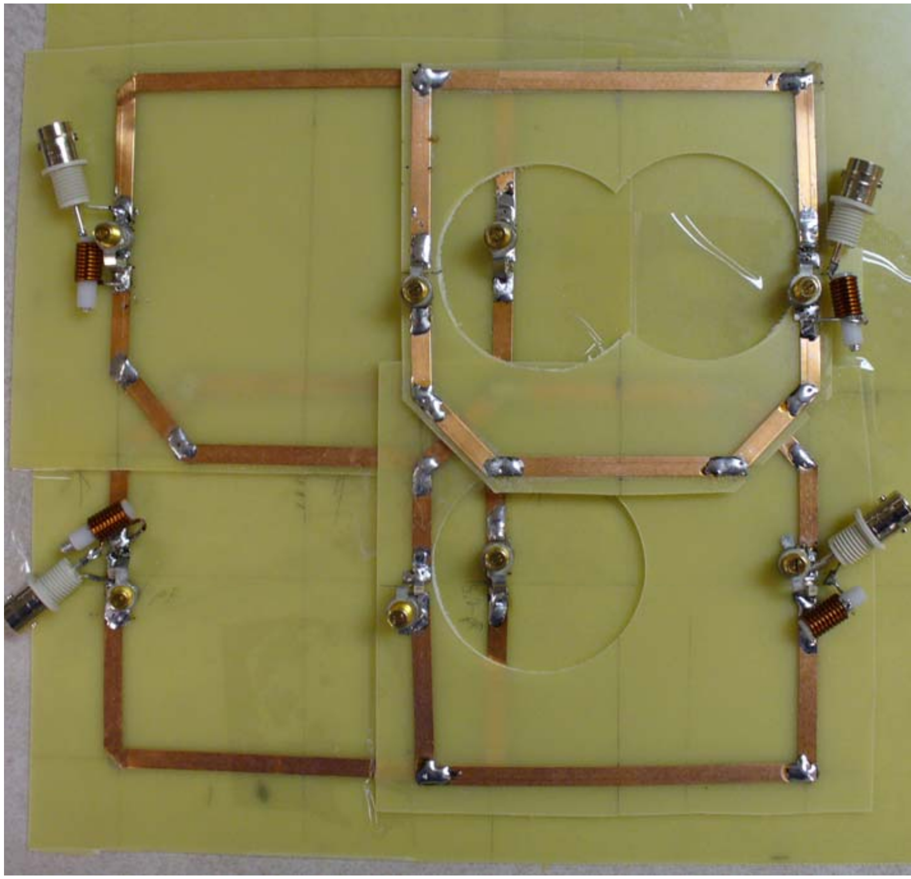
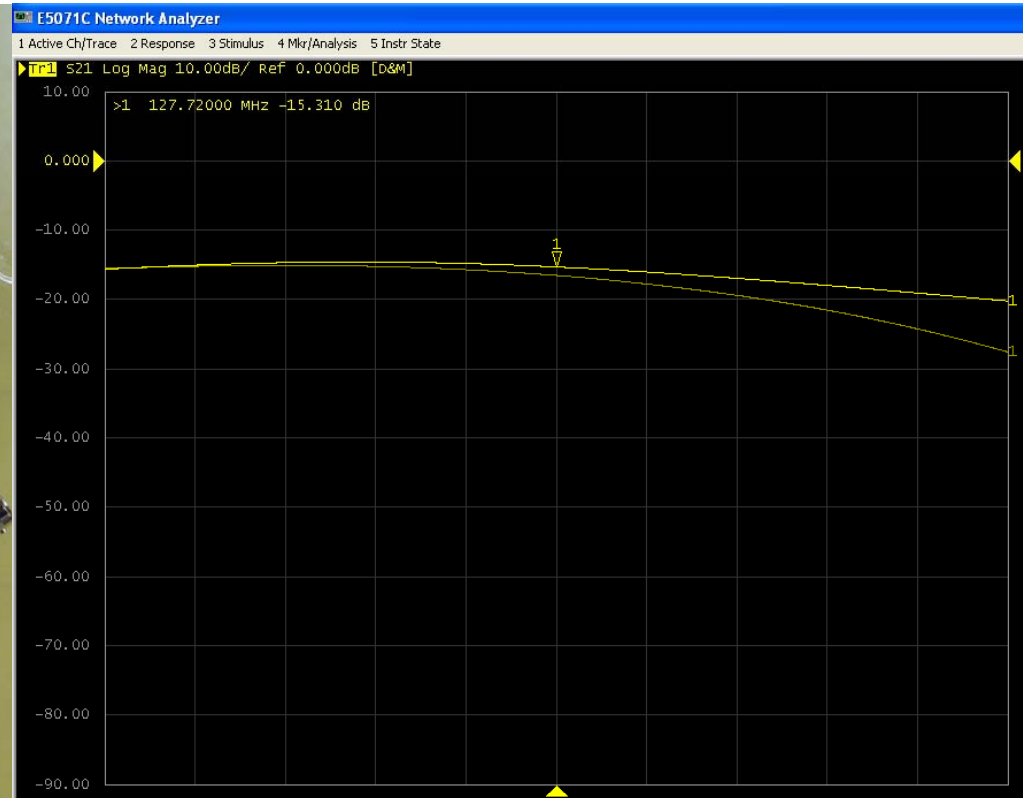
Does 18mm still provide for lowest coupling in the Y direction?…yes



18mm Overlap Minimizes Coupling

Experimental Verification





	Optimized Overlap from Simulation	Optimized Overlap from Experiment
Y direction overlap	18mm	18mm
X direction overlap	16mm	17mm

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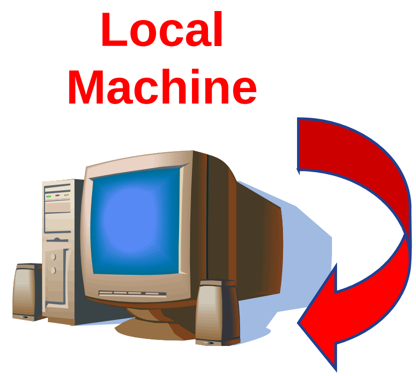
Remote Analysis

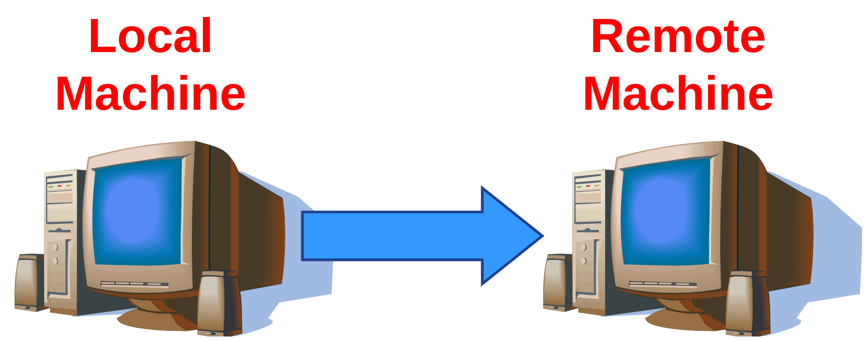
Local Analysis:

Analysis solved on **same** machine as machine that requested simulation



Remote Analysis:

Analysis solved on **different** machine than the one that requested simulation



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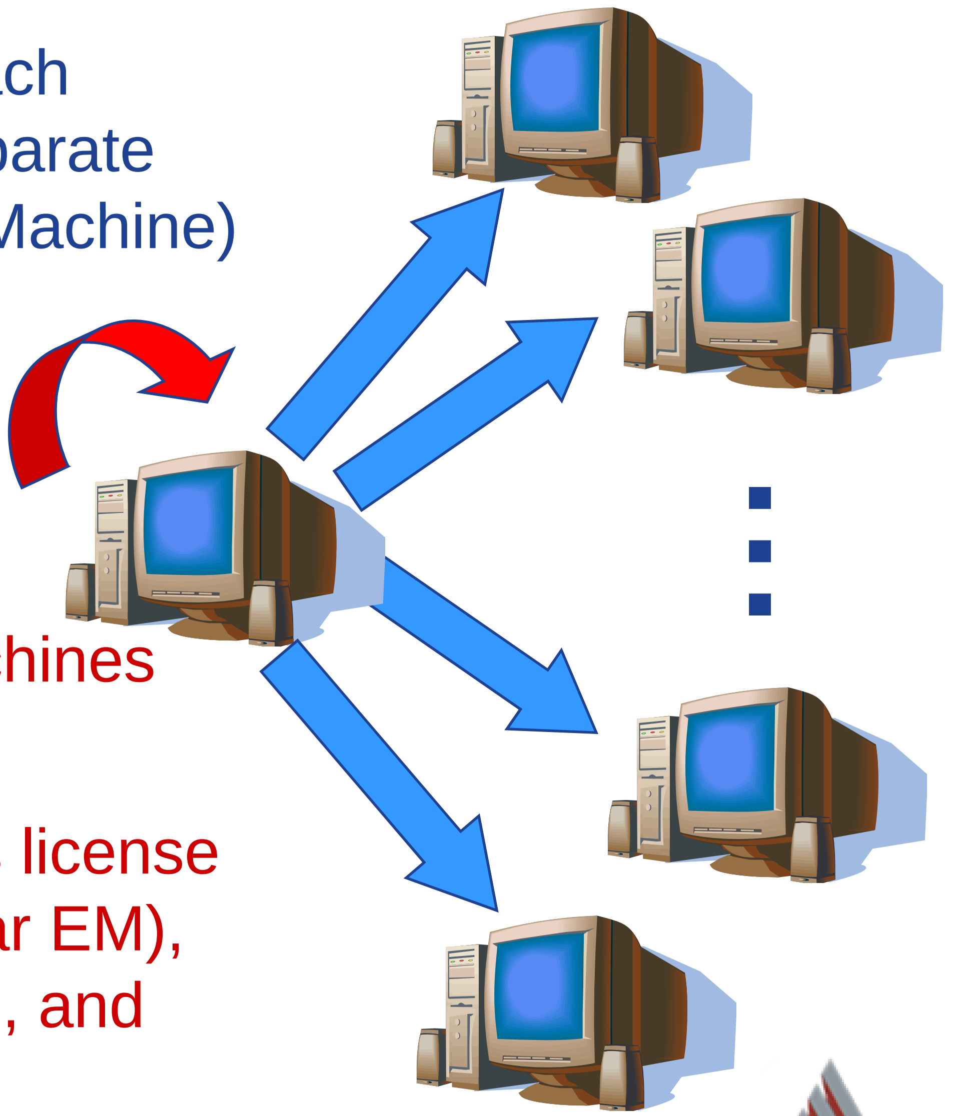
Distributed Analysis

Problem is subdivided, and each subproblem is solved on a separate machine (including the Local Machine)

Available distributions
- Parametric variable sweeps
- Frequency sweeps (HFSS)



- No limit to number of machines that may be used
- Same distributed analysis license works for Designer (Planar EM), ePhysics, HFSS, Maxwell, and Q3D Extractor

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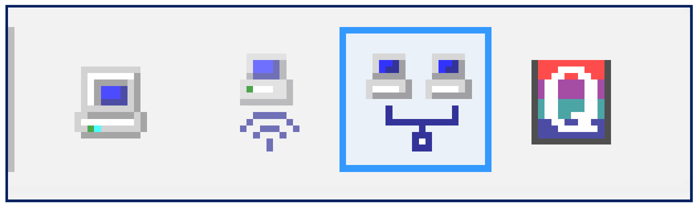
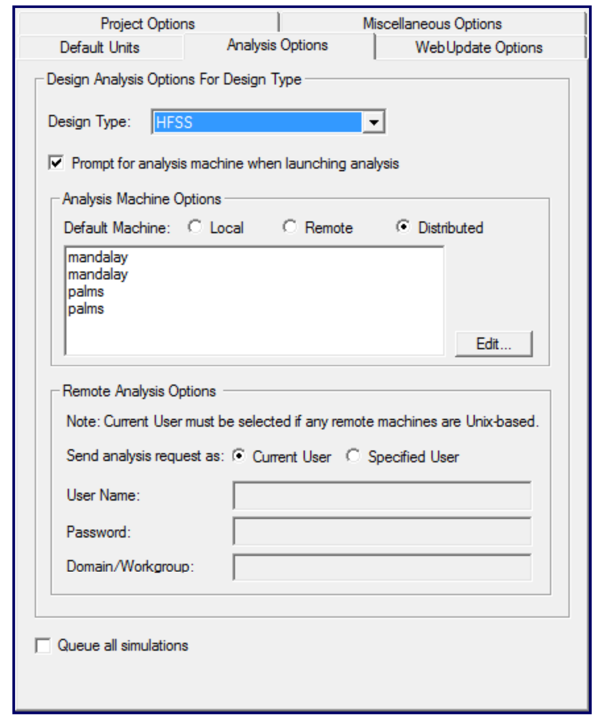
Distributed Solve

Analysis runs with current selected "mode"

- Local
- Remote
- Distributed





A single frequency sweep will be <u>automatically</u> split up and distributed

- No special scripts are required

All Optimetrics analysis are supported in distributed mode

- Parametric, optimization, Sensitivity and Statistical

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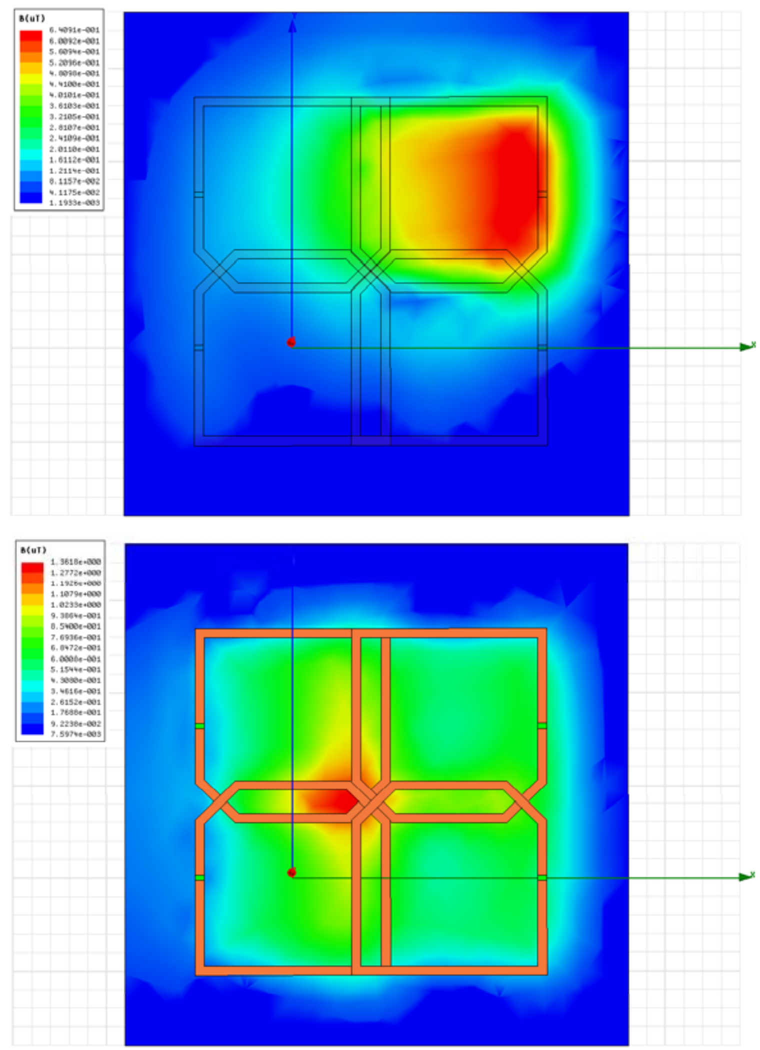
Postprocess Raw Field Data

G-factor and SNR Maps

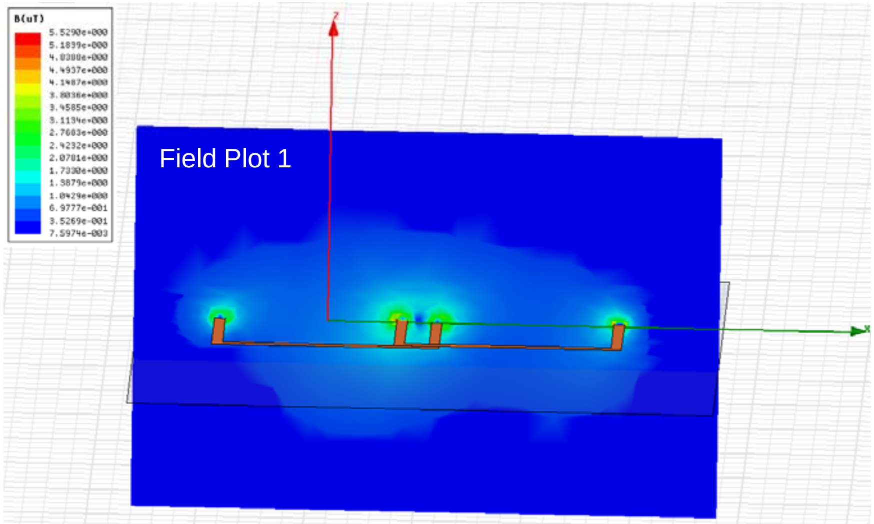
$$g_\rho = \sqrt{\left(S^H \Psi^{-1} S\right)^{-1}_{\rho,\rho} \left(S^H \Psi^{-1} S\right)_{\rho,\rho}} \geq 1$$

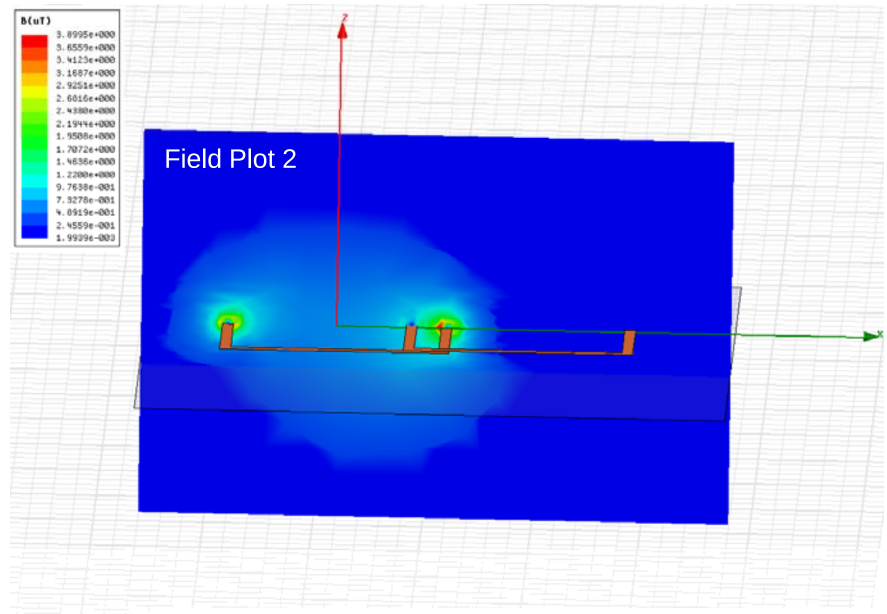
$$SNR_\rho^{reduced} = \frac{SNR_\rho^{full}}{g_\rho \sqrt{R}}$$

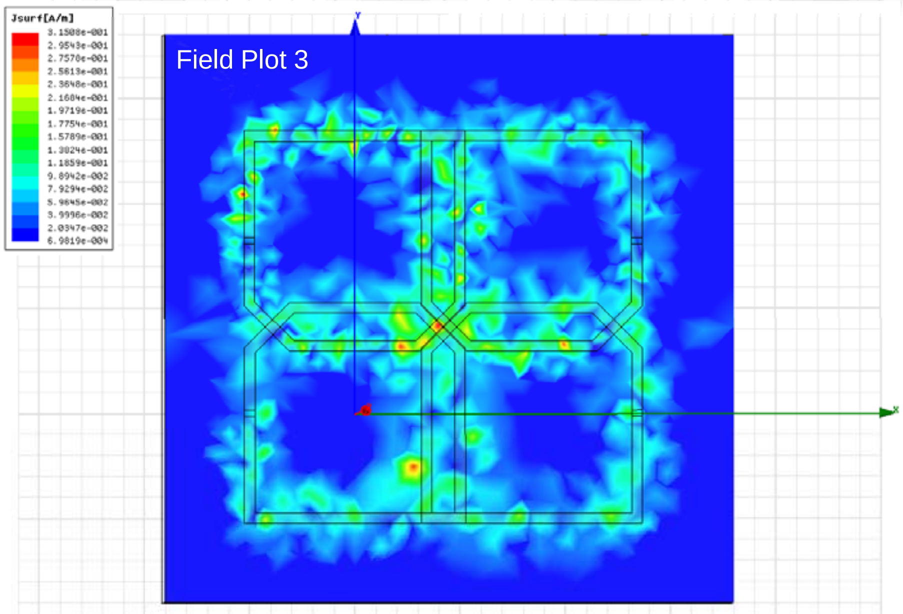


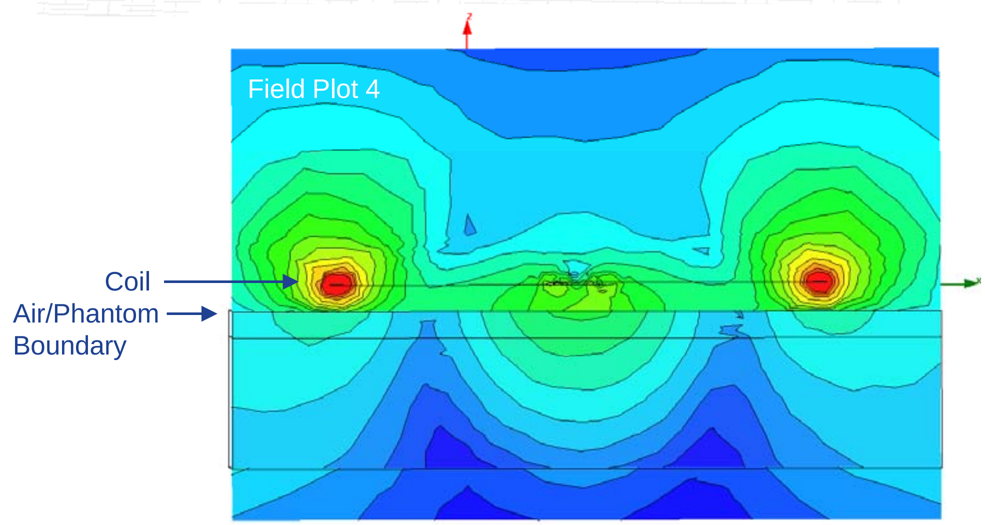
Pruessmann et. al., "SENSE: Sensitivity Encoding for Fast MRI," Magnetic Resonance in Medicine, vol. 42, pp. 952-962, 1999

Field Plots


Field Plot 1


Field Plot 2


Field Plot 3


Field Plot 4
Coil
Air/Phantom
Boundary

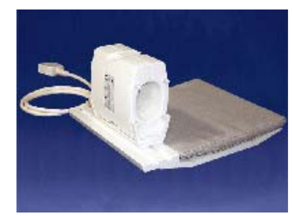
The Finished Product

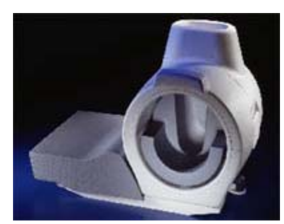











Conclusion

- Simulation agrees well with measurements
- EM tool may be most useful for optimizing large arrays

Thanks!

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