Simulating Complex Power-Ground Plane Shapes with Variable-Size Cell SPICE Grids

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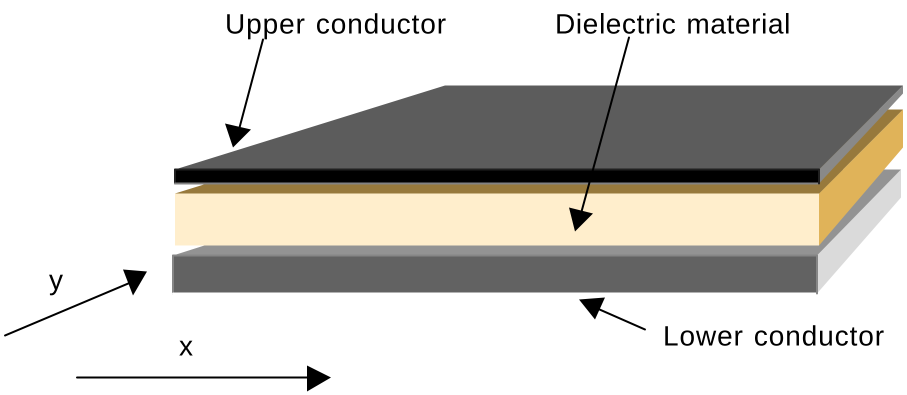
Outline

- Uniform, rectangular plane models
- Need for adaptive, non-uniform grids
- Impedance profiles with various cutouts
- Hardware correlation with adaptive grid
- Conclusions

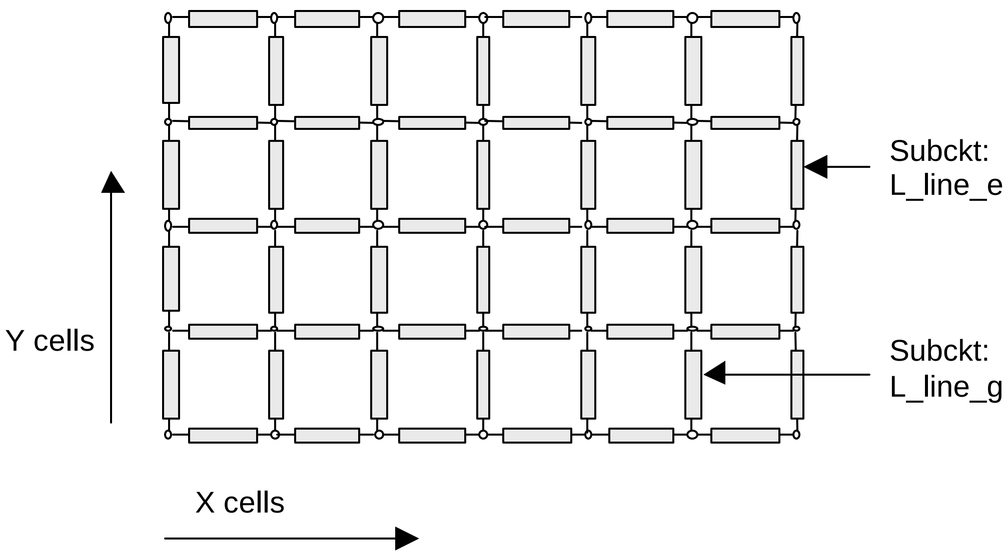
Simulation Model for Plane Pairs

(Rectangular and Uniform)

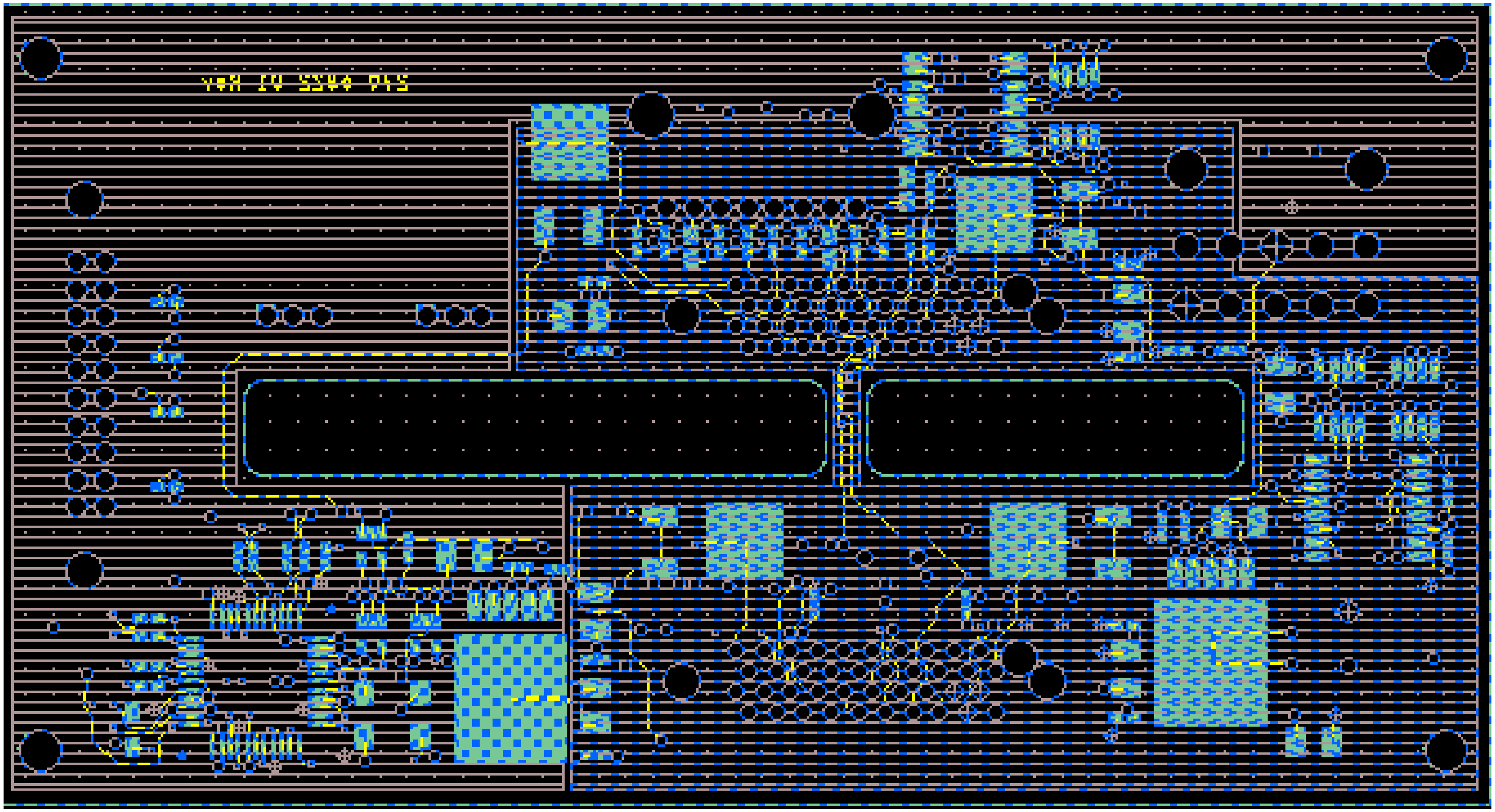
Conductive plane pair with dielectric separation:



Grid subcircuit model:

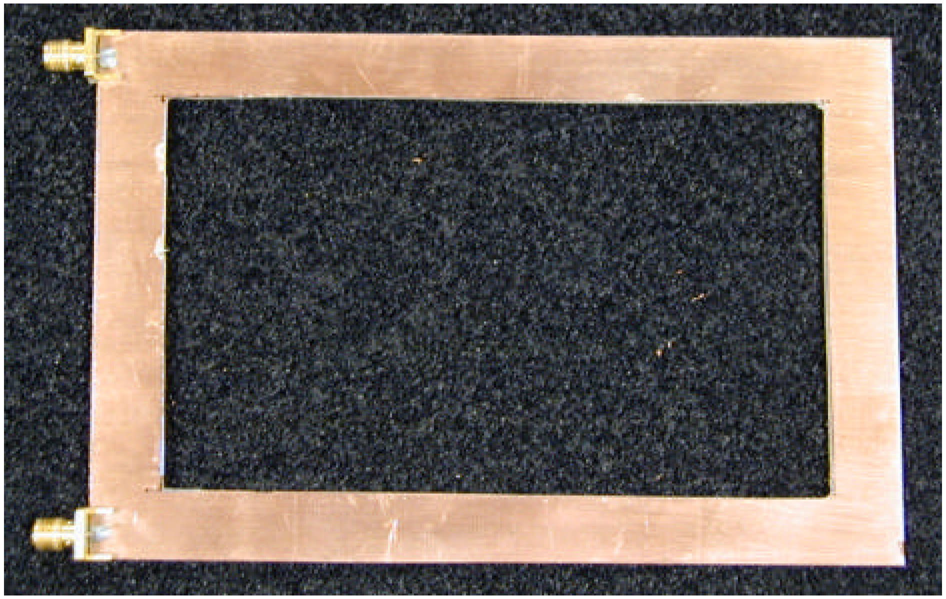


Irregular Plane Shape with Cutouts

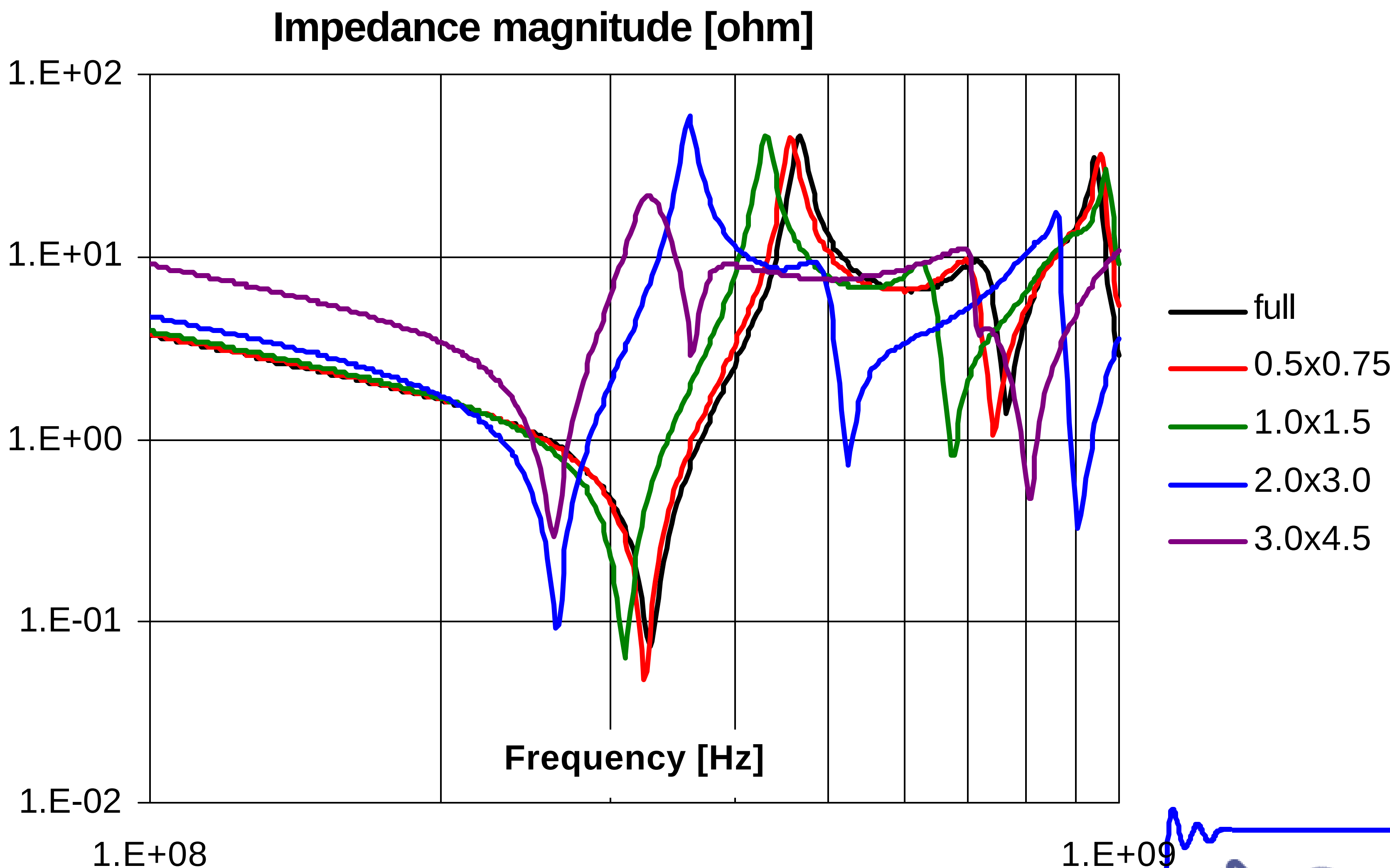


Symmetrical Cutout in Middle (1)

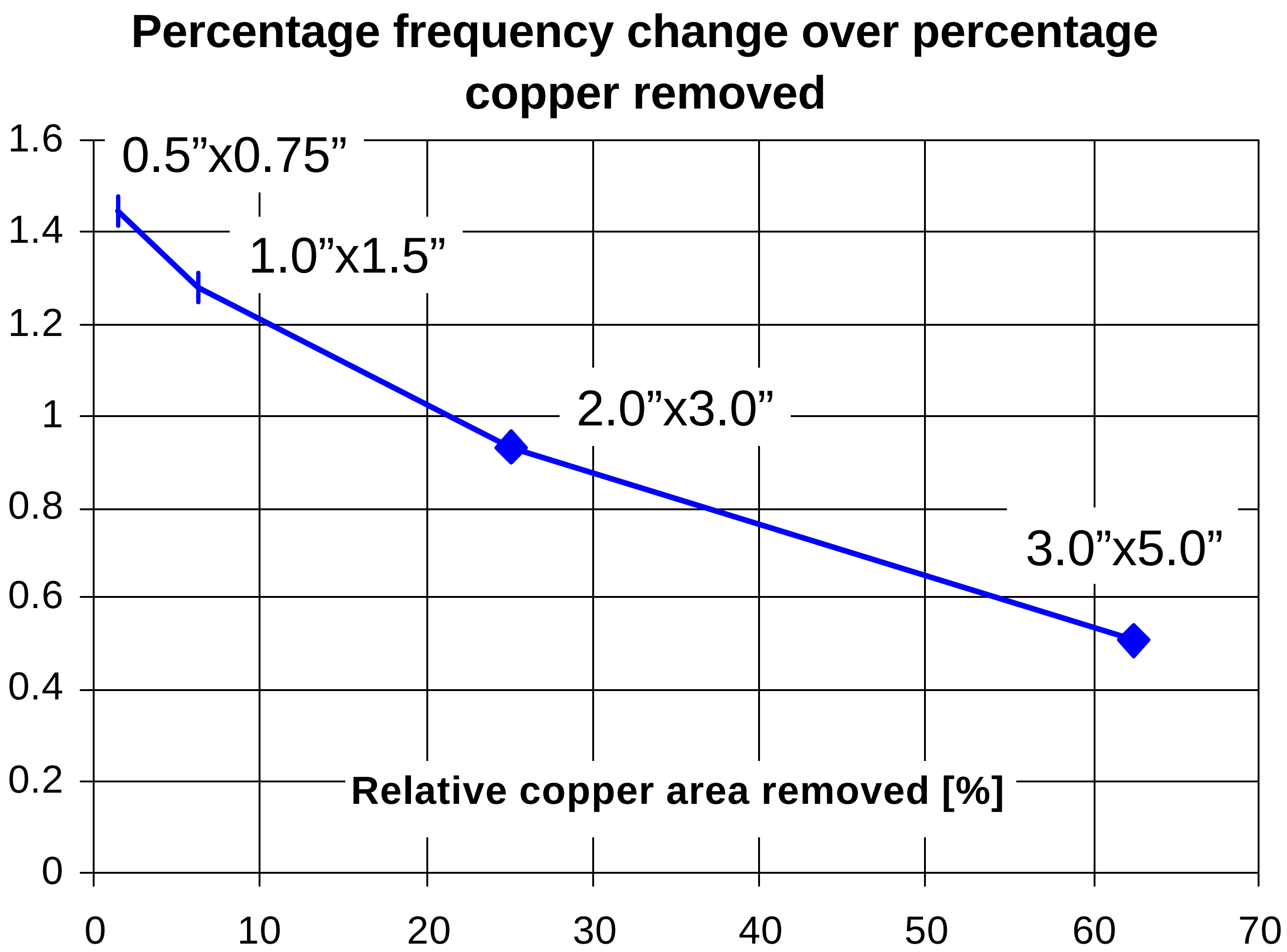
- 1/16” FR4 double-sided 4”x6” rectangular plane pair
- Transfer impedance along shorter side
- Removed copper
  - None
  - 0.5”x0.75” rectangular cutout
  - 1”x1.5” rectangular cutout
  - 2”x3” rectangular cutout
  - 3”x5” rectangular cutout



Symmetrical Cutout in Middle (2)



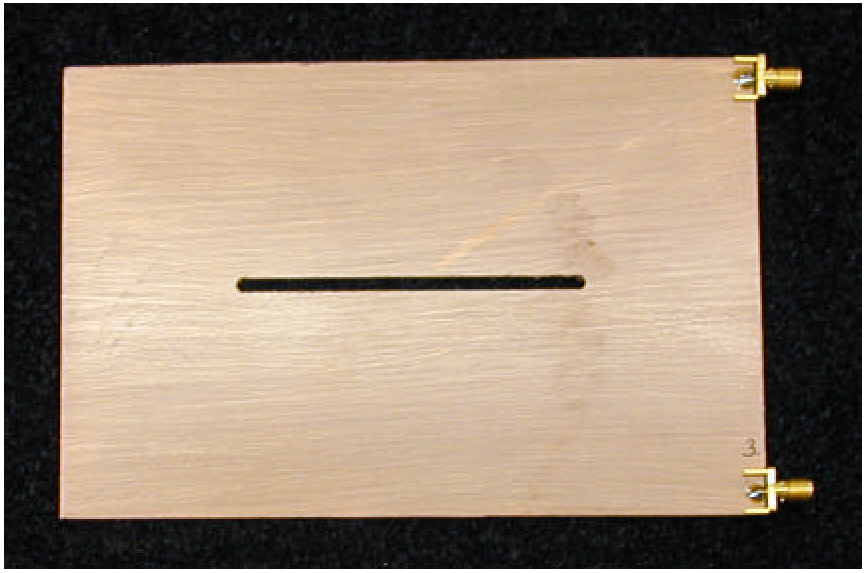
Symmetrical Cutout in Middle (3)



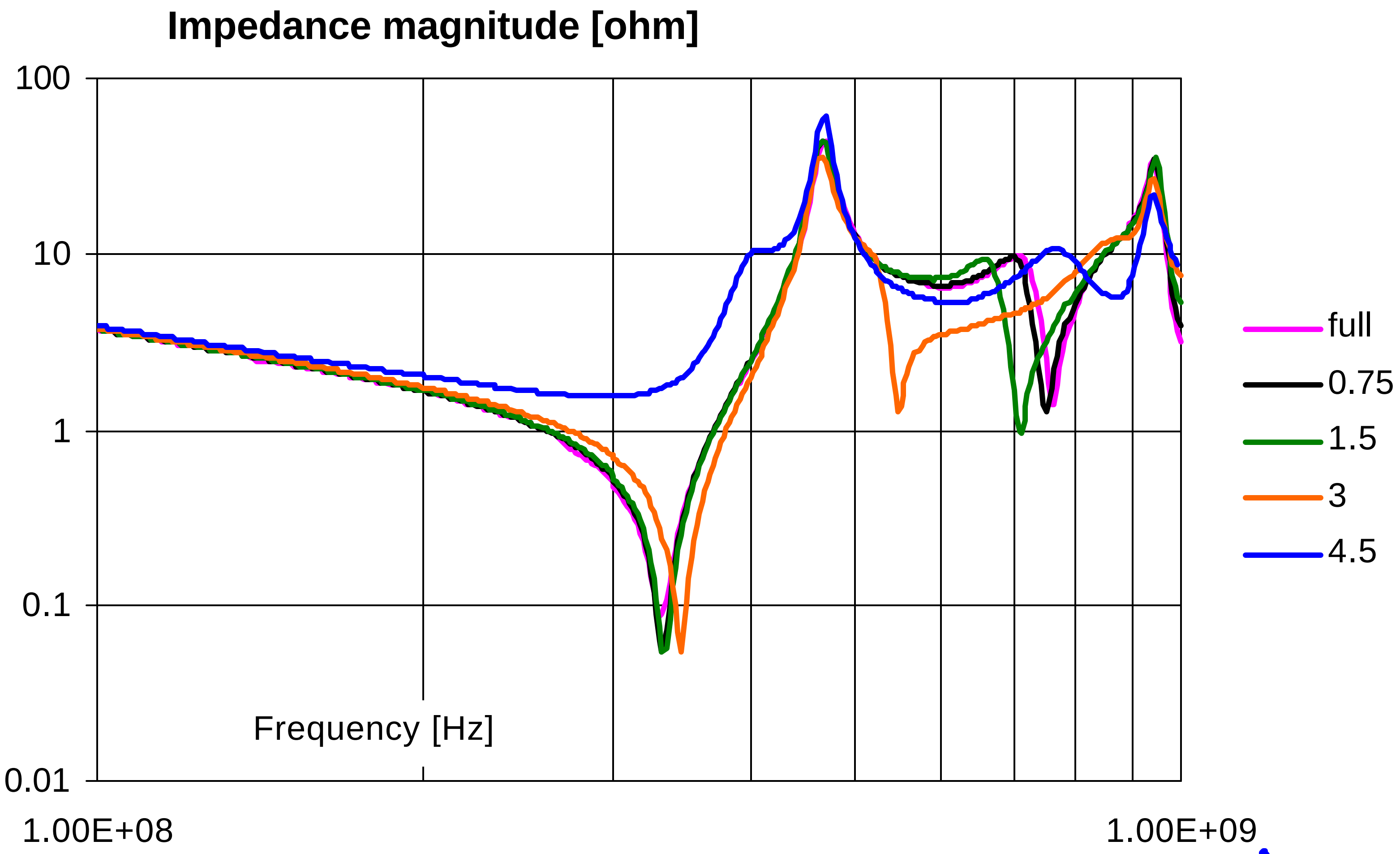
Frequency of first modal resonance peak

Symmetrical Slot in Middle (1)

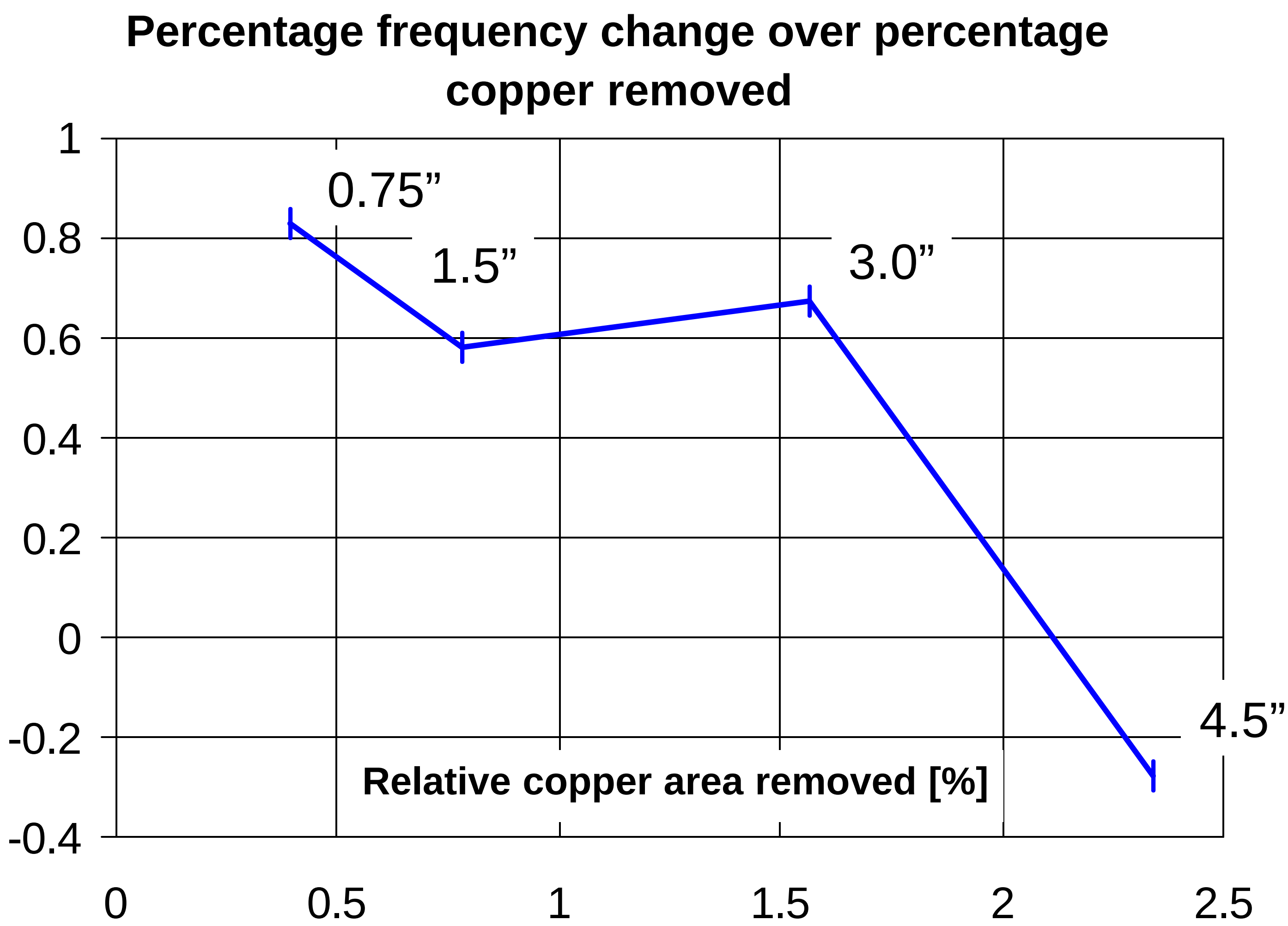
- 1/16” FR4 double-sided 4”x6” rectangular plane pair
- Transfer impedance along shorter side
- Slot in middle, 0.125” wide
  - None
  - 0.75” rectangular cutout
  - 1.5” rectangular cutout
  - 3” rectangular cutout
  - 4.5” rectangular cutout



Symmetrical Slot in Middle (2)



Symmetrical Slot in Middle (3)

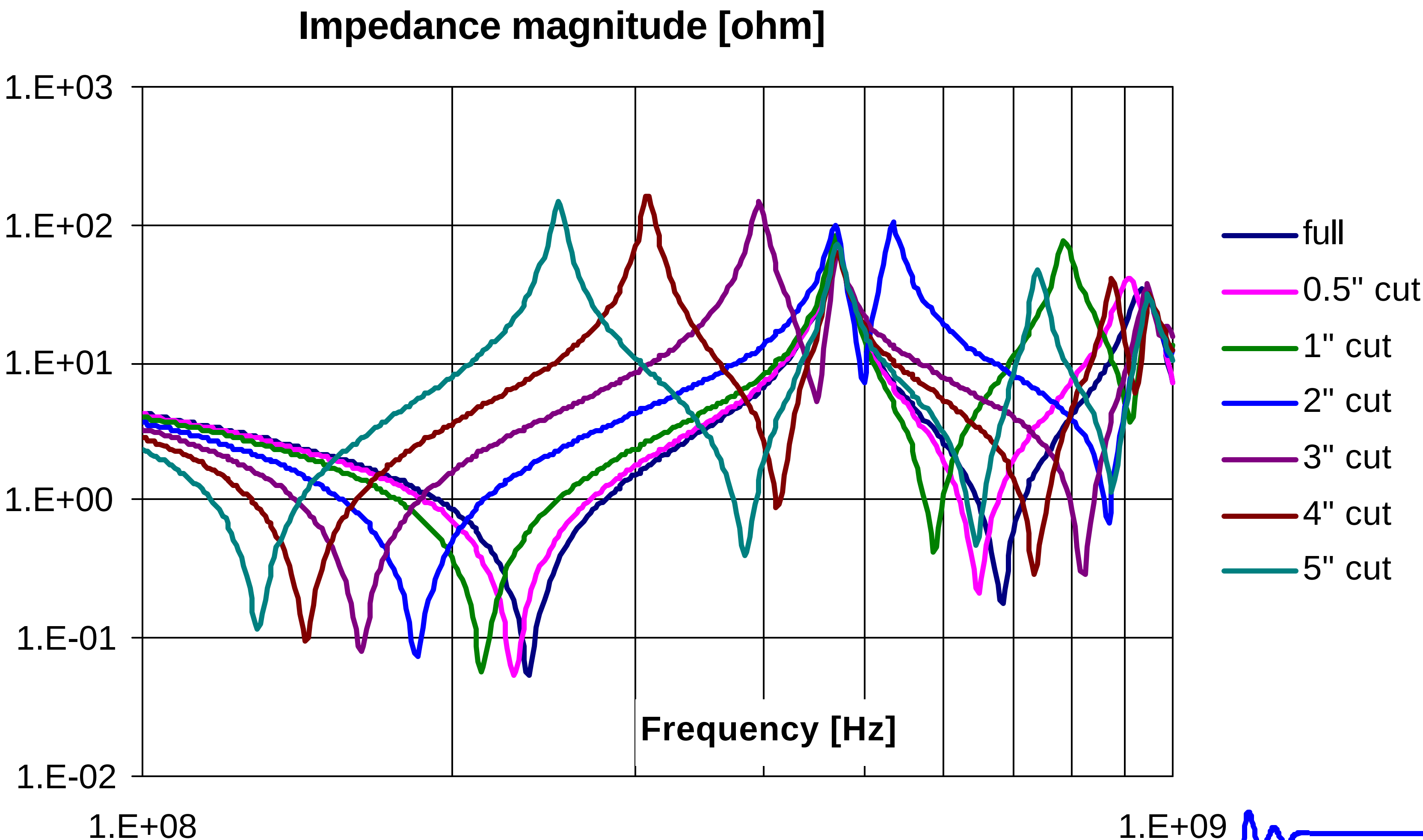


Frequency of first modal resonance peak

Cut from Side (1)

- 1/16" FR4 double-sided 3"x6" rectangular plane pair
- Transfer impedance along 1" on side
- Cut from side, 0.03" wide
  - None
  - 0.5" cut
  - 1" cut
  - 2" cut
  - 3" cut
  - 4" cut
  - 5" cut

Cut from Side (2)



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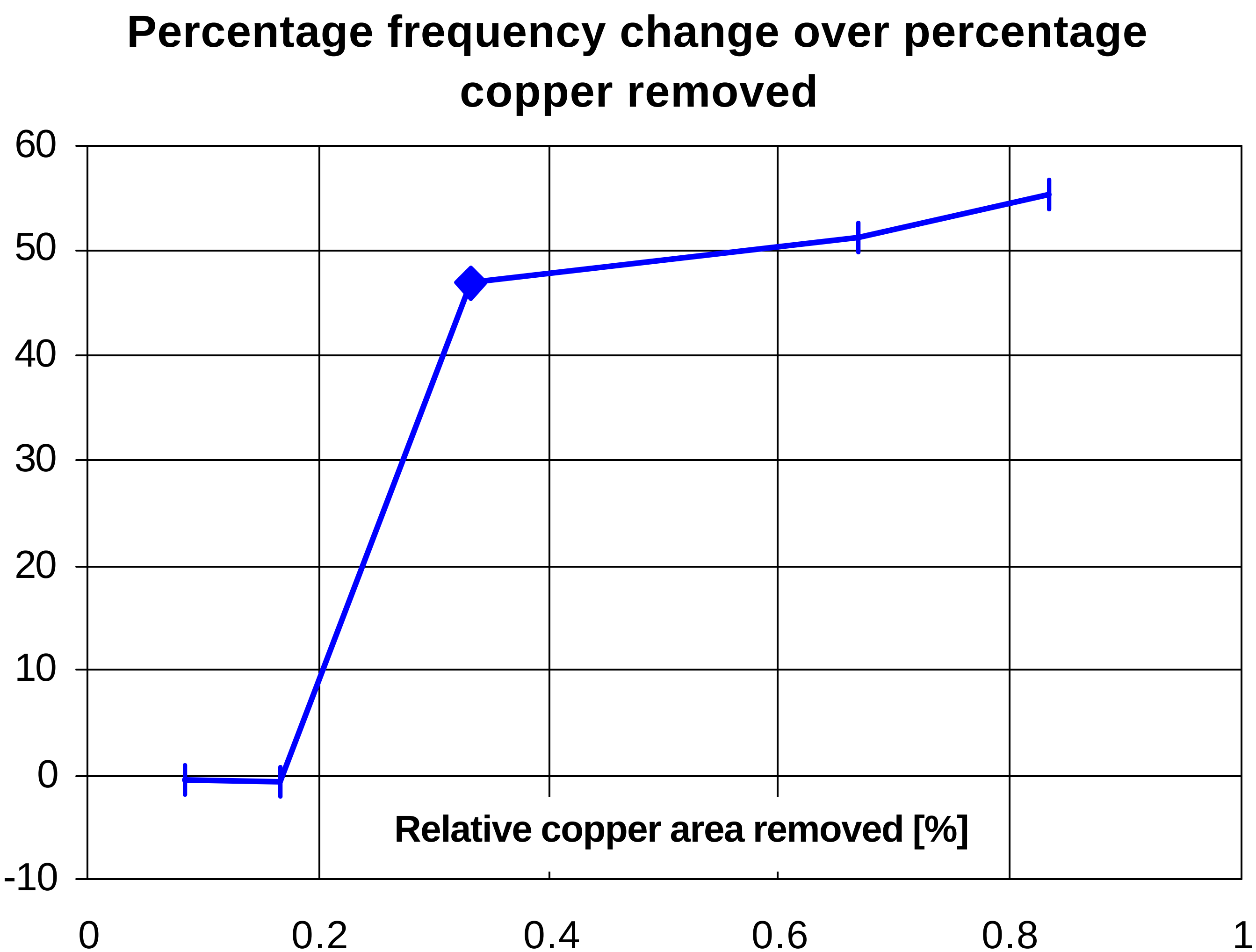
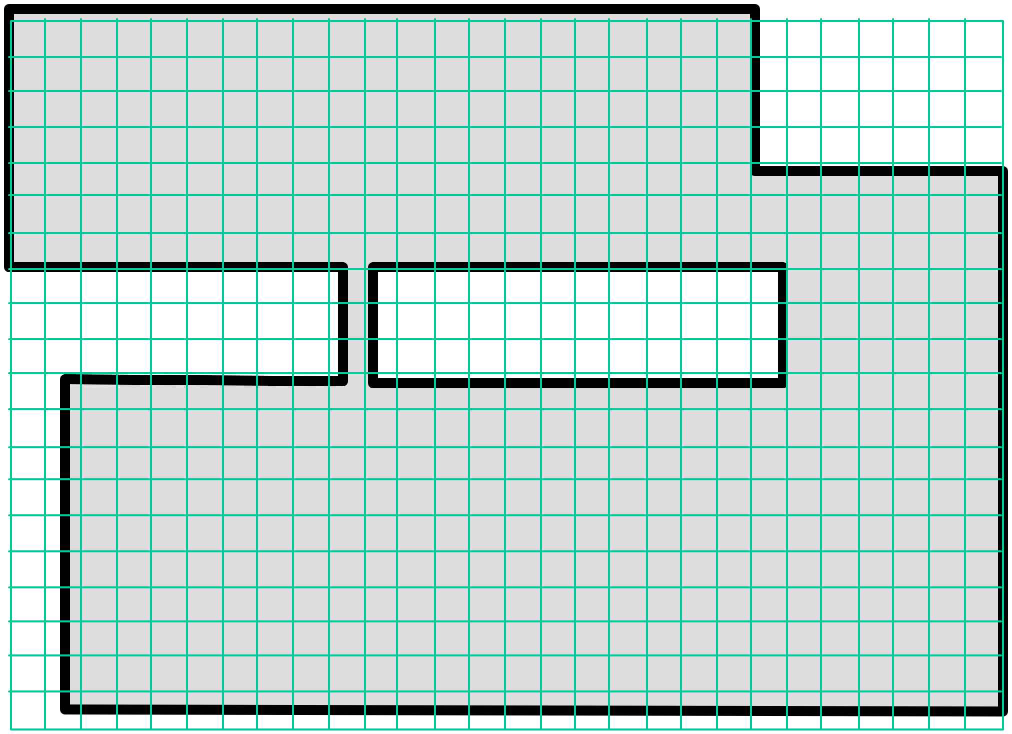
Cut from Side (3)



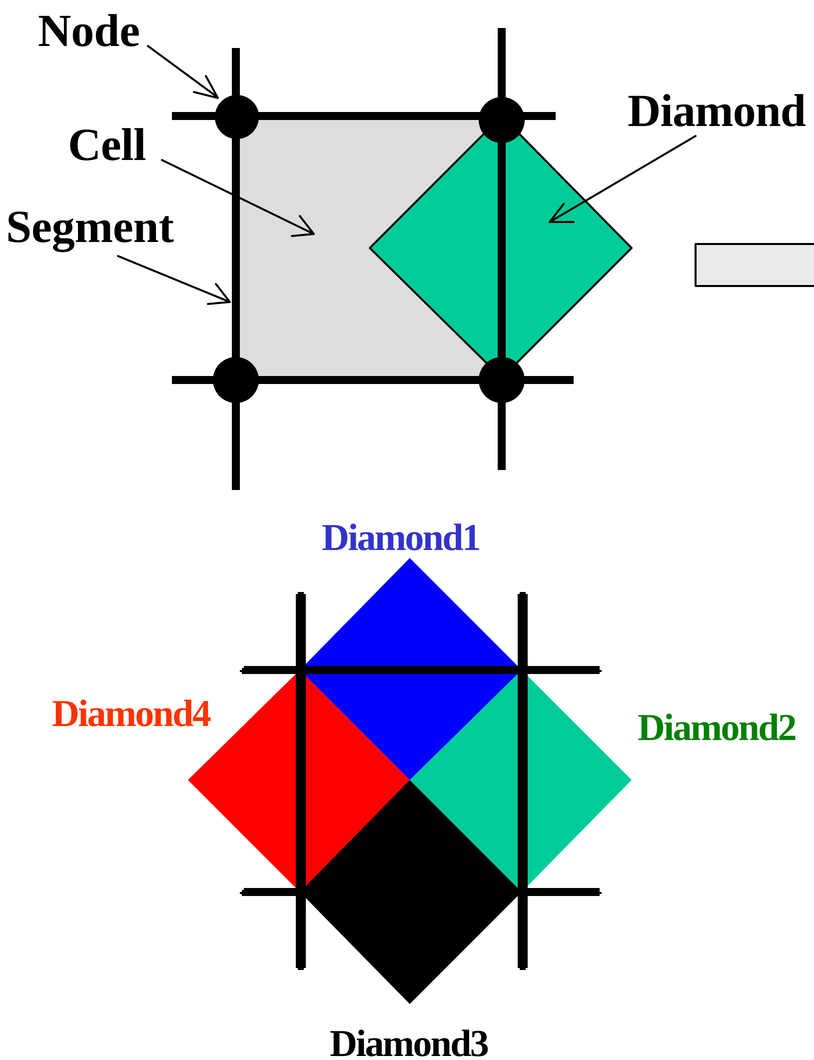
Frequency of first modal resonance peak

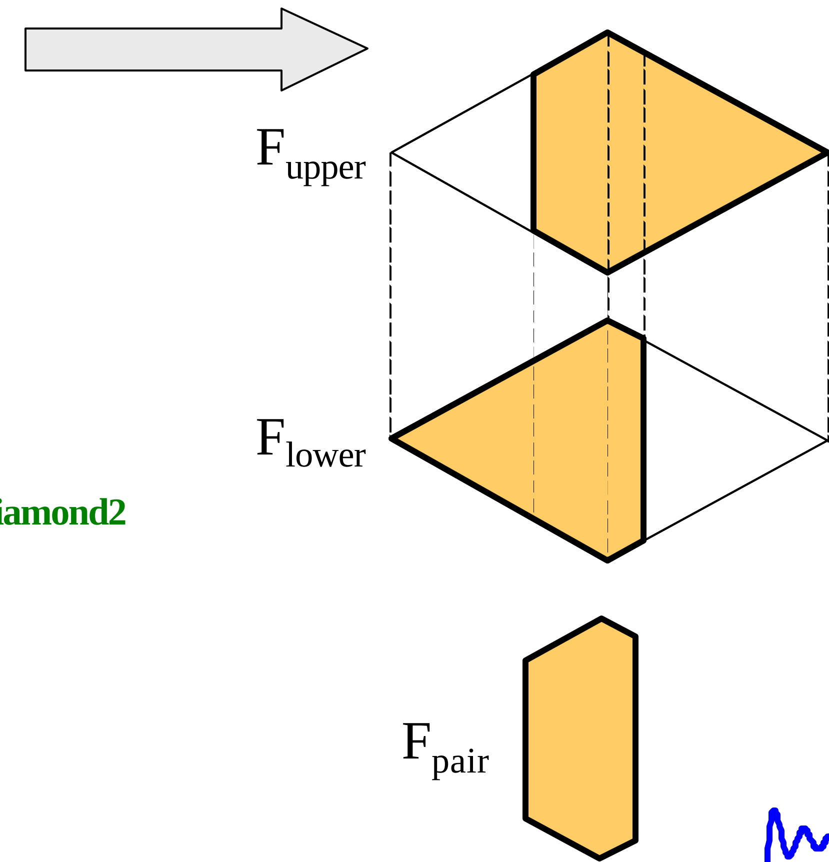
Limitations of Rectangular Uniform Grids



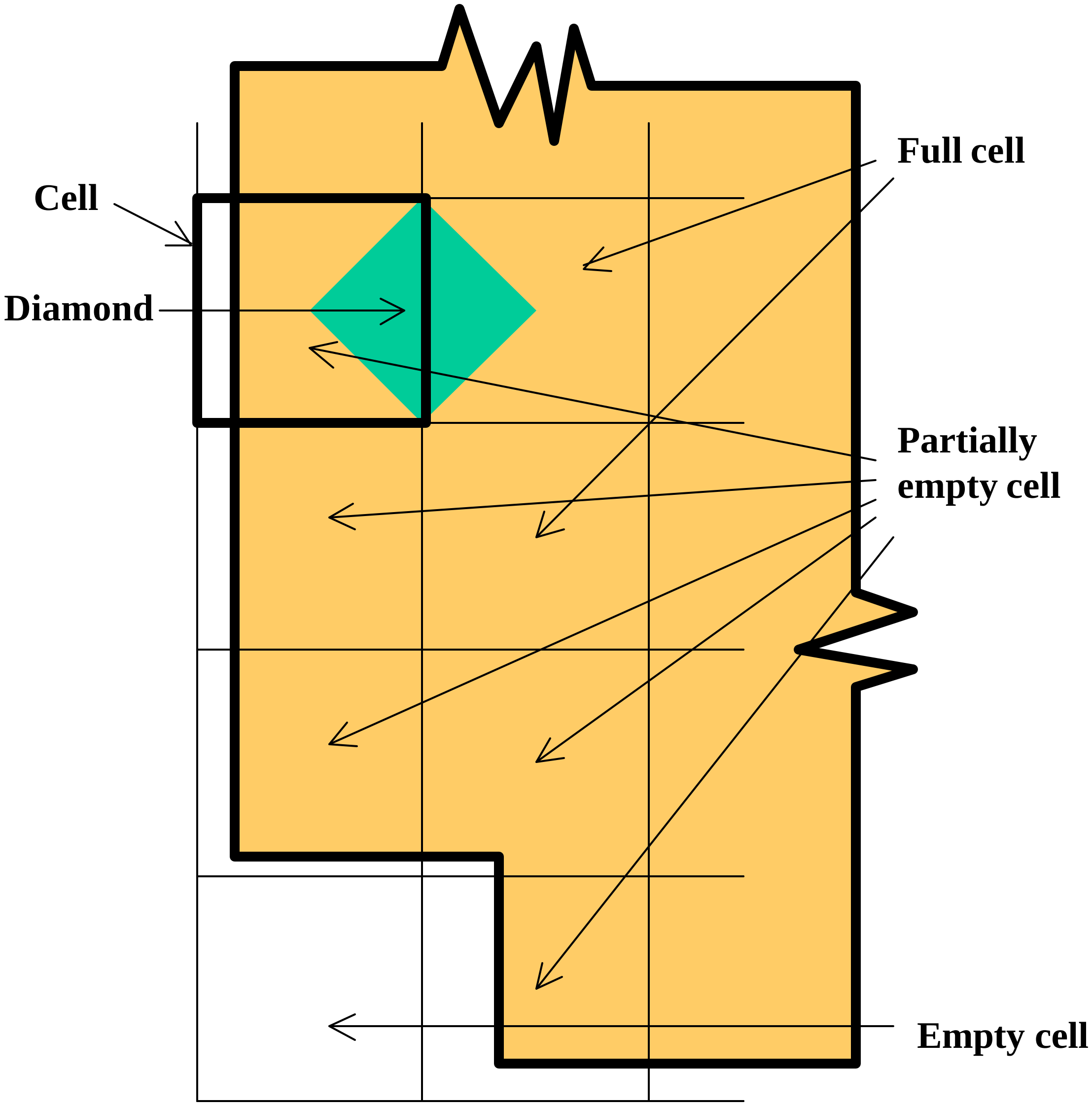
- Many cells may fall outside of shape
- SPICE run-time grows sharply with node numbers
  - Unnecessary nodes increase run time
  - Cant switch to fine mesh in sensitive areas
- Modal resonances may not be captured correctly

Cell and Diamond Definitions

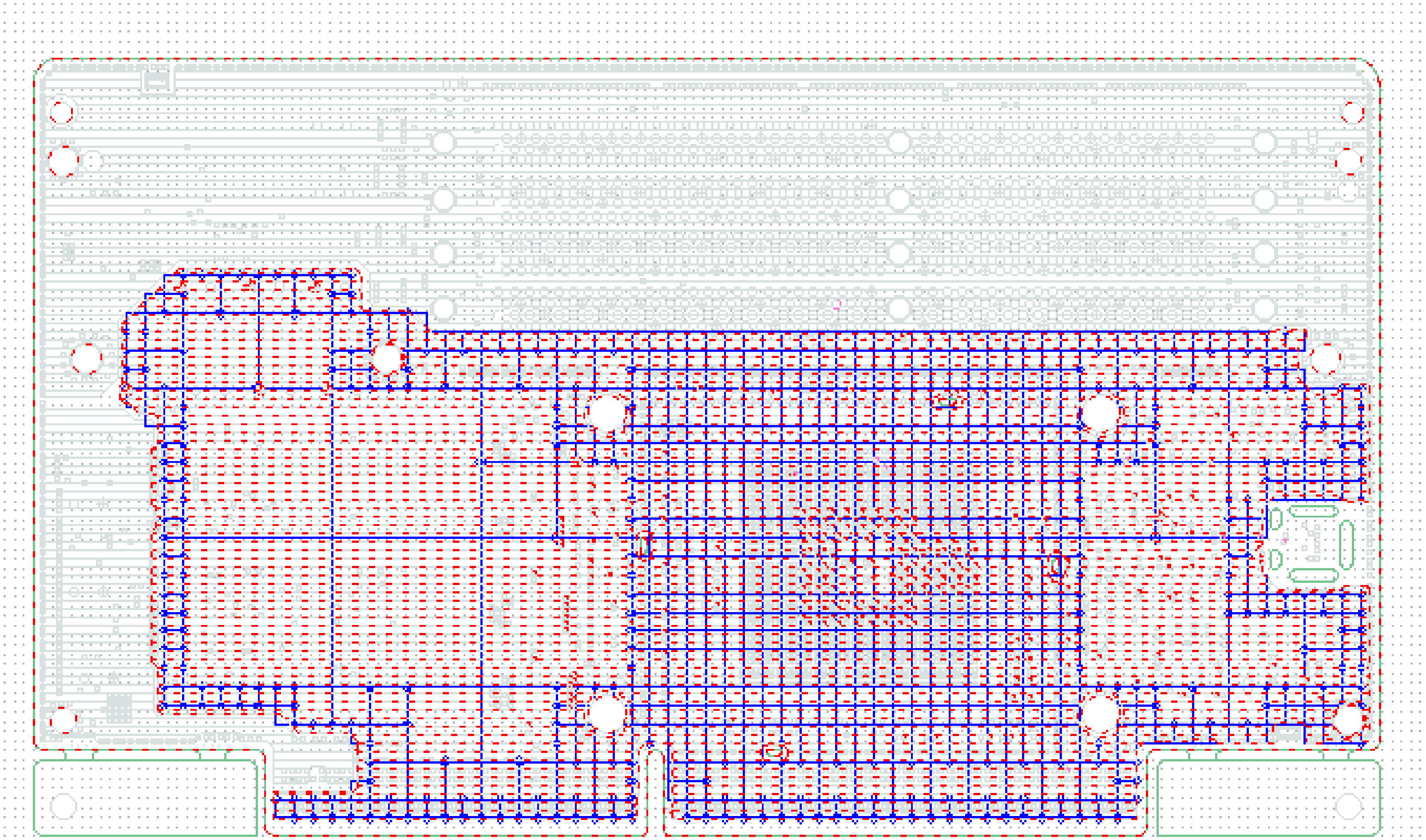




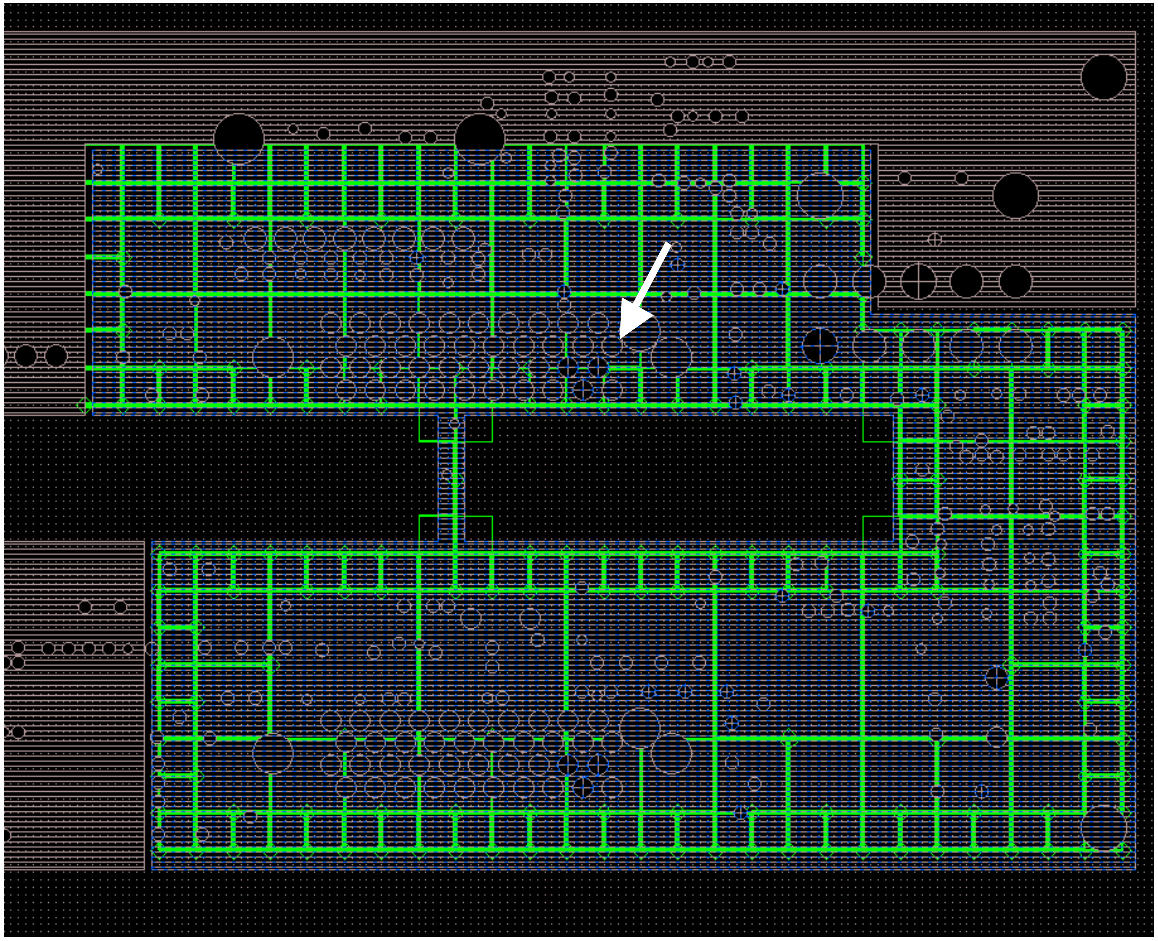
Definitions of Example Shape



Grid with Adaptive Sub Gridding



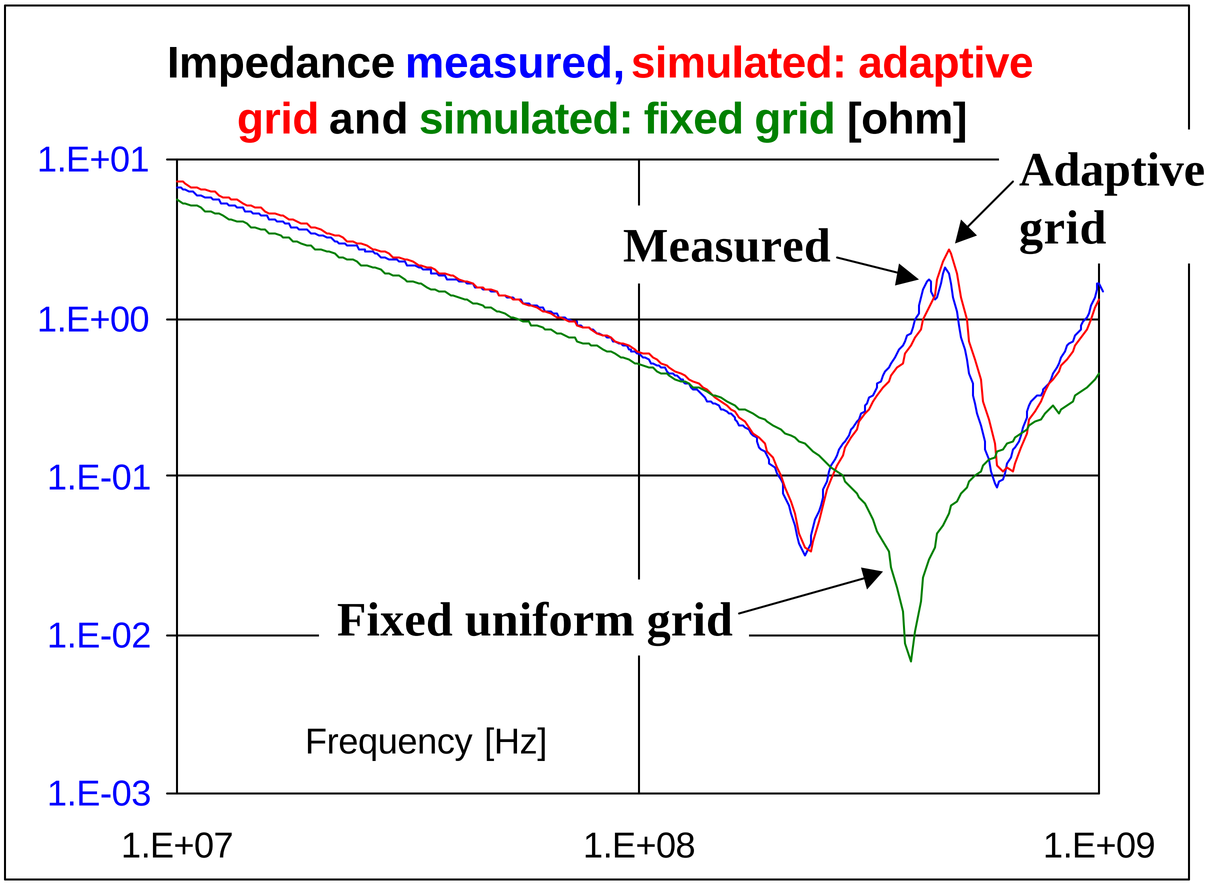
Correlation on Modal Resonances (1)



Example shape from Slide 4:

- Irregular outline
- Cutouts

Correlation on Modal Resonances (2)



Self-impedance at white arrow

Uniform grid:

- Overestimates static capacitance
- Overestimates resonance frequencies

Adaptive grid:

- Good correlation

Acknowledgement

Pre-processor SKILL script was written by Roger Cleghorn, Cadence

SPICE equivalent circuits were created by perl code, written by Ken Laird, North Eastern University

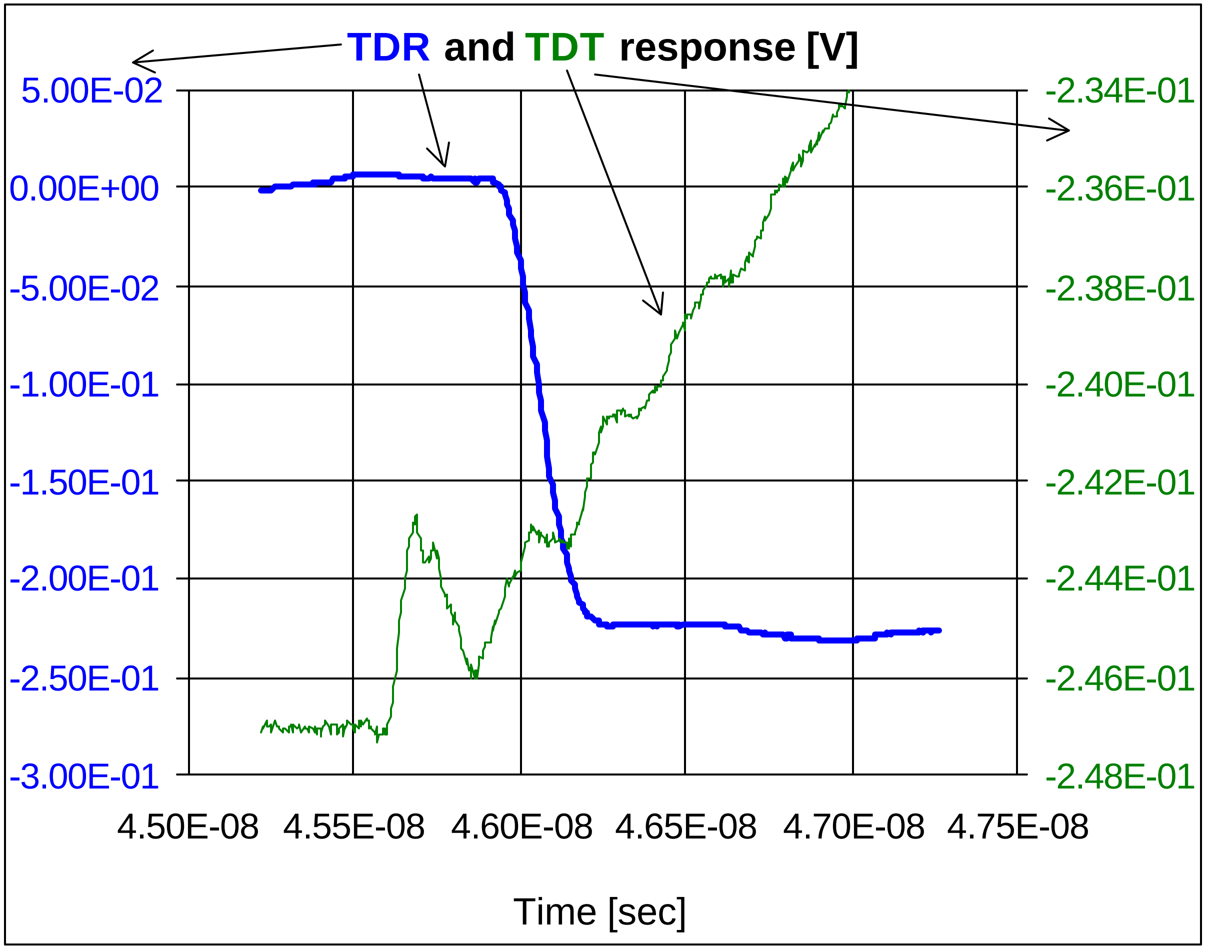
Further contributions and support:

- Hemant Shah (Cadence)
- Nick Laplaca (SUN)
- Deborah Foltz (SUN)
- Paul Baker (SUN)
- Paul Sorkin (SUN)

Conclusions

- Odd shapes, cutouts and perforations change
  - Static capacitance
  - Modal resonances
- Modal resonances do not scale with static capacitance
- Adaptive, non-uniform plane models can
  - Allow for finer mesh in critical areas
  - Capture modal resonances of odd shapes
  - Capture signatures of perforated planes
- Adaptive grid showed good hardware correlation

Correlation on Perforated Plane (1)



1.8”x1.6”x0.002”

Measured in the middle, front/back

Via pair: 20mil drill, 50-mil center-to-center

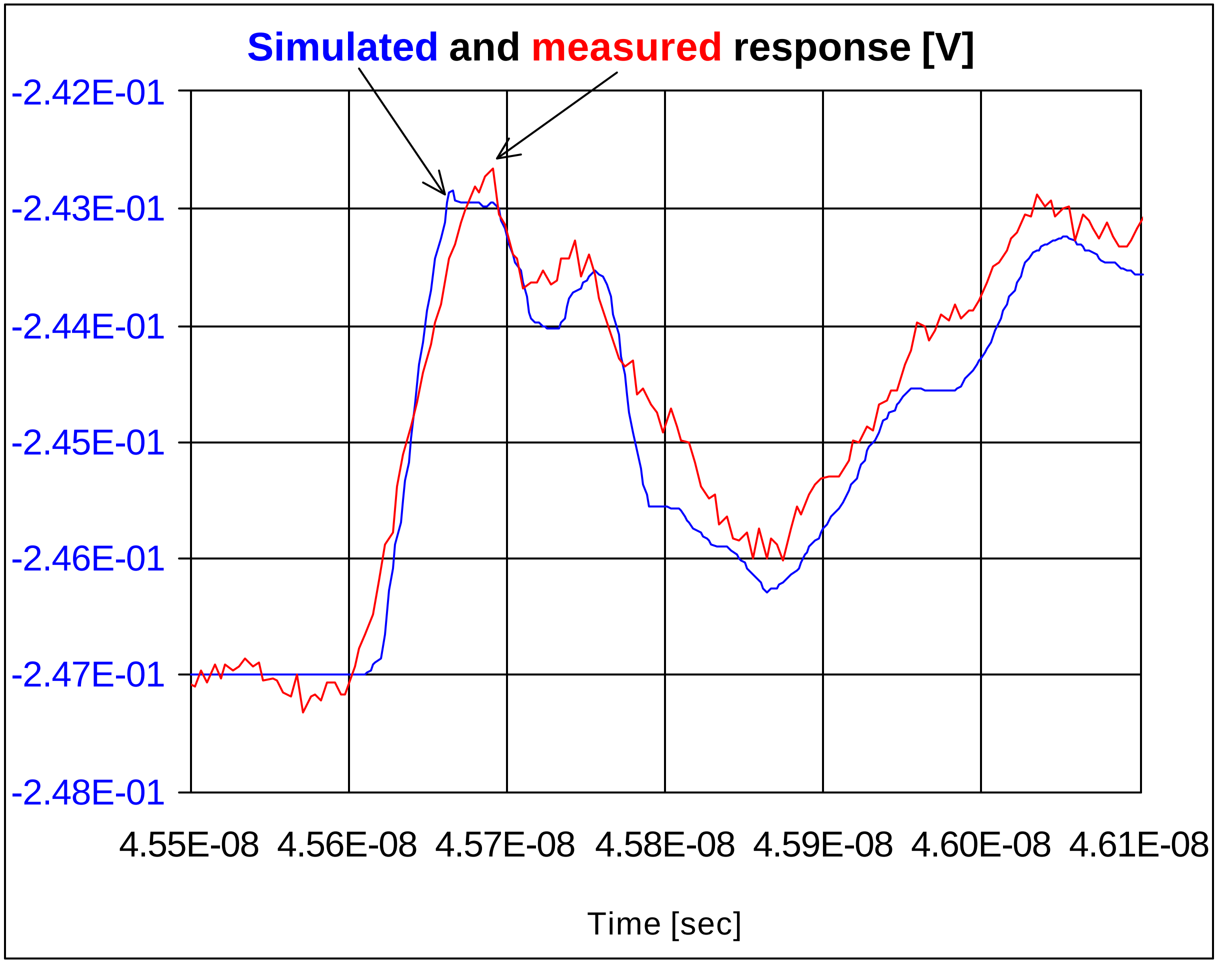
TDR source:

- 150psec
- 50 ohm

TDT input:

- 50 ohm

Correlation on Perforated Plane (2)



Adaptive grid captures accurately:

- Plane perforations
- Edge reflections