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Proper Ground Return Via Placement for 40+ Gbps Signaling

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SPEAKERS

Donald Telian

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Building on over 35 years of SI experience at Intel, Cadence, HP, Donald's focus is helping his customers implement today's highest-speed serial links. He is widely known as the SI designer of the PCI bus and the originator of IBIS modeling and has taught SI techniques to thousands of engineers in more than 15 countries. His new book "Signal Integrity, In Practice" brings fresh articulation to the practice of SI for the decades ahead.

Michael Steinberger

Consultant Software Engineer, MathWorks

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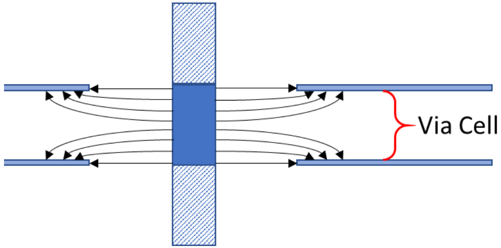
Michael has over 30 years of experience designing very high-speed electronic circuits. Dr. Steinberger holds a Ph.D. from the University of Southern California and has been awarded 14 patents. He was DesignCon2015's Engineer of the Year. He is currently responsible for the behavioral modeling of mixed analog and digital circuits. Before joining MathWorks, Dr. Steinberger was lead architect for high-speed serial channel analysis at SiSoft.

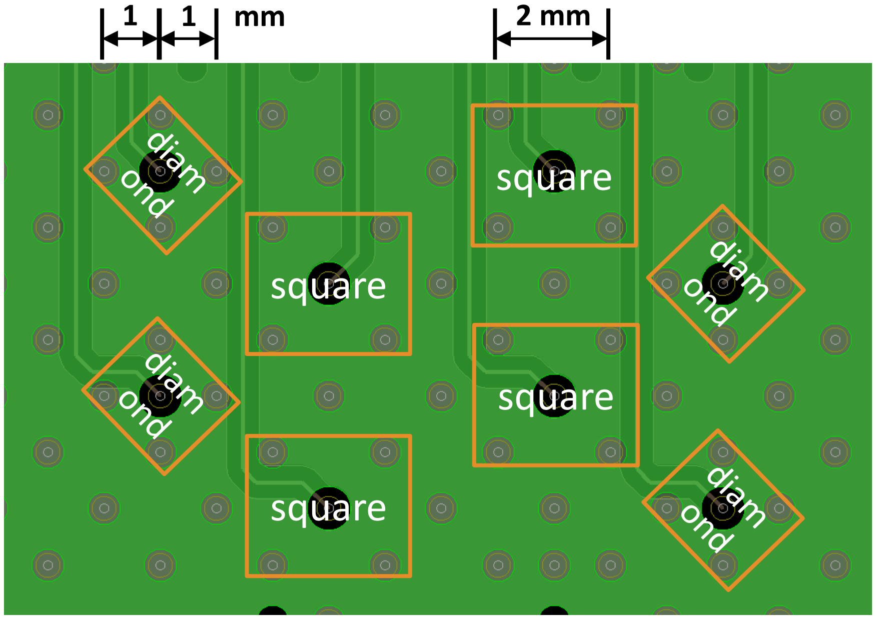
AGENDA: Ground Return Via Placement

- Introduction
- Technical Overview
- Ground Return Vias & Currents
- Computation & Measurement
- Summary



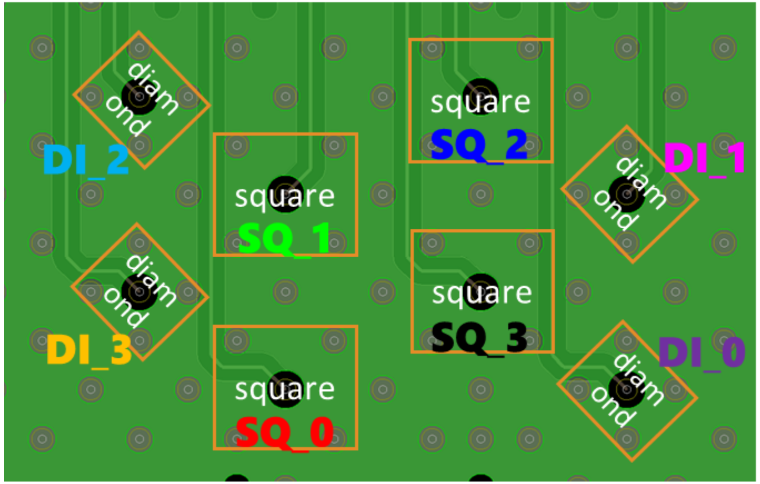
Ground Return Vias (GRVs) & Test PCB

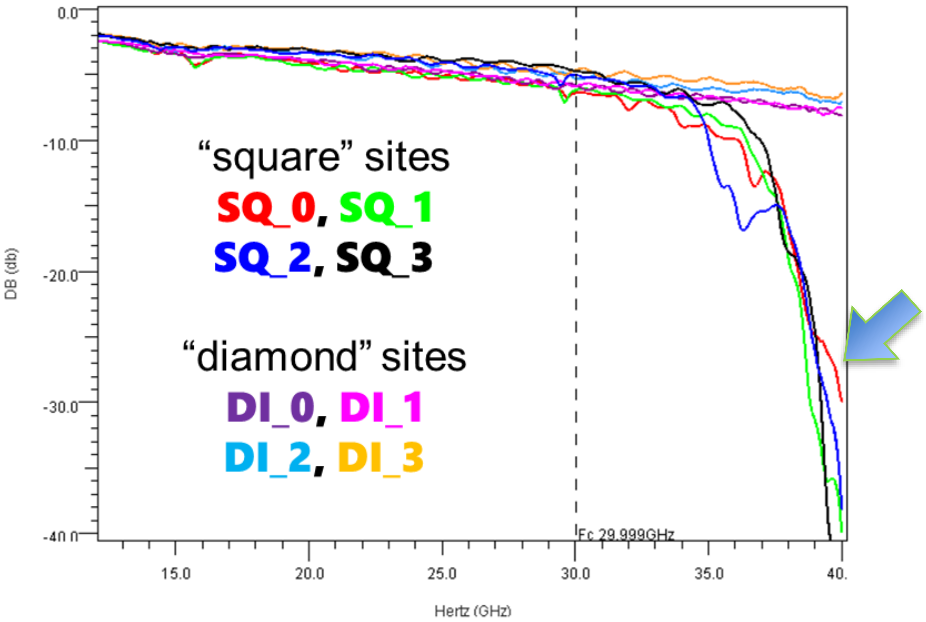
- **8 signals within GND grid**
  - Single ended
- **1mm pitch BGA**
- **GRVs on 2mm grid**
- **4 signals in “square” grid**
- **4 signals in “diamond” grid**
- **GRVs closer in “diamond”**



Are these GRVs sufficient? …if so, up to what frequency?

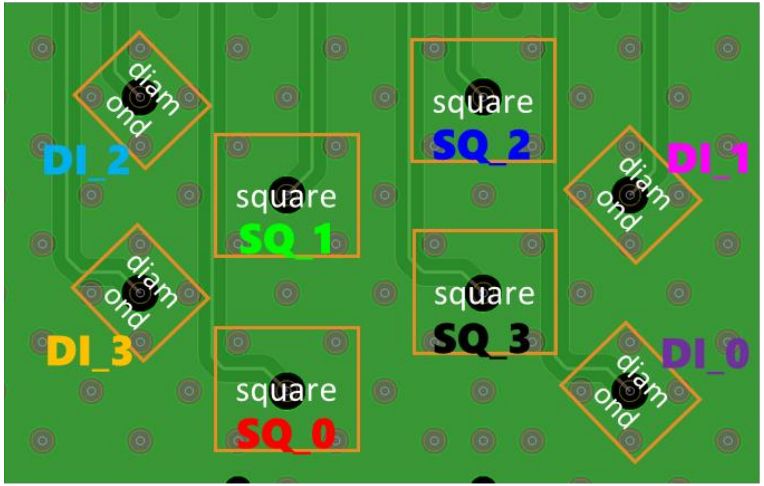
“Square” Insertion Loss Drops to -40 dB

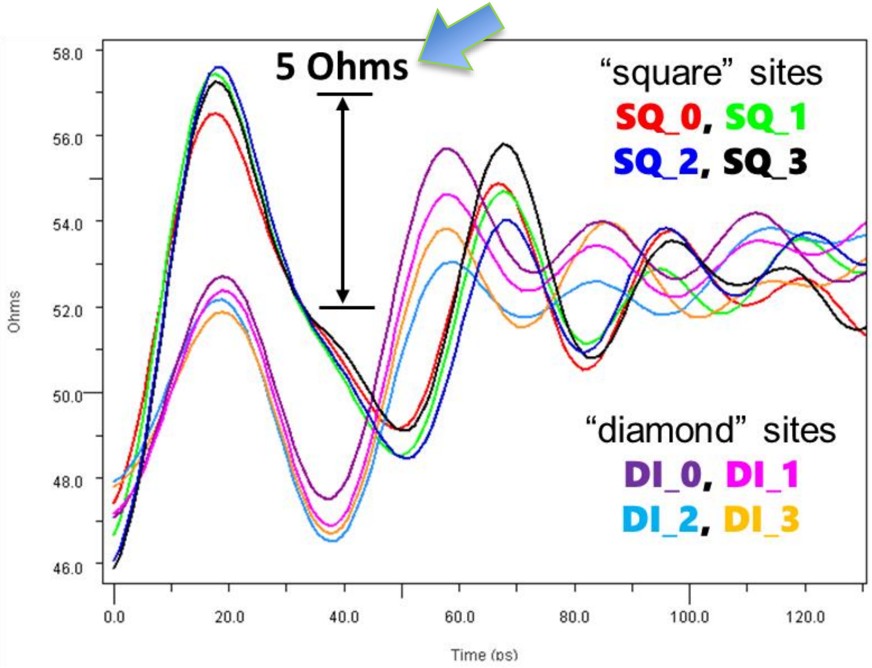




- **99% of “square” signals lost at 40 GHz – 100 mil via IL greater than 15” trace**
  - “Diamond” remains linear, to measurement limit
- **Only difference is GRV configuration. What is happening??**

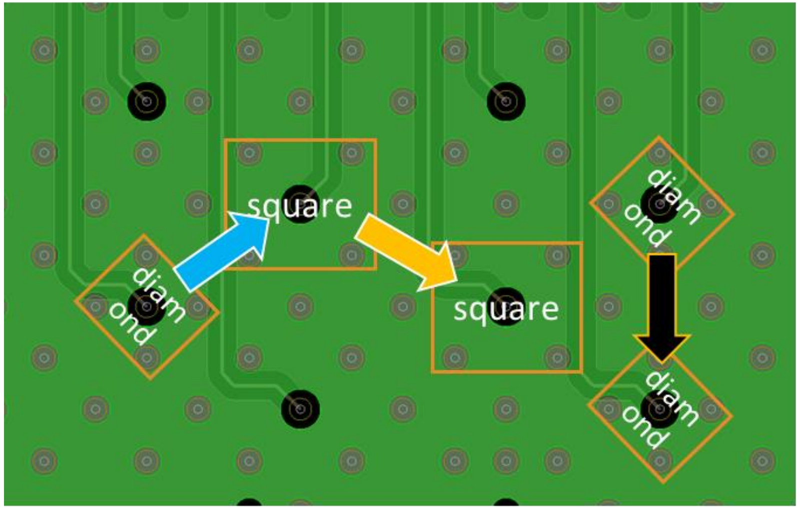
“Square” = Unexpected Discontinuity

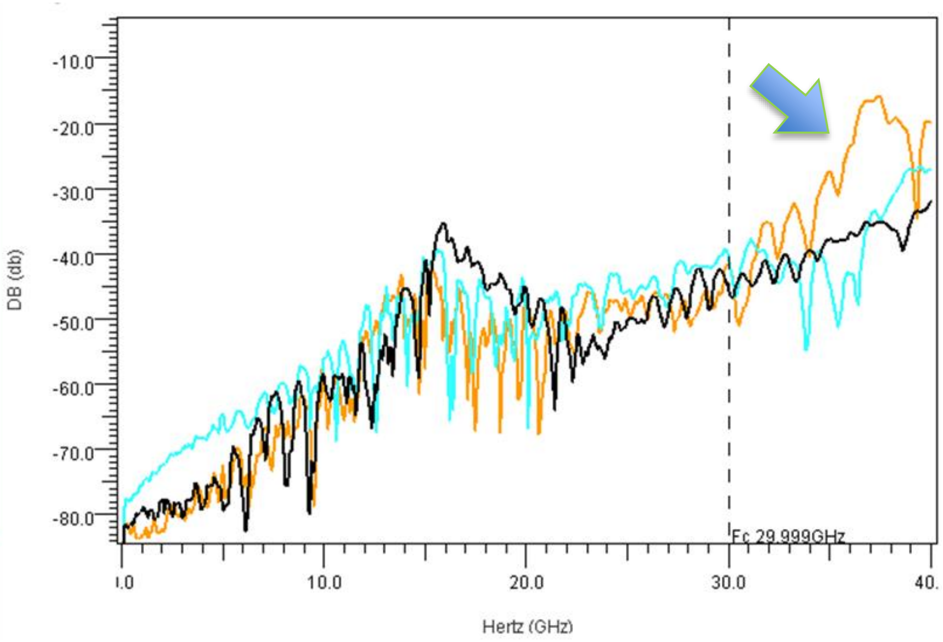




- **50 Ohm signal via misses by 5 Ohms, due to GRV config**

Crosstalk Tracks with GRV Config





- **Significant high-freq crosstalk, though all vias 140+ mils center-to-center**

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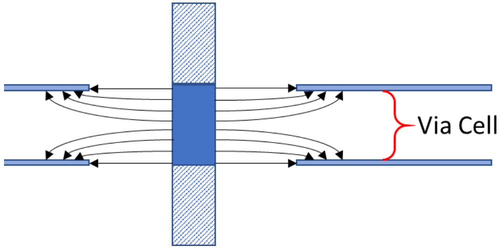
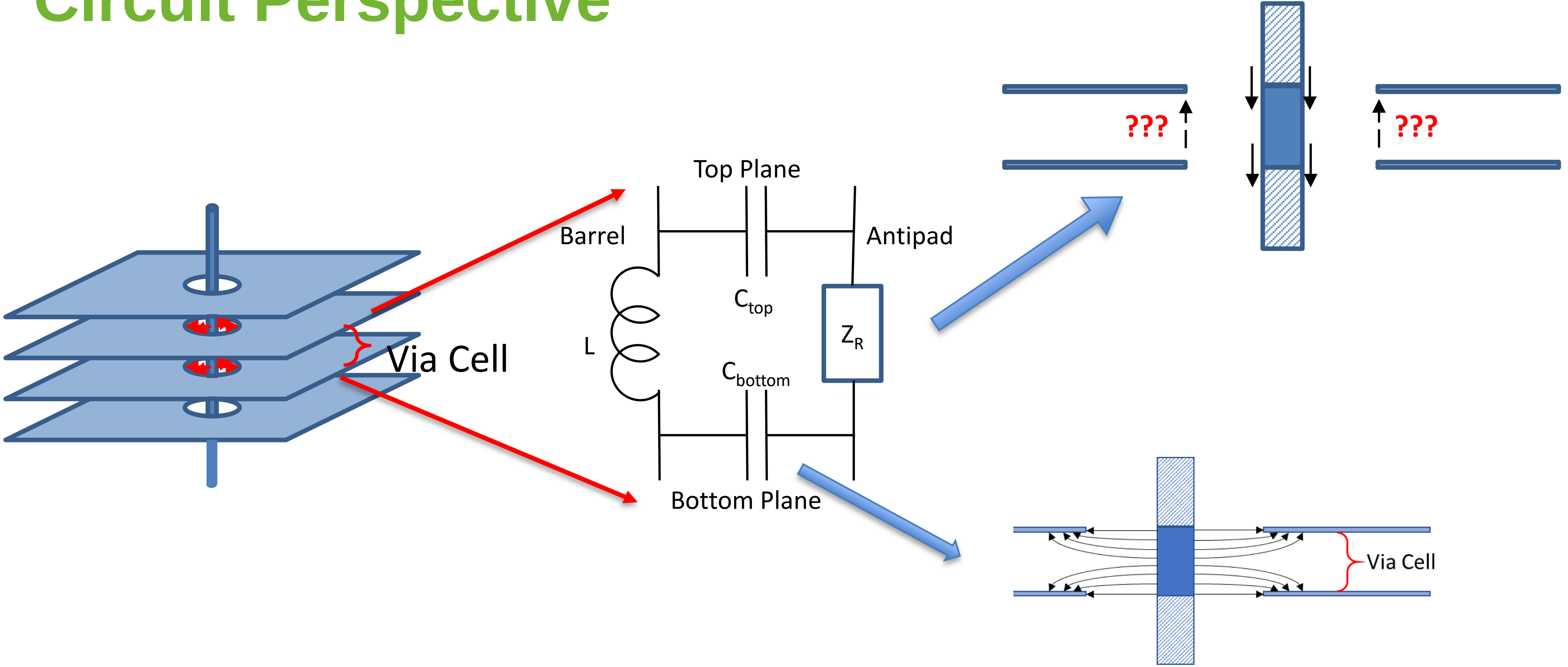
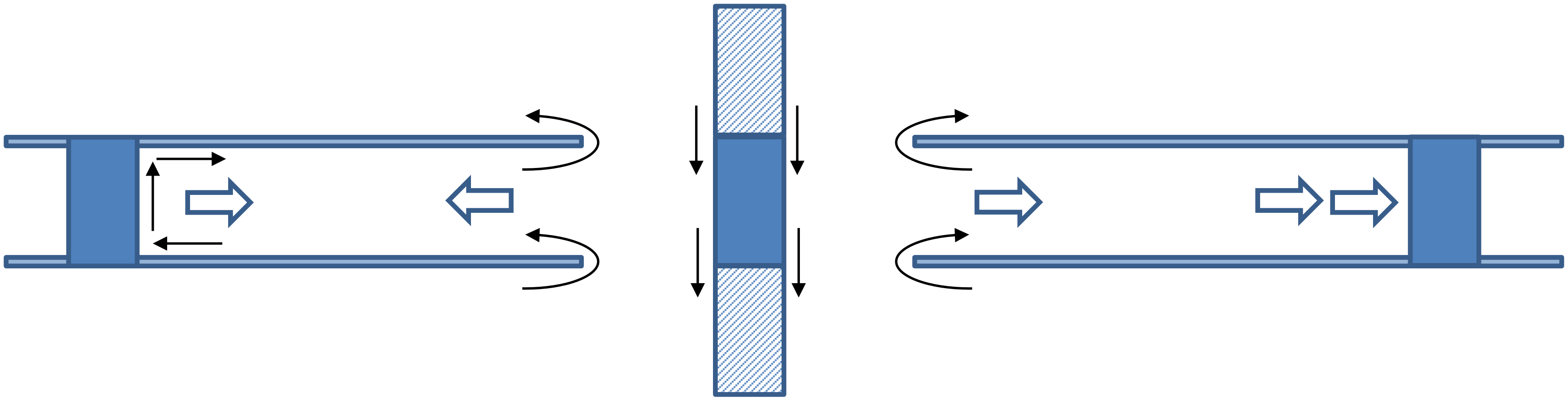


Circuit Perspective



How Return Current Gets from Here to There



$$E_Z = AH_0^{(2)}(kr)$$

$$H_\phi = \frac{j}{\eta} AH_1^{(2)}(kr)$$

$$V = -E_z d$$

$$I = 2\pi r H_\phi$$

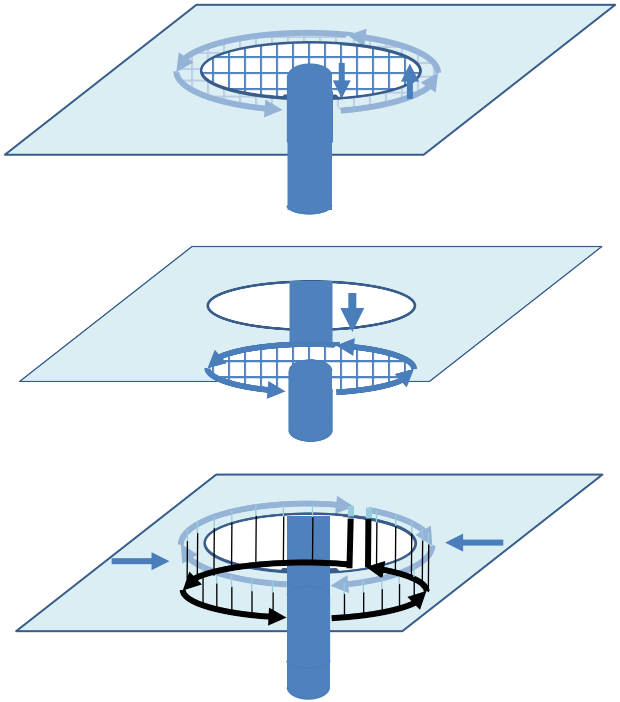
$$Z = \frac{jd\eta}{2\pi r} \frac{H_0^{(2)}(kr_a)}{H_1^{(2)}(kr_a)}$$

$$P(j,k) = \frac{H_0^{(2)}(kR_{jk})}{H_0^{(2)}(kr_k)} \quad j \neq k,$$
$$= 0 \ otherwise$$

$$\Gamma(j,j) = -1 \quad j > n,$$
$$= 0 \ otherwise$$

$$\mathcal{V}_{return} = (I + P)(I - \Gamma P)^{-1} Z\mathcal{I} \equiv Z_{return}\mathcal{I}$$

Contour Conclusions



- Zero total current passing through the antipad.
- Return current at edge of antipad exactly balances barrel current.

- Between the top and bottom planes, the magnetic field at the edge of the antipad can be determined from the barrel current.

- The magnetic field at the edge of the antipad can equally be determined from the return current in the top or bottom plane.

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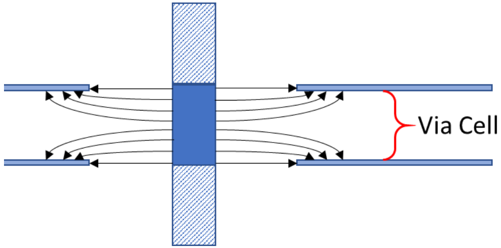
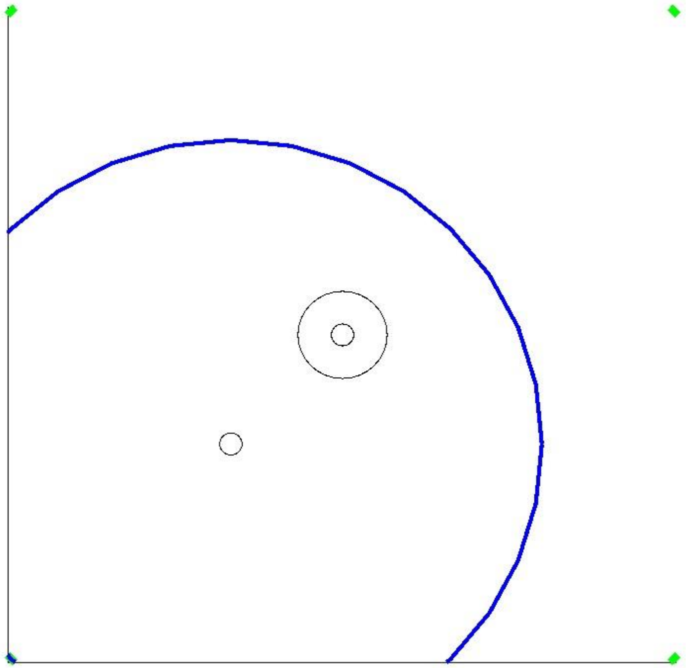
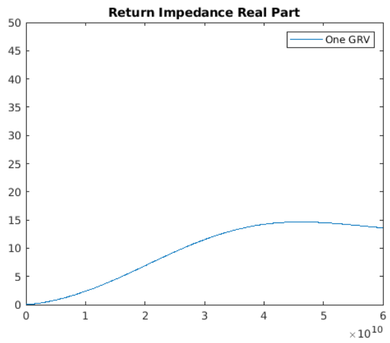
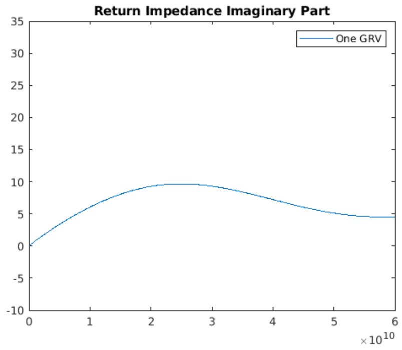
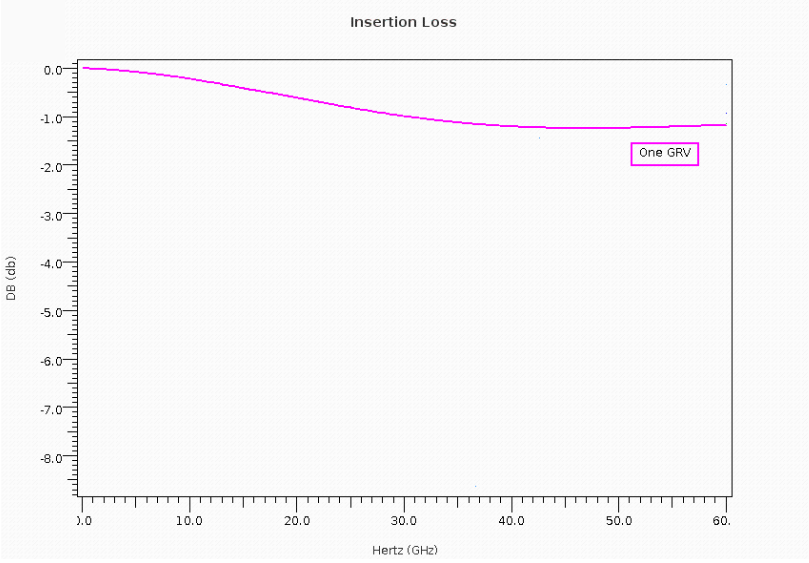


Interaction with Single GRV

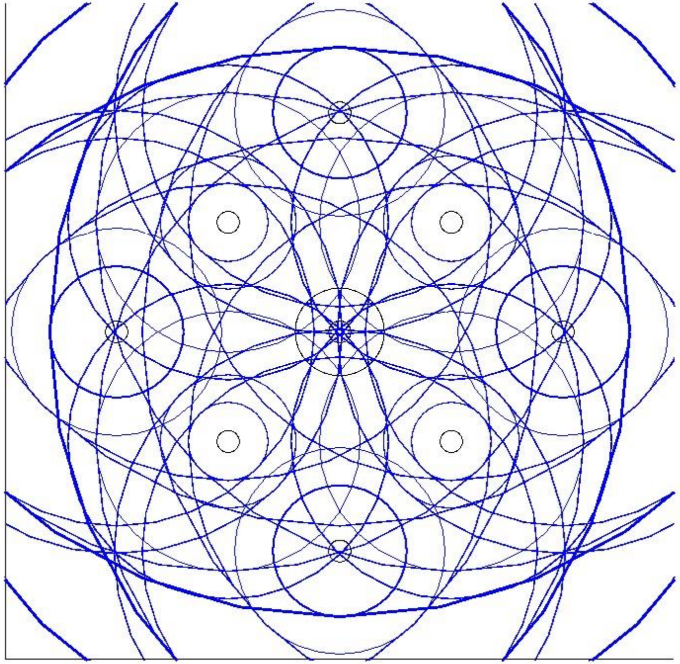


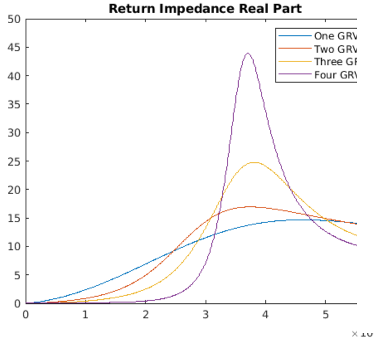


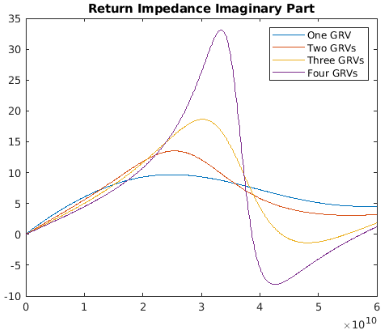


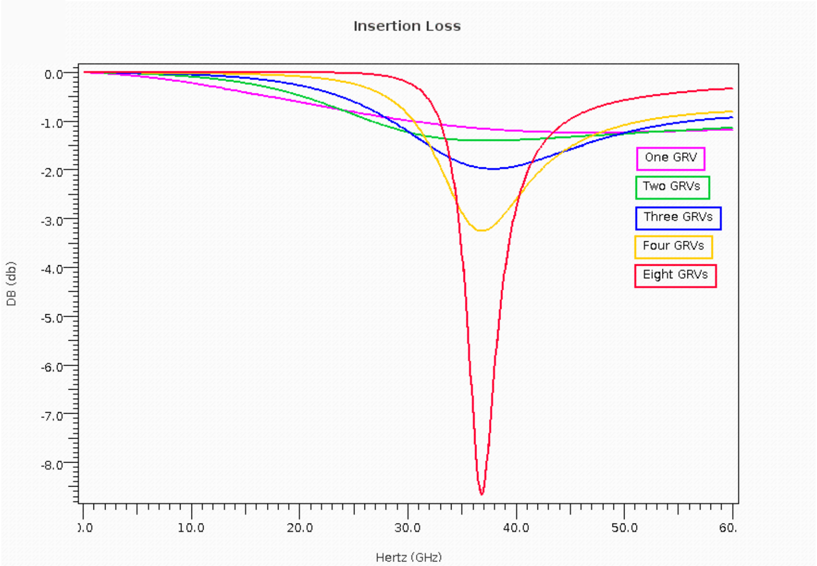


Interaction with Multiple GRVs

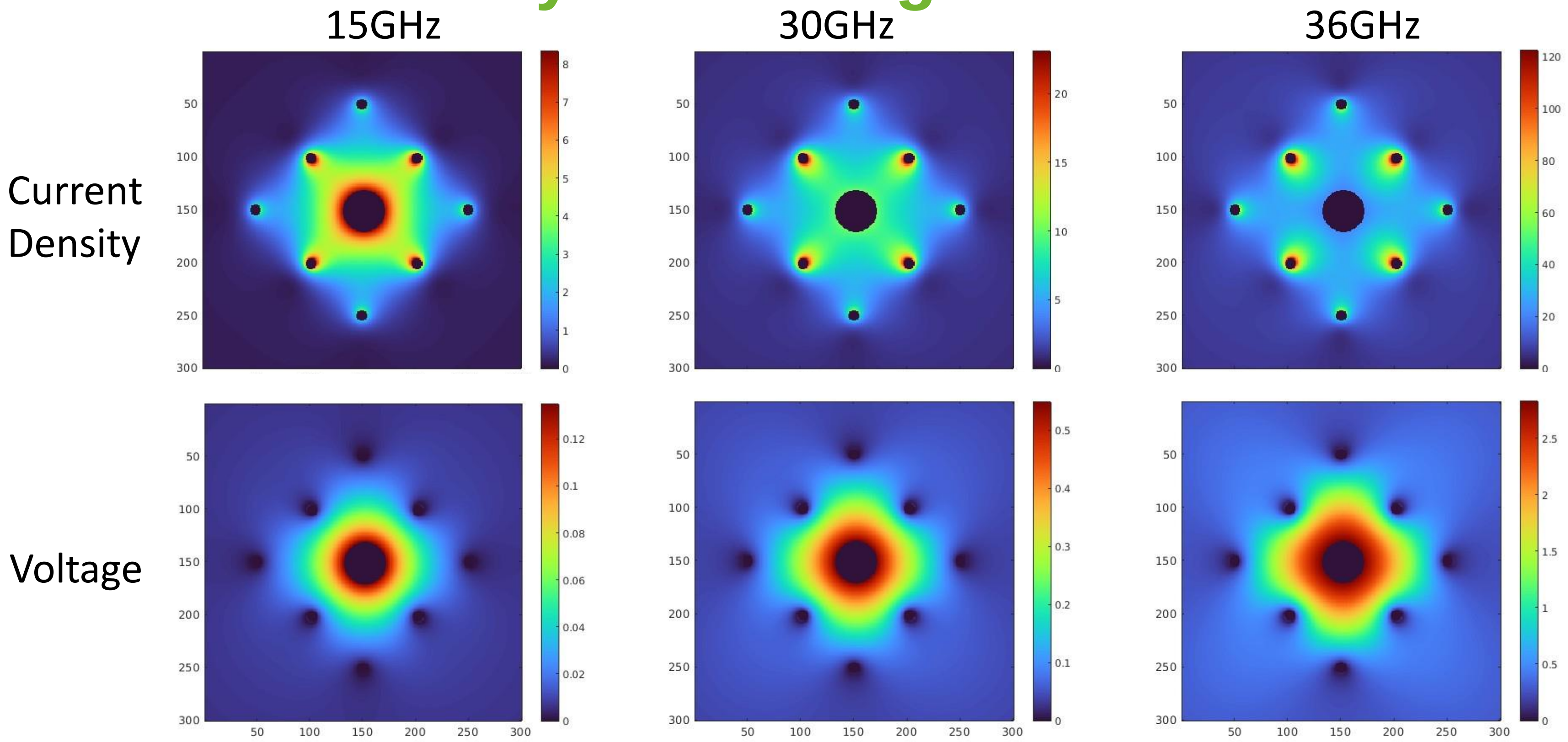




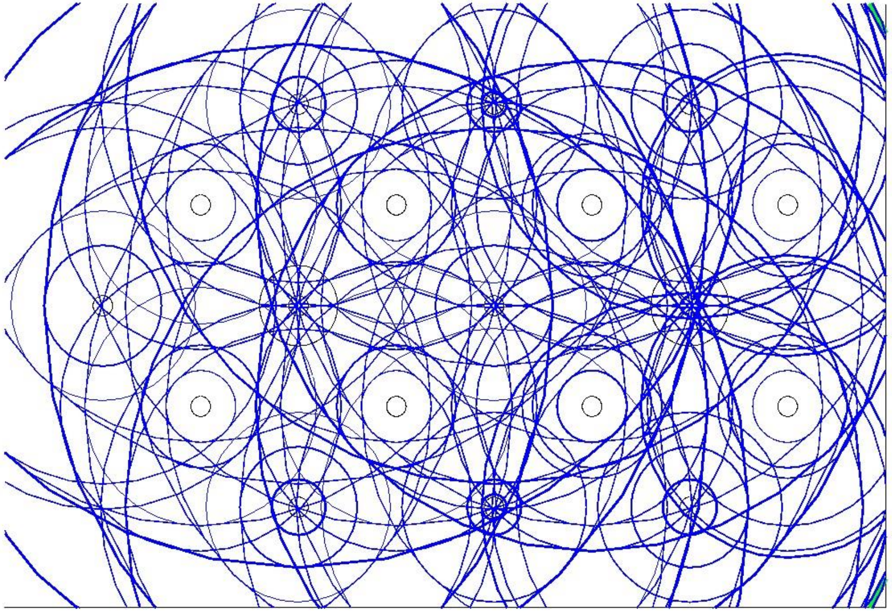




Current Density and Voltage



Crosstalk Signal Propagation



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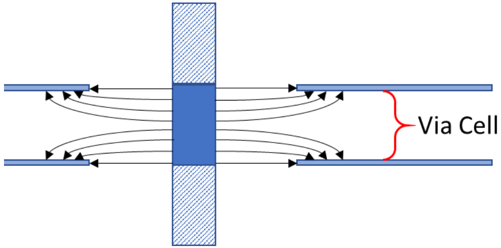
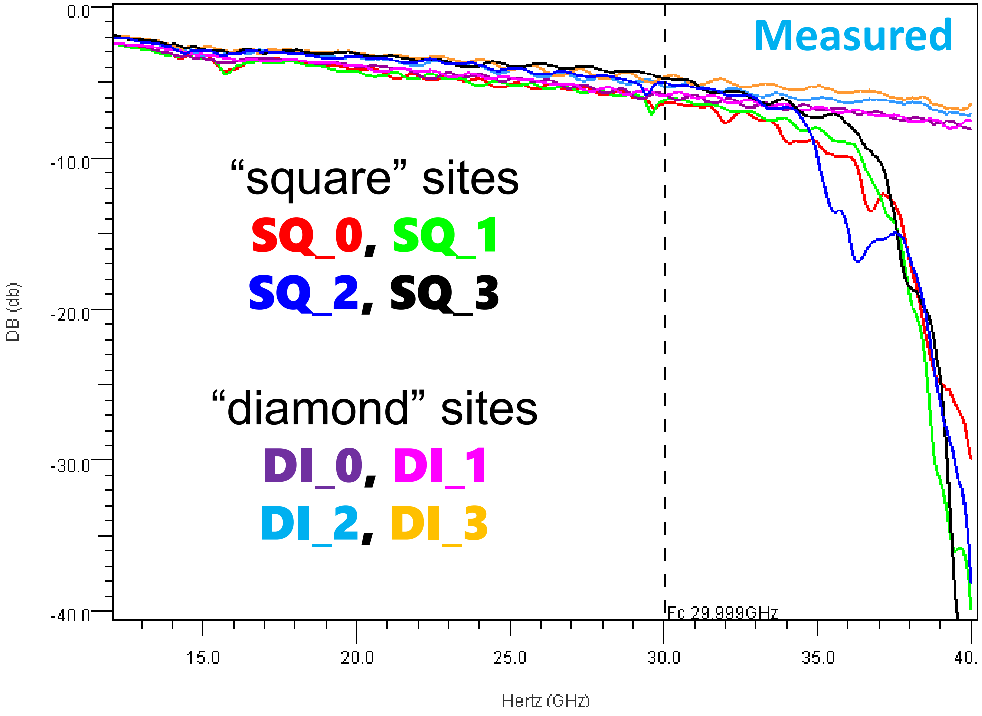
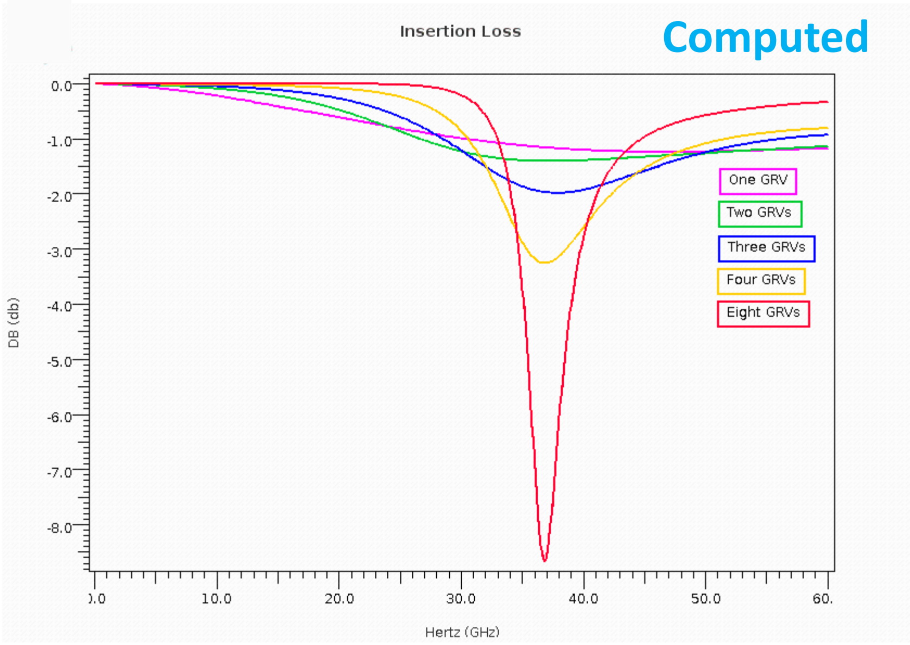


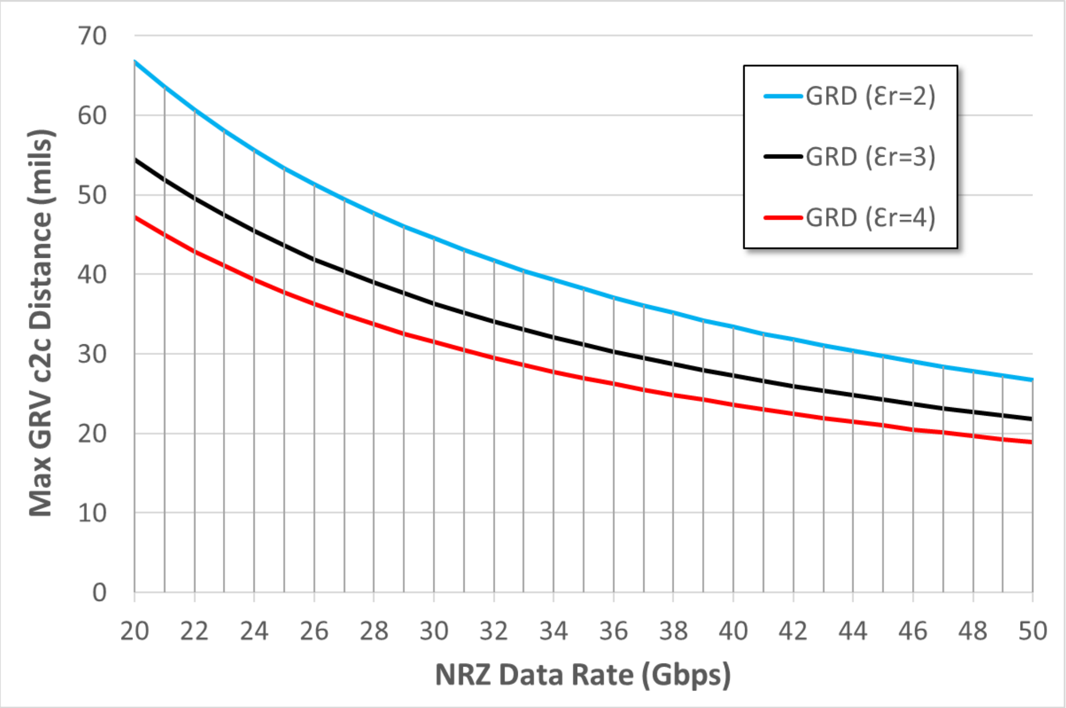
Meas/Comp Correlation: Insertion Loss



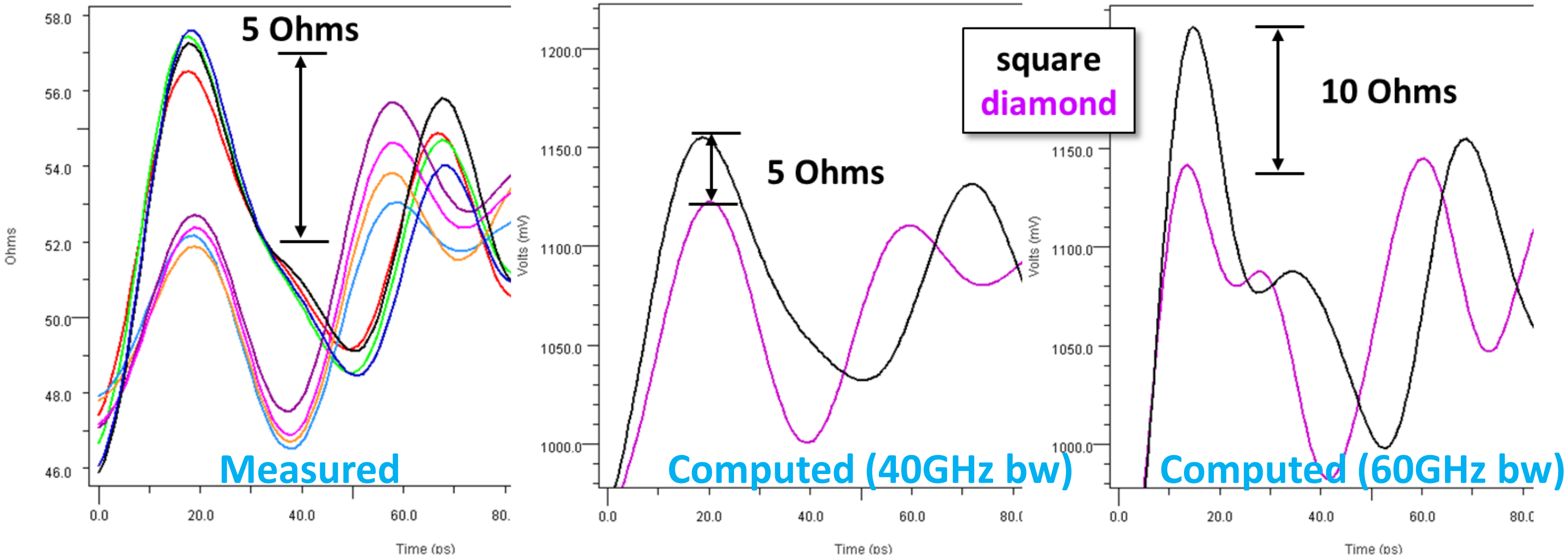


Do Not Place GRVs Beyond Gap-Rate Distance

- **Paper defines "*CW*" (Critical Wavelength) for resonance**
- **Math converts *CW* to Gap-Rate Distance (GRD)**
  - With guard bands
  - Dependent on dielectric
- **Directly apply to GRV placement**
  - Or, adapt math / plot to your variables

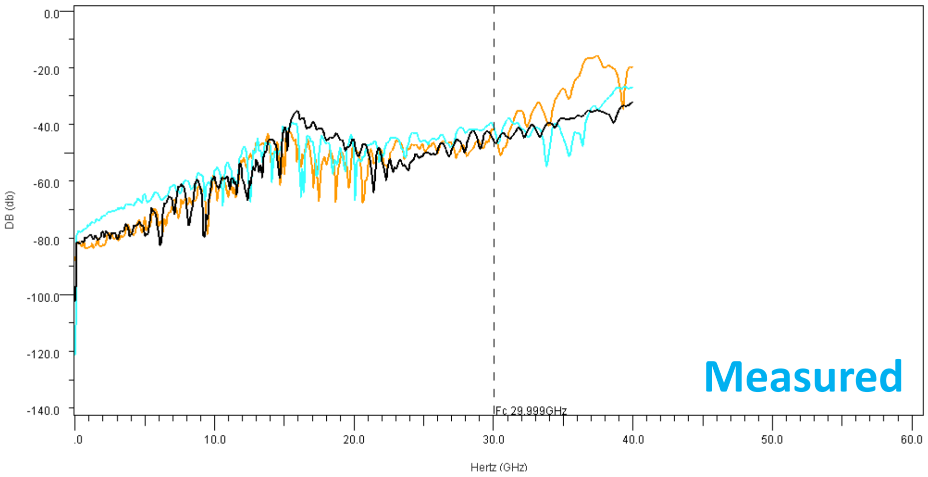


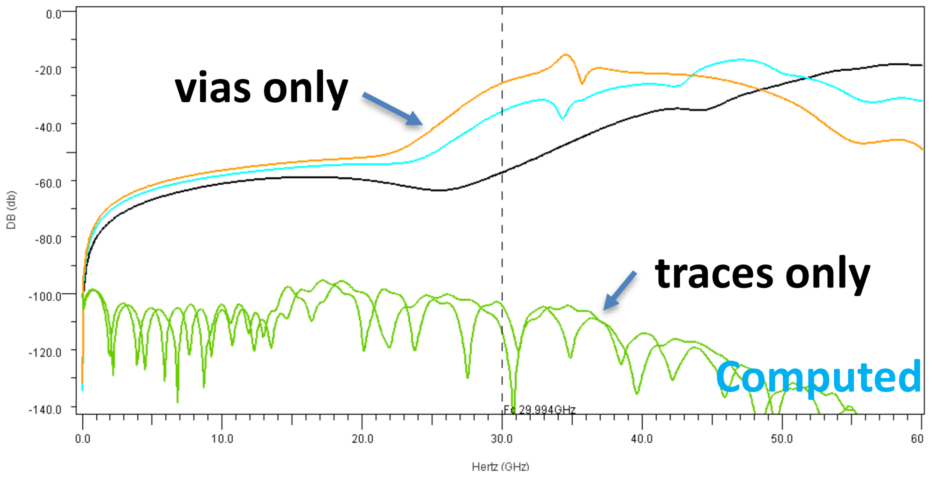
Meas/Comp Correlation: Impedance / TDR



- **Math agrees – with caution for higher-frequencies**

Meas/Comp Correlation: Crosstalk





- **Via crosstalk is GRV-dependent and dominate phenomenon, although…**
- **Vias compared to traces are 20x shorter with more than 2x separation**
- **Implications for higher data rates, watch this space**

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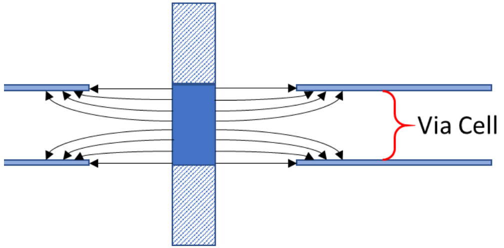

Summary / Conclusions

- **Measurement, math, and computation agree: GRV placement and configuration is critical beyond 20 GHz**
- **GRV return currents interfere constructively, forming resonant cavities with high Q**
- **High Q means GRVs can provide a nearly ideal return path OR adversely impact signal performance**
    - As such, it is imperative to know where resonance occurs *and avoid it using GRD*
- **Crosstalk between vias becomes significant beyond 20 GHz, even when separated by substantial distance**
    - And is a function of GRV placement and return current interactions

MORE INFORMATION

- Much more in Paper
- MathWorks.com, SiGuys.com
- References at right →
- msteinb@mathworks.com telian@siguys.com

References

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Thank you!

QUESTIONS?