Predicting and Correcting Board-Level Signal Integrity Problems in High Data Rate Digital Systems

Ansoft Design Forum

June 2002

Agenda

- Description of the Signal Integrity problems.
- Simulating the effects.
- Strategies for mitigating the effects.
- Predicting the system-level performance.
- Summary.

Power and Groundplane Resonances

- What are they?
  - Electromagnetic standing waves set up in the dielectrics between the conducting planes.
- Why should we worry?
  - They cause non-local coupling.
  - Strongly frequency dependent.
- How can we handle them?
  - Using Full-Wave electromagnetic analysis……
  - SIwave and HFSS.

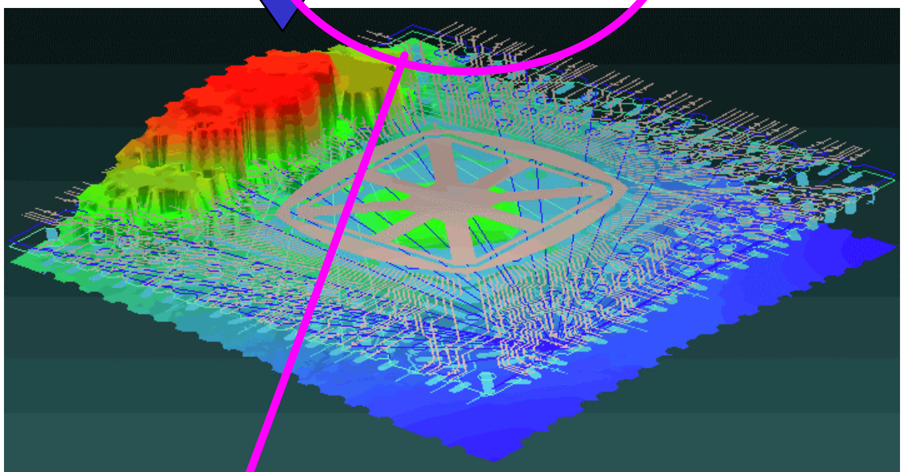
Modelling BGA Board Resonances and Quantifying Decoupling Strategies

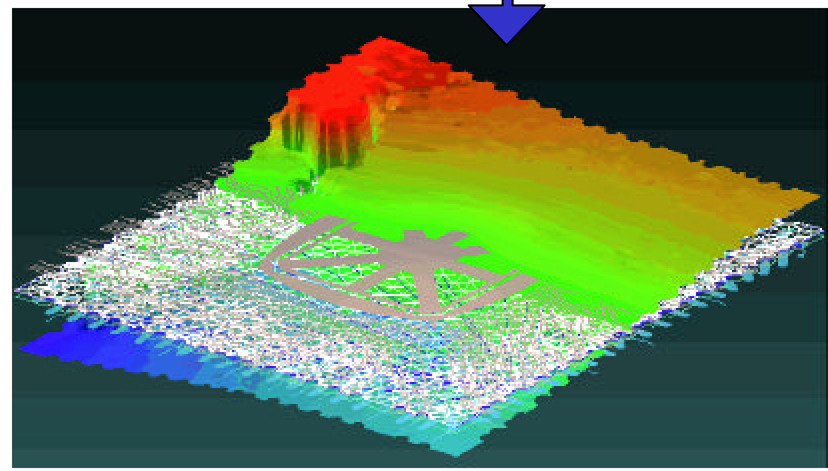
- Full model of a BGA board, translated by AnsoftLinks from Cadence APD.
- SIwave analyses resonant frequencies and modal shapes.
- Decoupling capacitors placed interactively and system re-simulated.

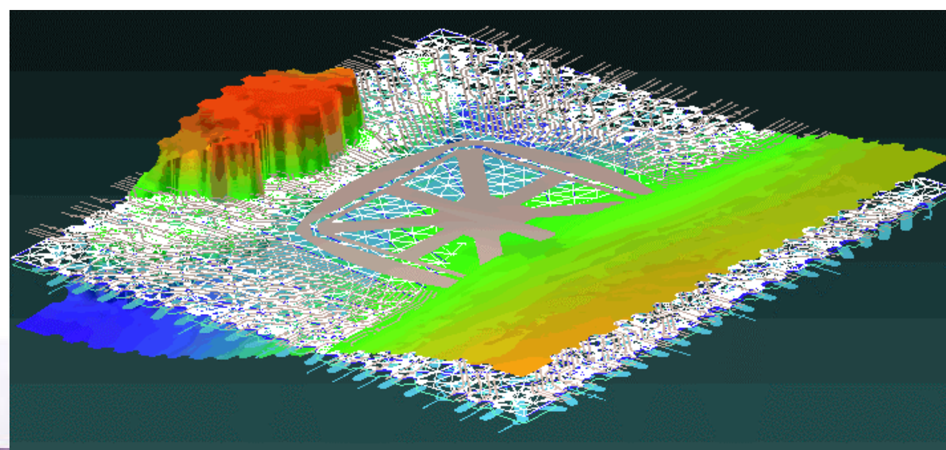
Power/Ground Resonances

Resonant Modes

Re. Freq (GHz)	Im. Freq (GHz)	k	Wavelength (m)
2.319178636	0.019977656	48.60639000	0.129266652
2.762208531	0.022483041	57.89161000	0.108533608
3.558985002	0.028734830	74.59081000	0.084235381





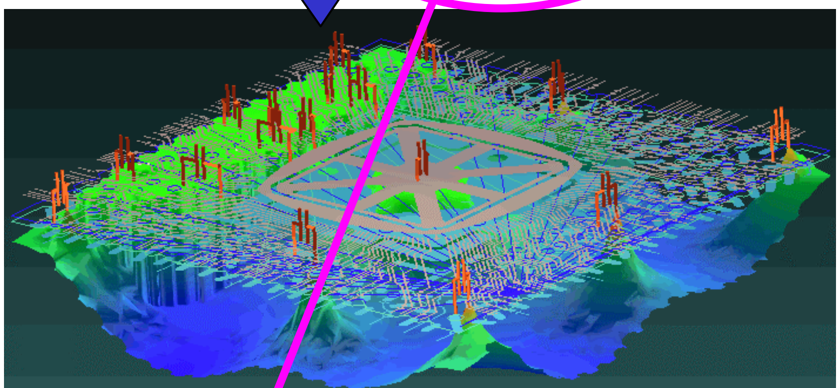


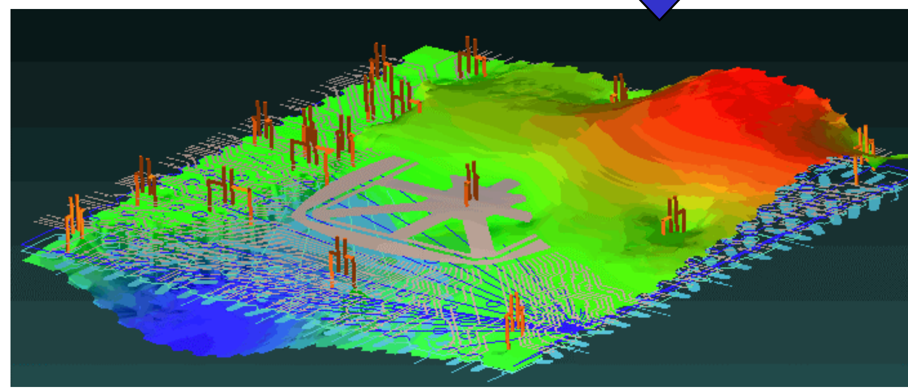
Note frequency range

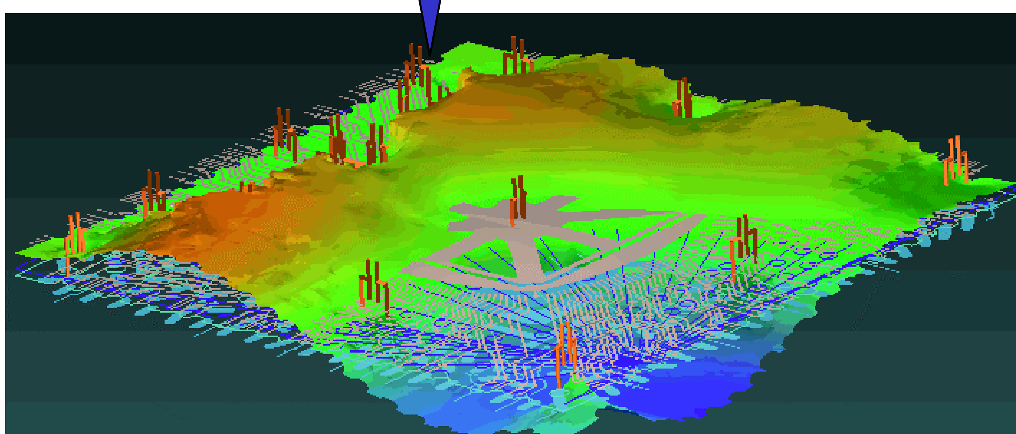
Decoupling Capacitors Added

Resonant Modes

Re. Freq (GHz)	Im. Freq (GHz)	k	Wavelength (m)
4.247993008	0.034713793	89.03135000	0.070572729
4.692164209	0.037825497	98.34049000	0.063892150
5.247348866	0.042215898	109.97630000	0.057132176







Note higher frequency range (factor of 2)

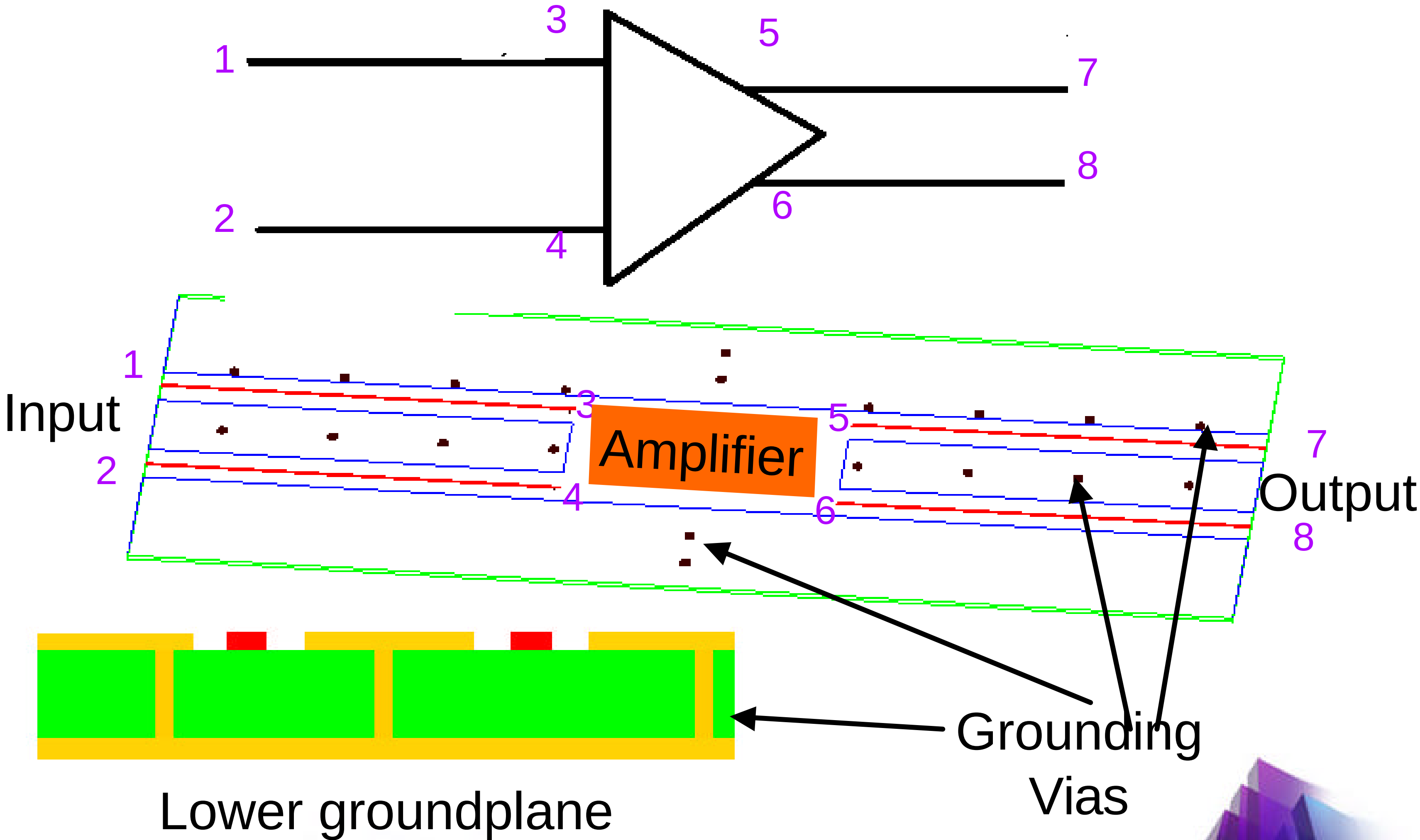
Interactive Placement of Capacitors and Damping Resistors

- SIwave assumes E field in resonant modes is Z-directed: a good approximation up to several hundred GHz.
- Allows us to use a Scalar formulation: much faster than a full 3D analysis.
- So can place components interactively.
- Allows designers to develop cost-effective decoupling arrangements.

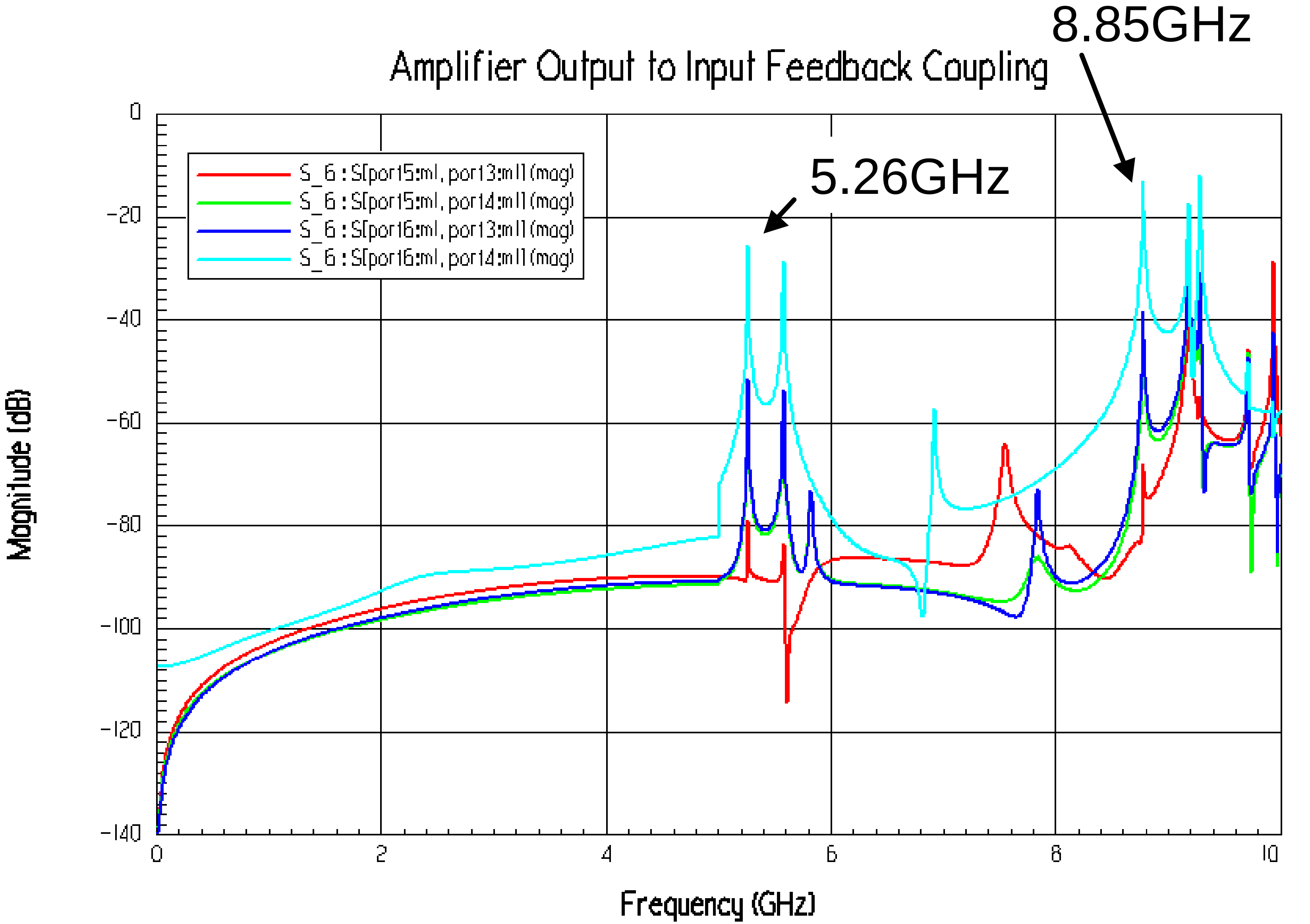
Optical Transceiver Amplifier

- Simplified geometry.
- Actual board layout is confidential.
- Simple example is faithful to the impedances and frequency ranges: it shows all the effects without putting me in court!

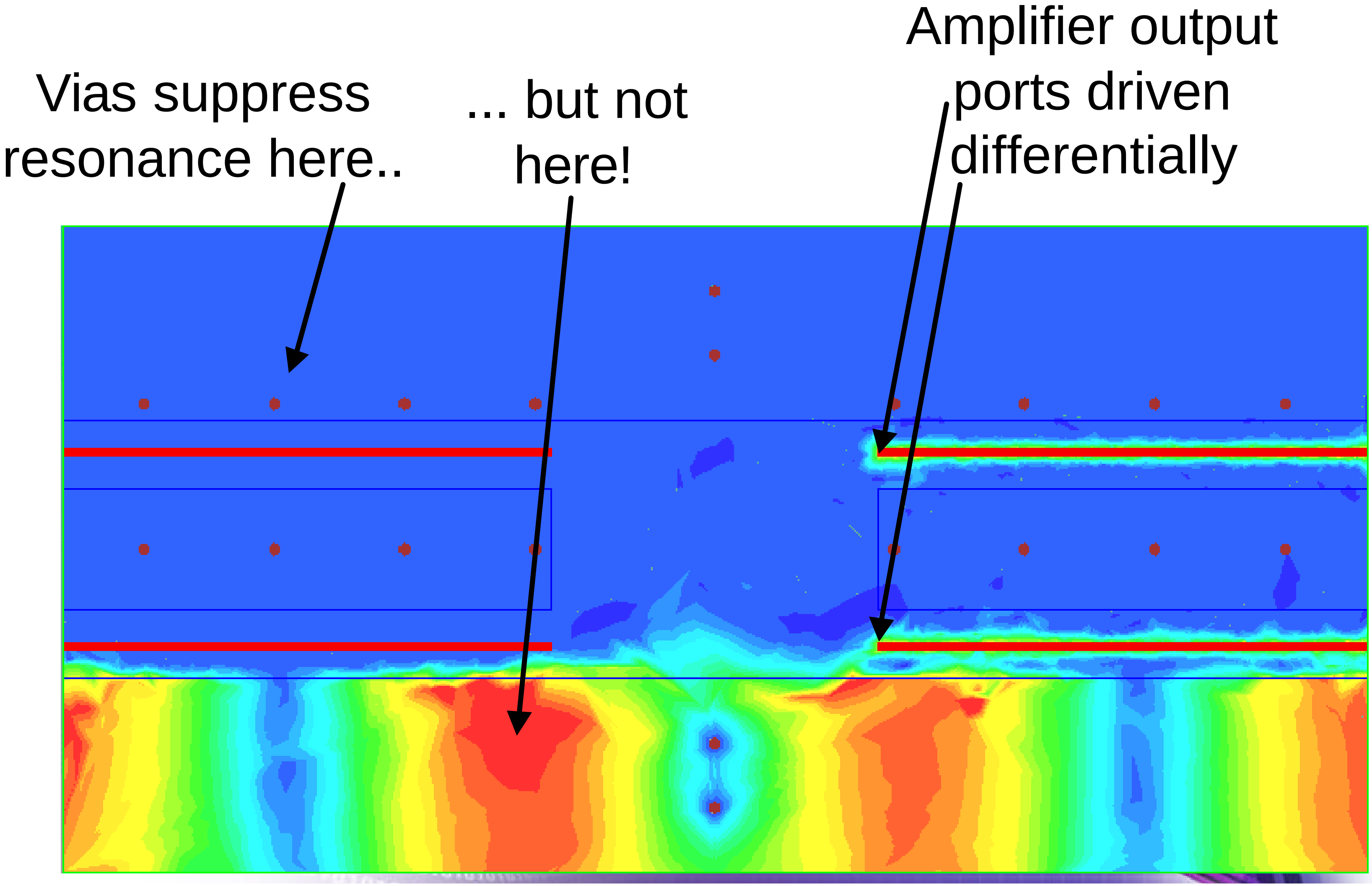
Simplified PCB Model Illustrating Resonance Effects



Coupling from Amplifier Output to Input

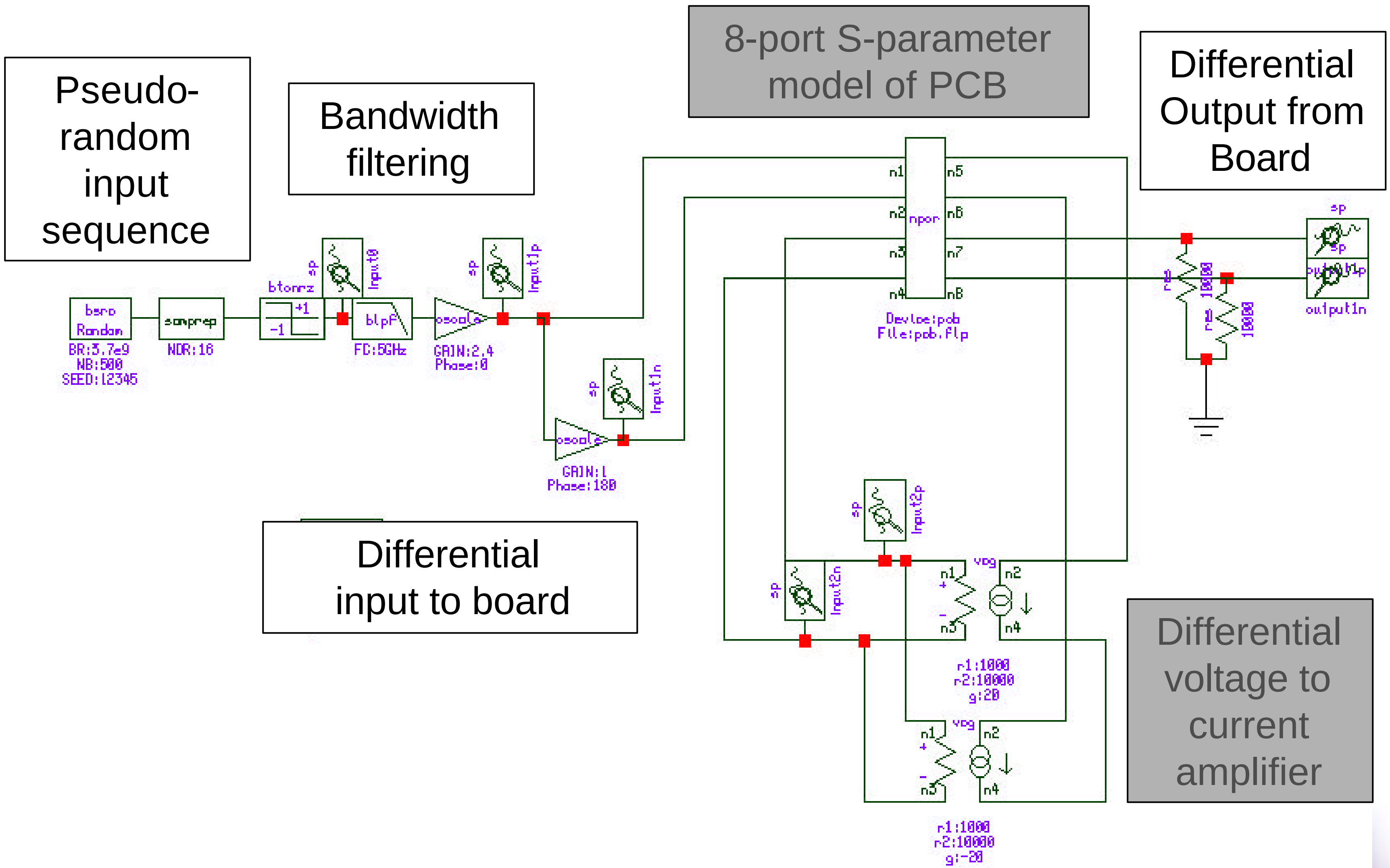


Electric Field in Dielectric at Resonance

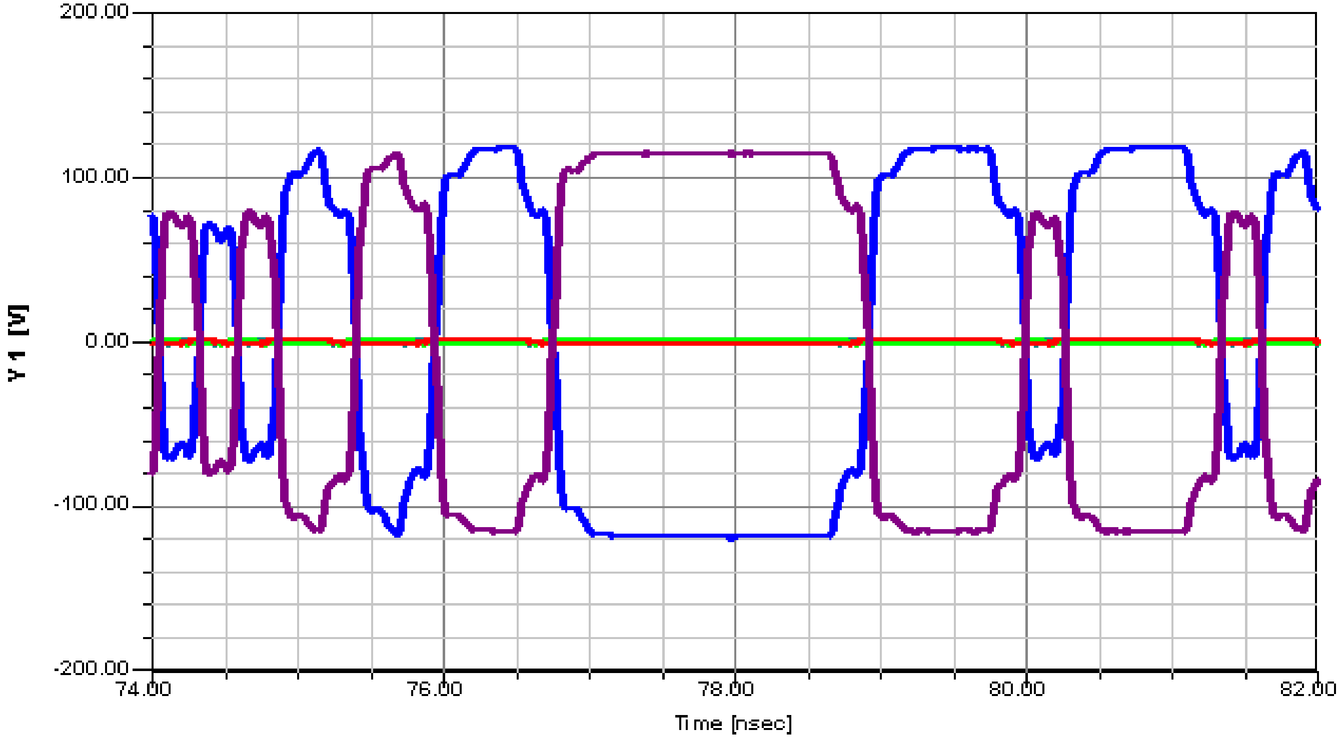


5.26GHz – same as first peak in S parameter plot

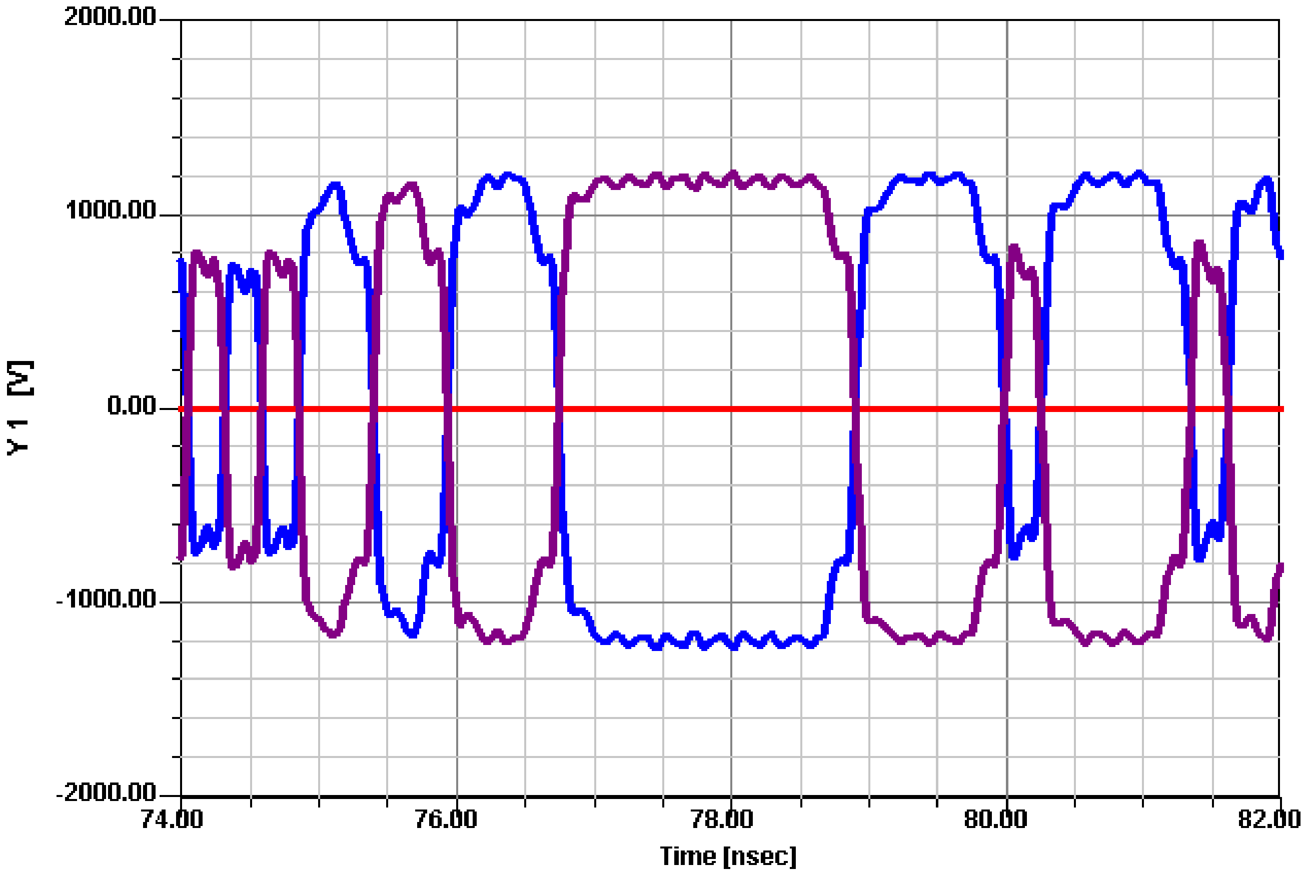
System-Level Model of Amplifier, PCB and Test Equipment



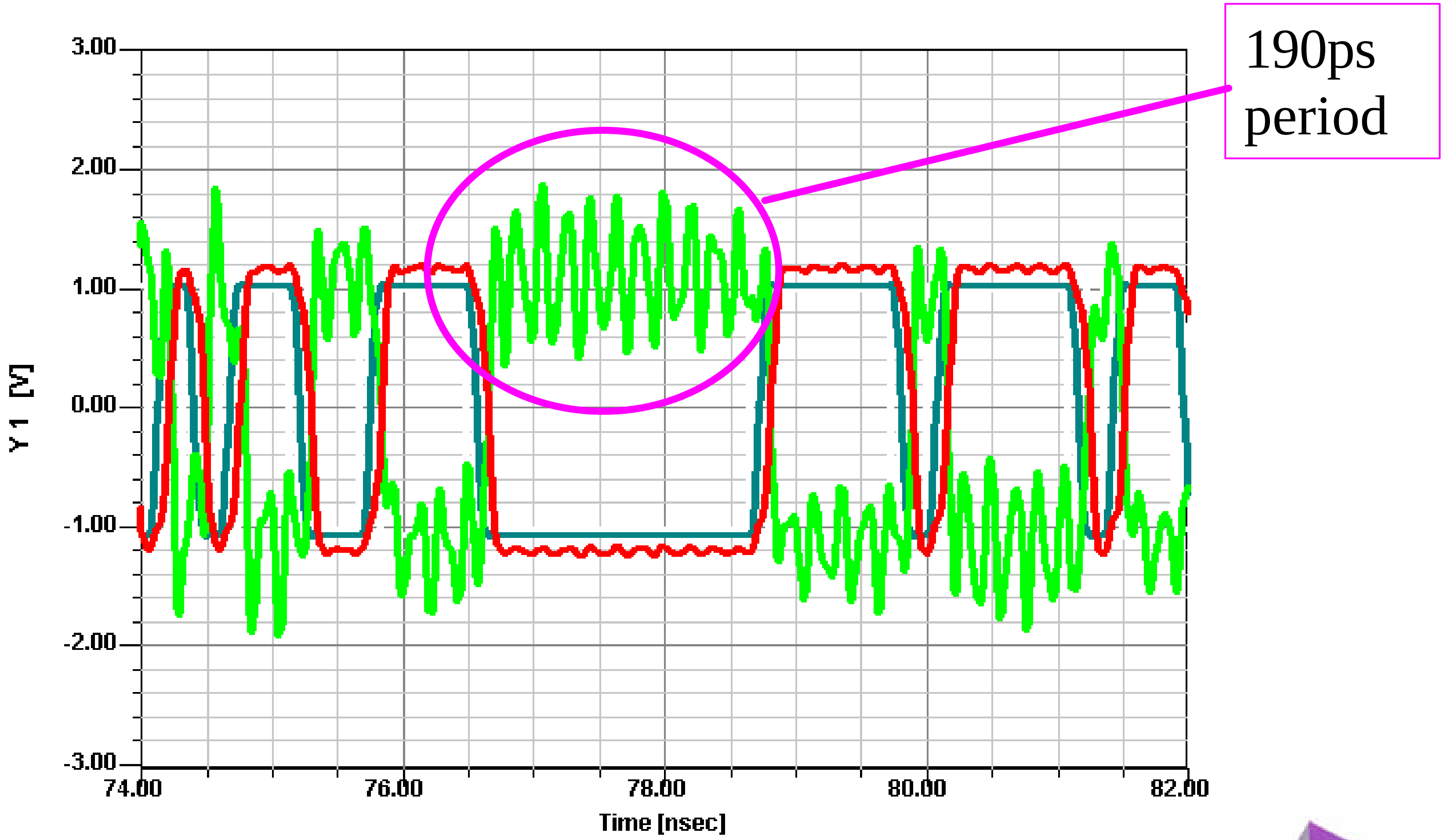
Output from Board
Low Gain, 3.7Gb/s Data Rate



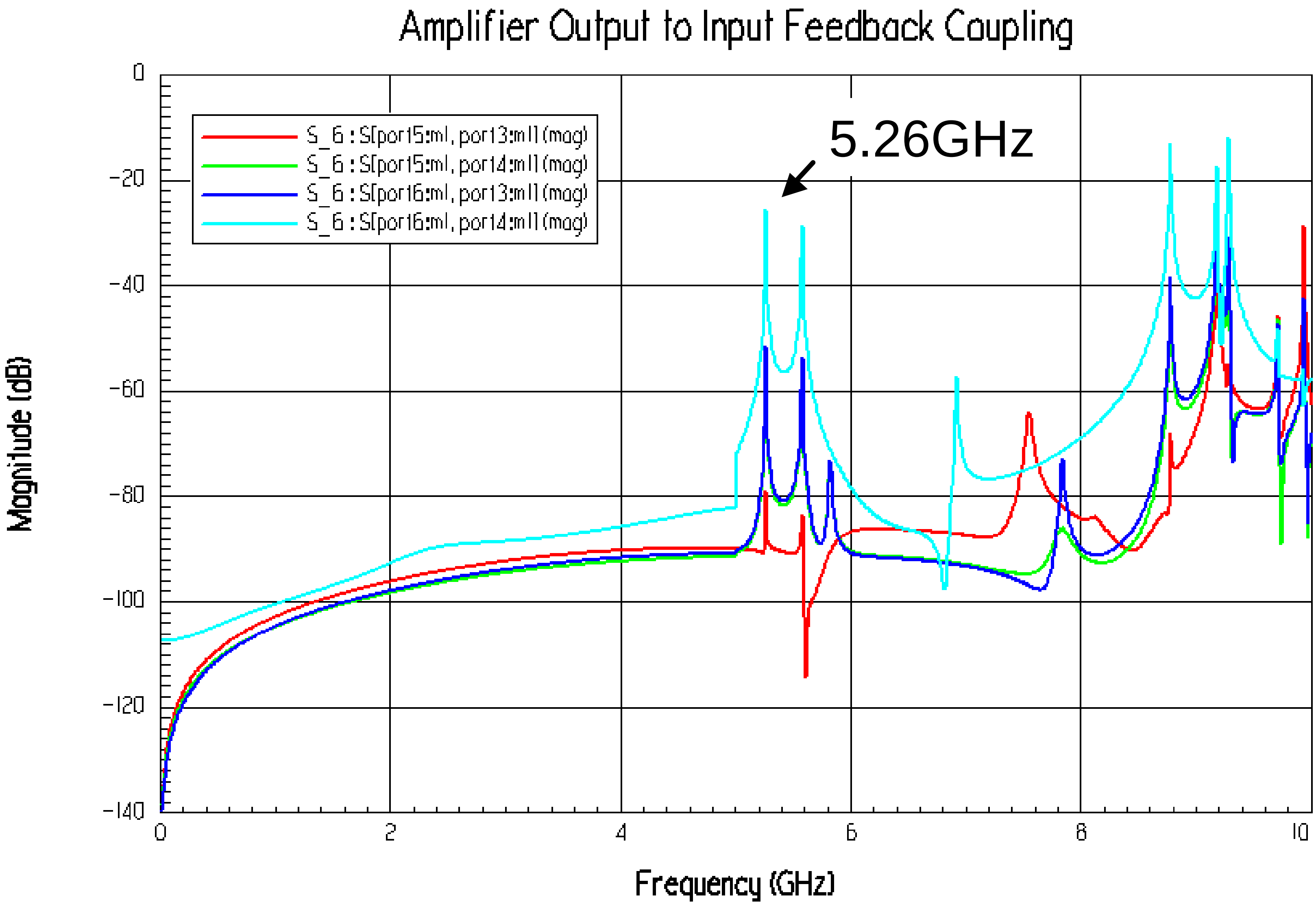
Output from Board
High Gain, 3.7Gb/s Data Rate



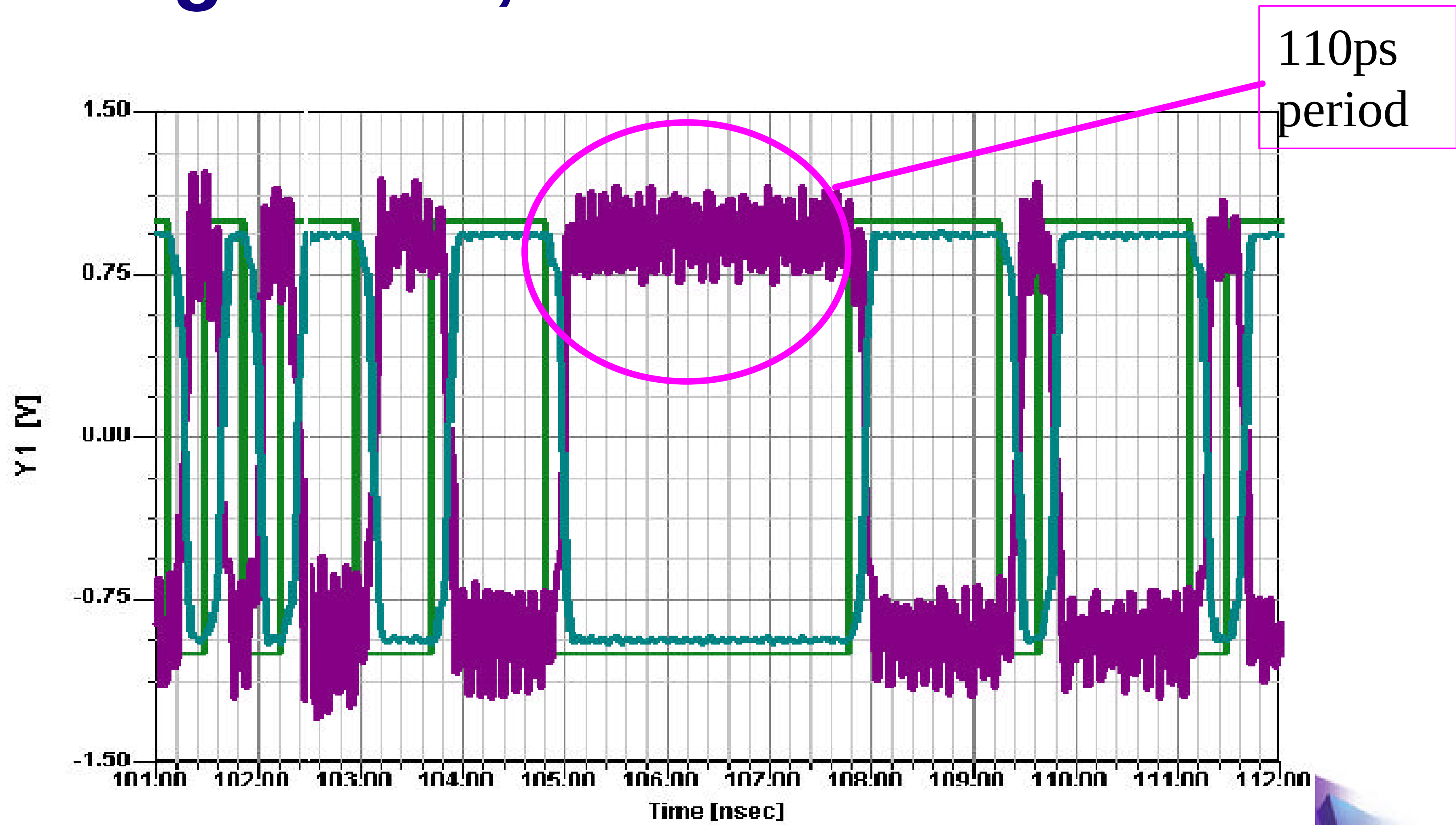
Input to Amplifier
High Gain, 3.7Gb/s Data Rate



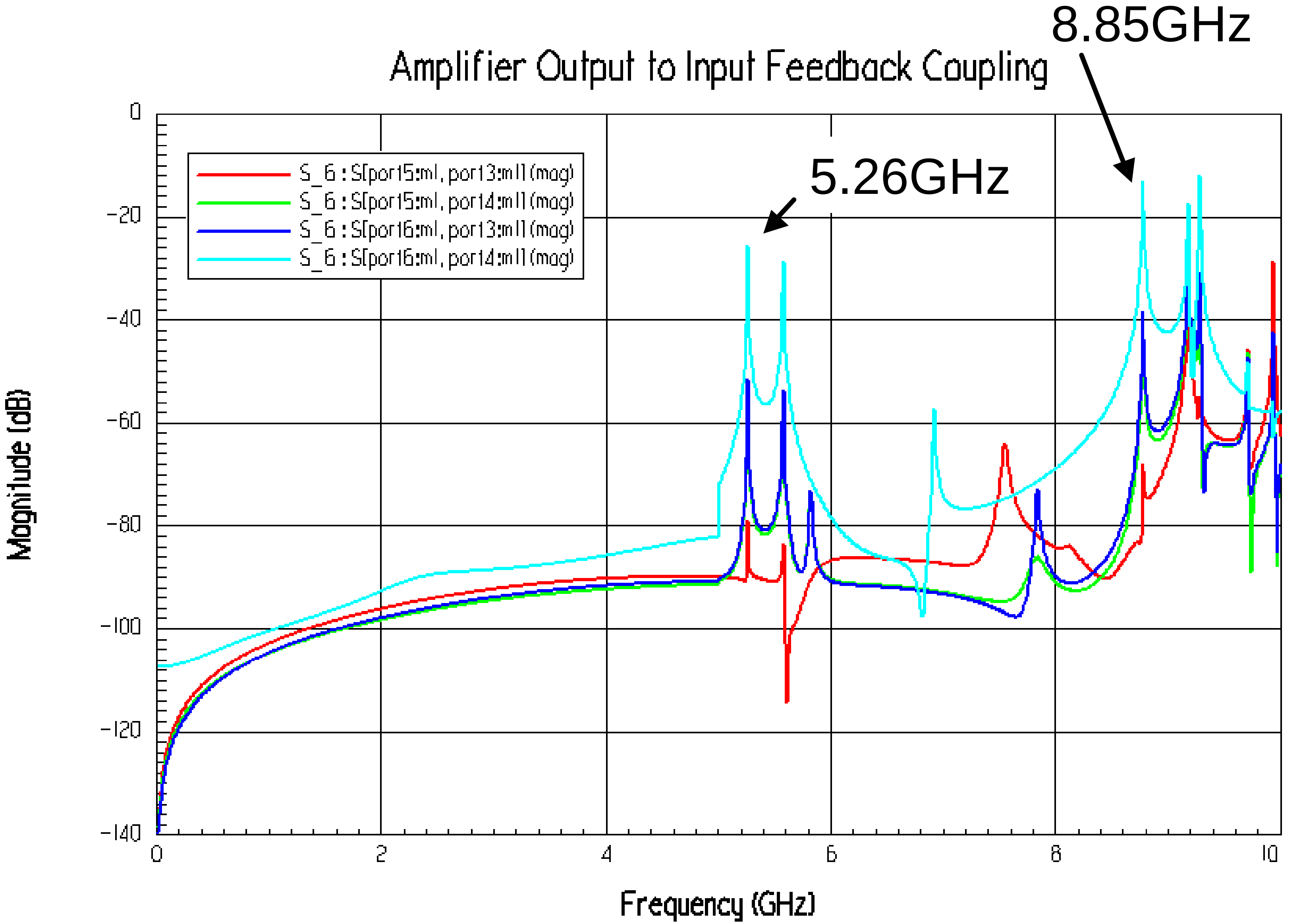
Coupling from Amplifier Output to Input



Input to Amplifier
High Gain, 2.7Gb/s Data Rate



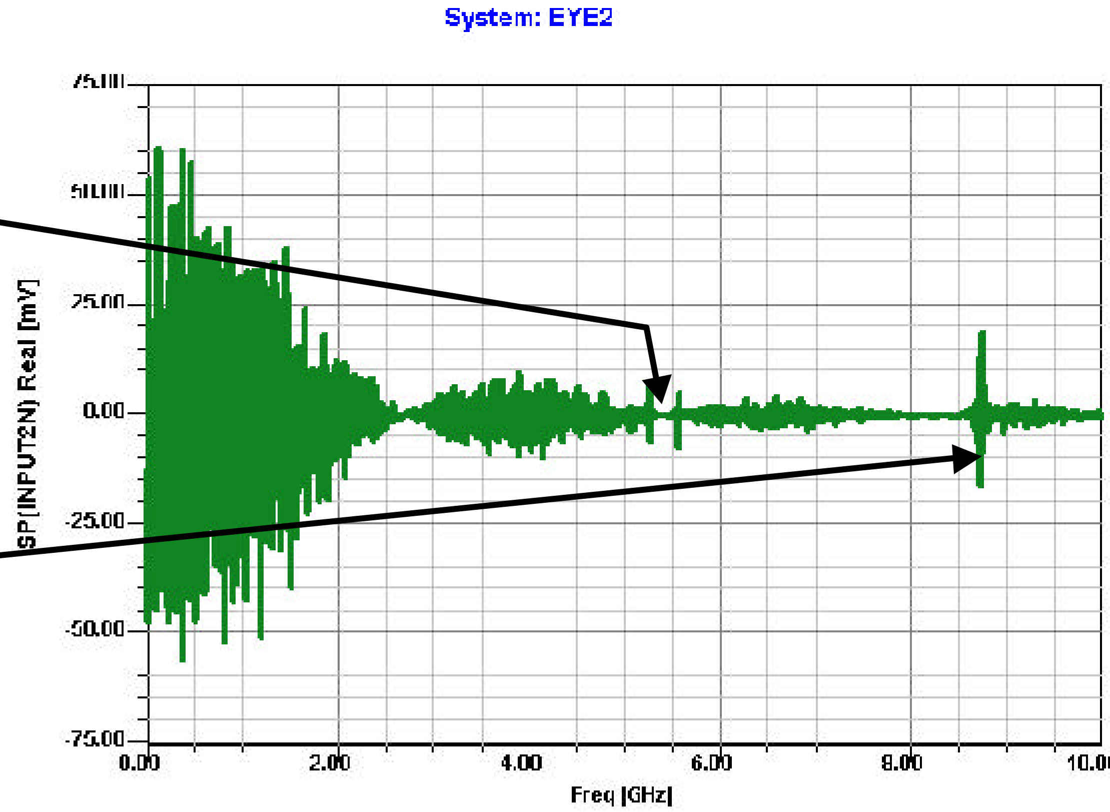
Coupling from Amplifier Output to Input



Input Spectrum at Amplifier High Gain, 2.7Gb/s Data Rate

Spectral null near 5.26GHz, so resonances near here are not strongly excited

Significant energy content at 8.85GHz, so resonance is excited



Summary

- High frequency applications (such as optical transceivers) are subject to a new class of “difficult” signal integrity problems not found at lower frequencies.
- Electromagnetic-based (EM) simulations predicts these effects, based upon a solution of Maxwell’s Equations, which describe the underlying physics.
- By incorporating models from the EM simulations into a system-level simulation, designers can predict the system performance across the domain of operation.
- Such virtual prototyping improves a designer’s insight into the high frequency signal integrity phenomena and leads to “right first time” designs.