

# A Hybrid Measurement and Field Solver Approach for the Design Of High-Performance Interconnects

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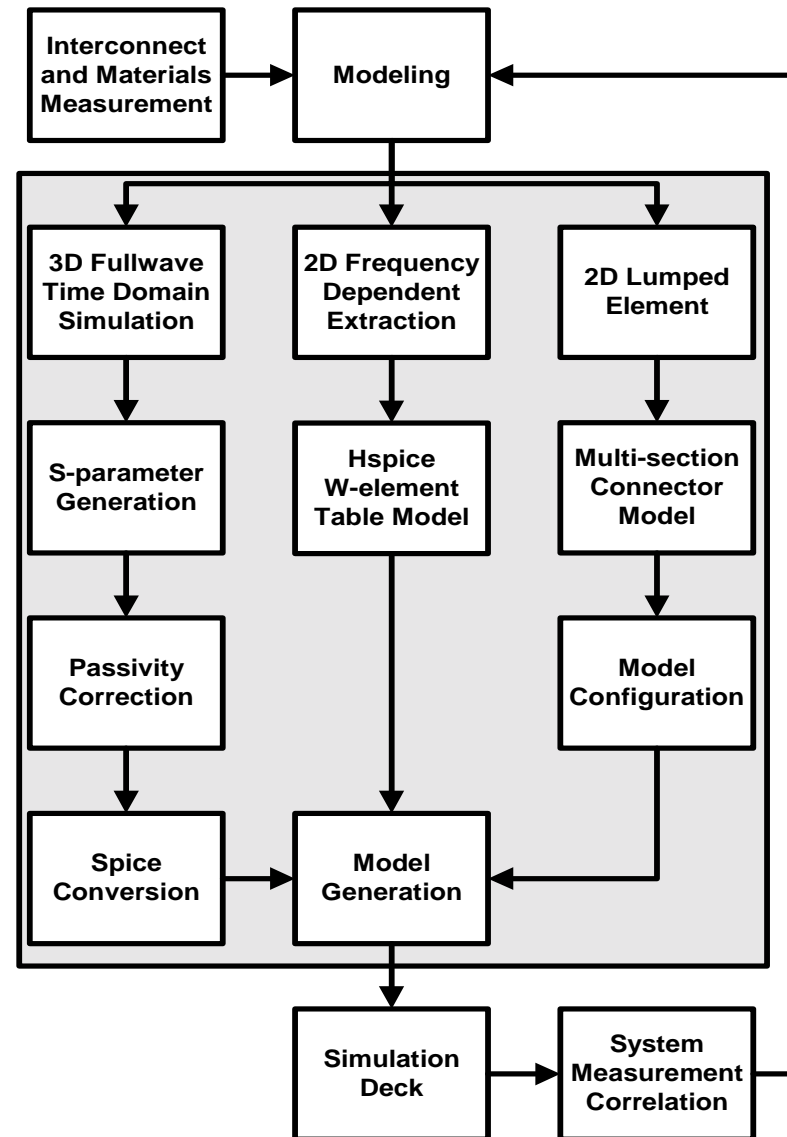


# Introduction

- We'll discuss
  - Why launches are important.
  - What makes a good (or a bad) launch?
  - A comparison of average launches.
  - Launch optimization.
  - Launch measurement and correlation.
  - Versatility of a good launch.



# Modeling and Evaluation Process Flow



# Typical Launch Pathologies

- Ringing
- Loss
- Risetime Degradation
- Measurement Opacity



# Ringling

- Ringing distorts the impedance measurement.
  - The effect on short traces and small features may totally obscure the behavior of the interconnect under test.
- Accurate comparison of solver techniques and time-domain modeling requires a true impedance profile.
  - Ringing phenomena must be separated from multiple reflections that may appear in very high-speed systems.
    - It is often difficult to determine where the launch ends and the interconnect begins.

## Loss

- Available measurement bandwidth is reduced.
  - A bad launch reduces the bandwidth of the system that can be measured.
  - This may render a specific test impossible to accomplish, such as the evaluation of the frequency response of a cable being tested.
- A good launch can be isolated from the interconnect.
  - This aids modeling in the frequency and time domain.

## Risetime Degradation

- Launches degrade the test edge rate.
  - Reduced risetime of a TDR pulse significantly limits the ability to accurately discern and measure small features:
    - Vias and pads
    - Stubs
    - Component packages
    - Connectors
    - Repetitive features in cables
- If you can't discern them, you can't make measurement based models of them.

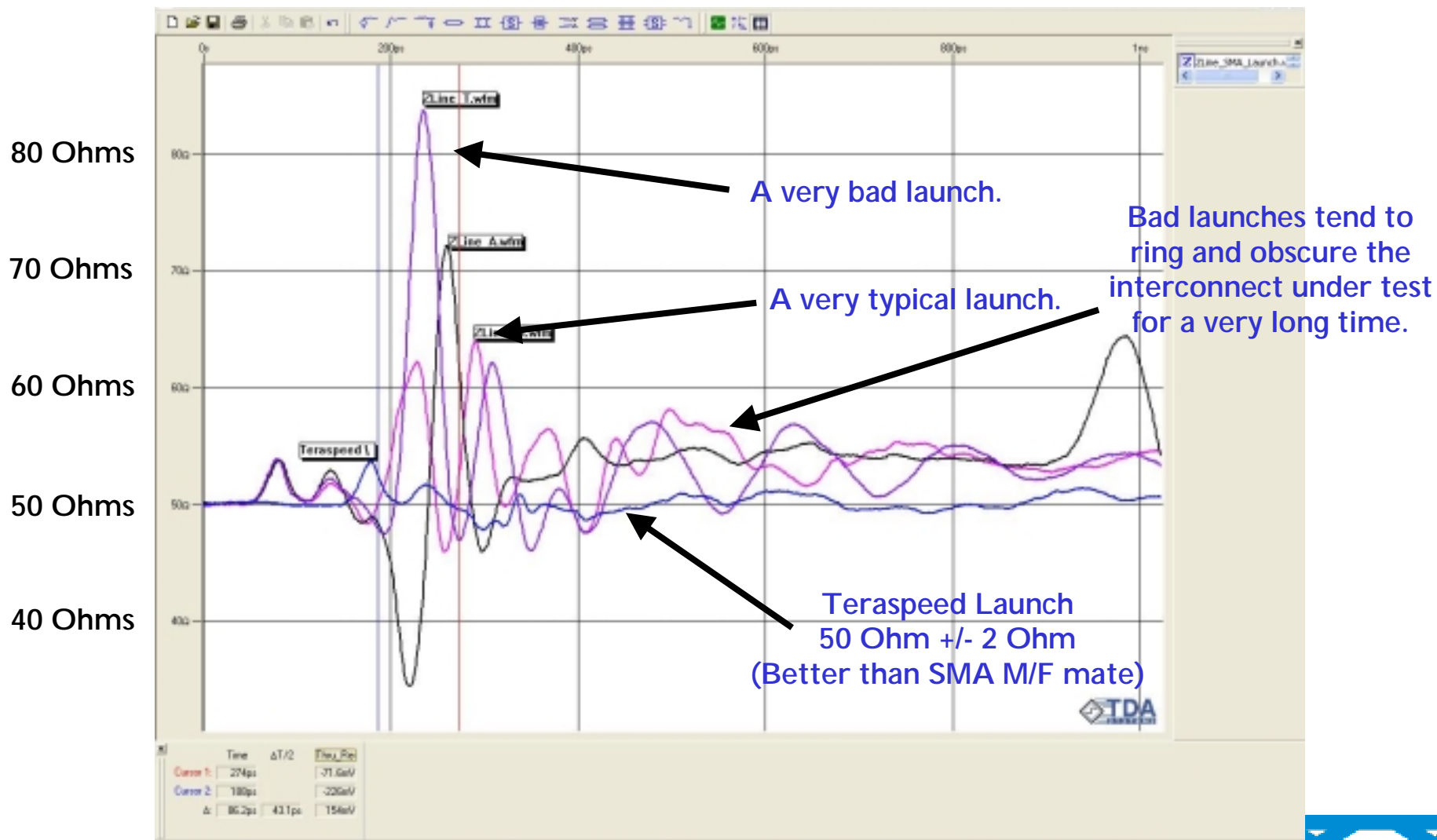


## Measurement Opacity

- The bandwidth of the test equipment, cables and PCB launches should be significantly greater than the system under test.
  - Otherwise the test system is opaque.
    - Important features are obscured and not seen.
    - The beginning and end of each interconnect feature is unsure.
    - TDR profiles show exceedingly flat response, or response dominated by launch reflections.
    - S-parameter measurements are unreliable.



# There's No Such Thing As A Free Launch



## The Rational for Good Launches

- Multiple impedances generate reflections that mask the true impedance profile, making it impossible to verify performance. Generating a true impedance profile is usually the first step in the measurement-based modeling process, since it indicates how the topology of the model should be constructed.

## Introduction

- A modified Molex flange mount SMA connector was used in a top launch PCB configuration.
  - PCB substrate
    - FR4 ( $\epsilon_r = 4.0$ , 63 mils thick)
  - SMA contacts with with layer 1 via pad which inserts the signal into the lowest stripline layer.
    - Maximum via stub length = 10 mils.

## Introduction

- Measurements made with Tektronix TDS-8000 with 20 GHz sampling TDR/TDT head using TDA Systems I-connect software.
  - Differential measurements were made with extremely short rigid coax connections to two identical SMA launches for maximum edge rate into SMA ( $< 25$  ps).
- 3D full-wave simulations performed with CST Microwave Studio.



# SMA Launches

- Test and evaluation boards require methods to accurately measure material and interconnect.
  - Off the shelf SMA connectors are attractive.
    - Easy to interface to.
    - Deceptively simple to place on boards.
    - But do they work well?
      - Generally the answer is no, without detailed transition development.
  - SMA connector launches are extremely complex 3-D non-TEM structures, which lend themselves to full-wave analysis and optimization.
    - If not optimized, SMAs will obscure measurement of real system performance.
      - The goal is to make the connection to instrumentation as transparent as possible.



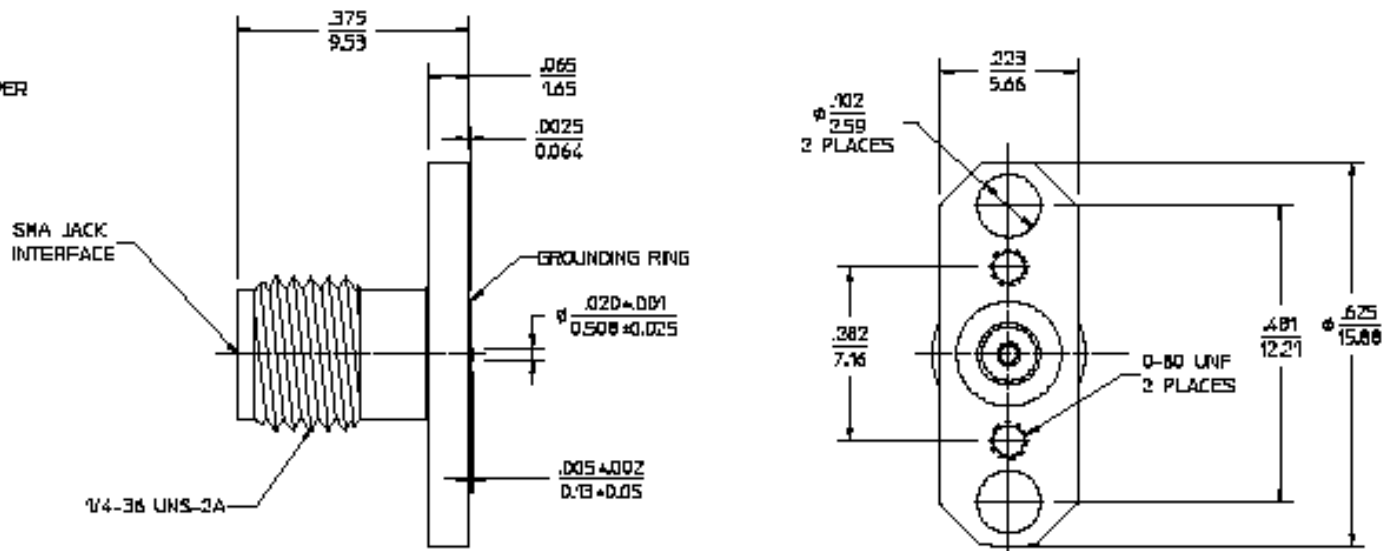
# Molex Surface Contact SMA

**MATERIALS AND FINISHES**

BODY STAINLESS STEEL  
PASSIVATED

CENTER CONTACT BERYLLIUM COPPER  
PLATED GOLD

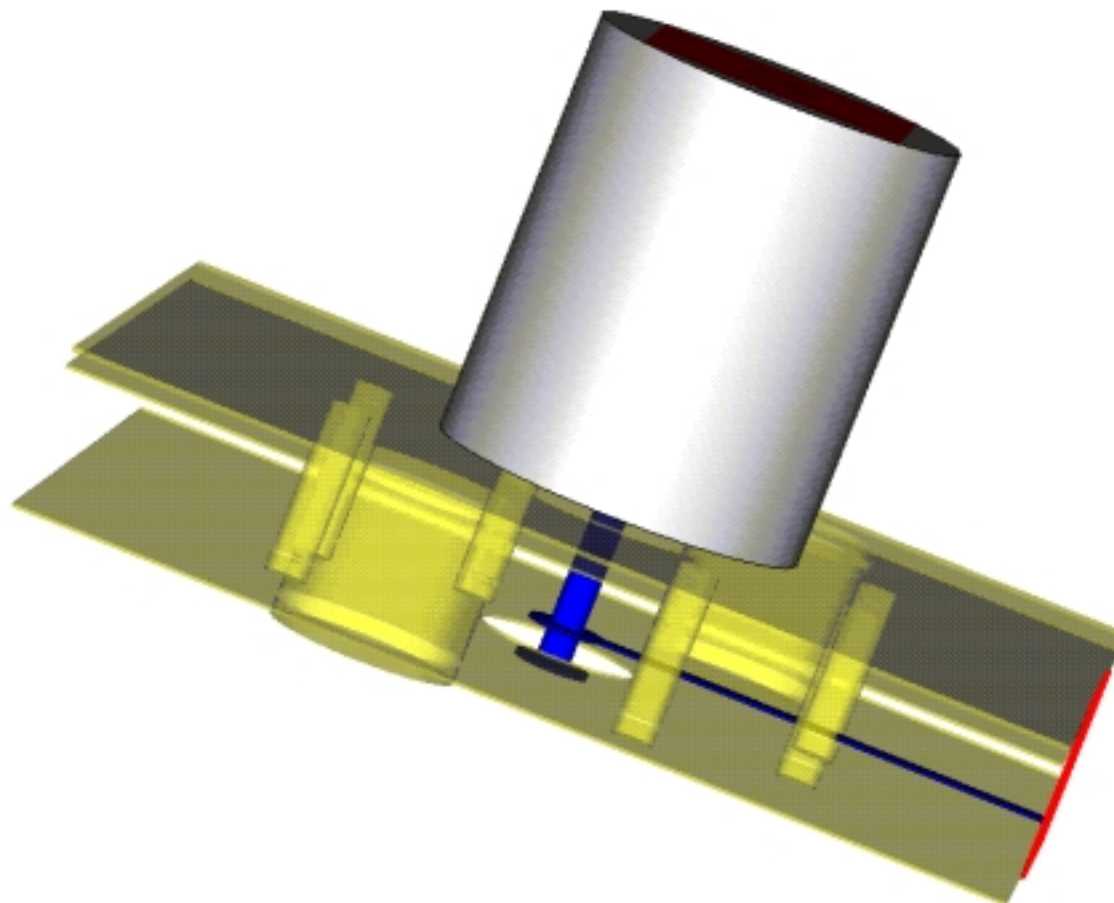
INSULATOR TEFLON



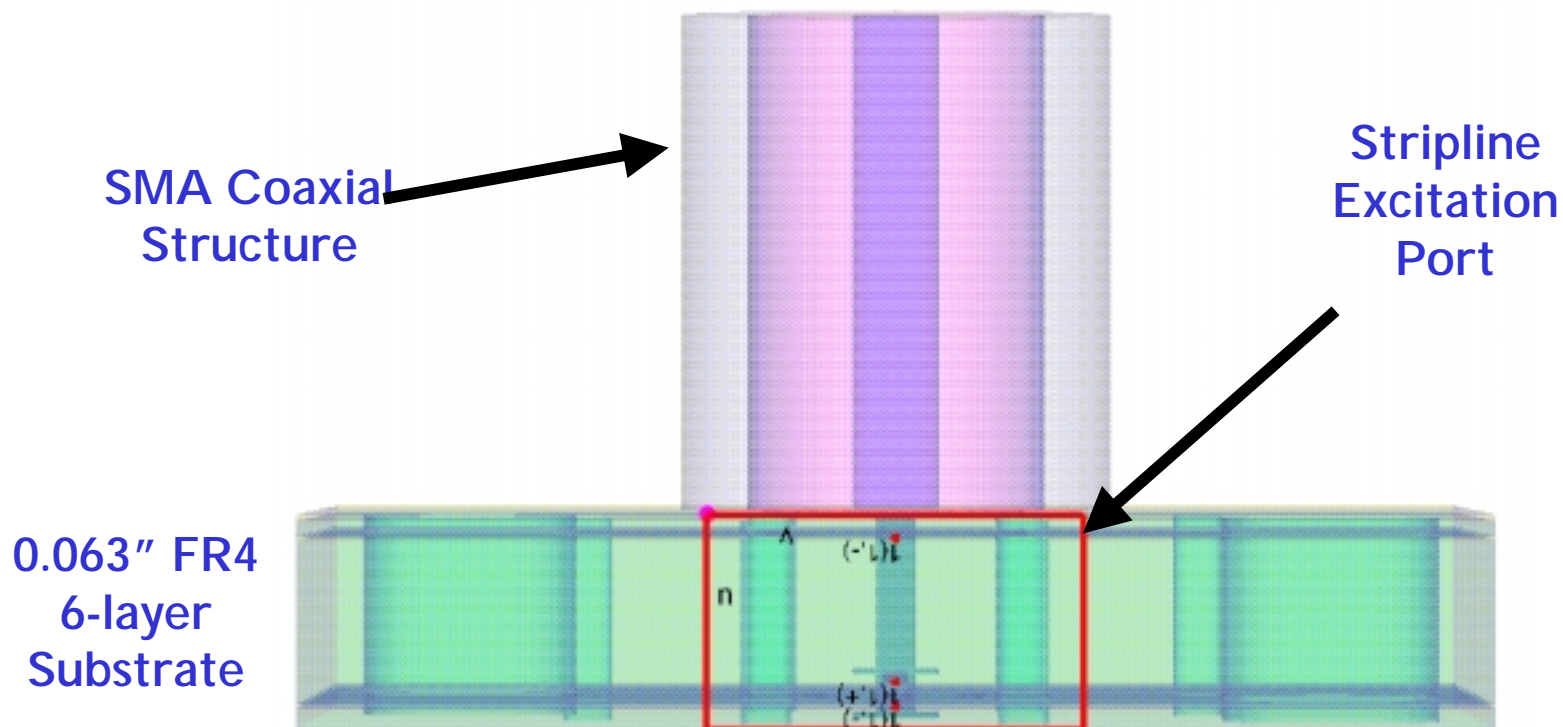
PART # 73251-185D



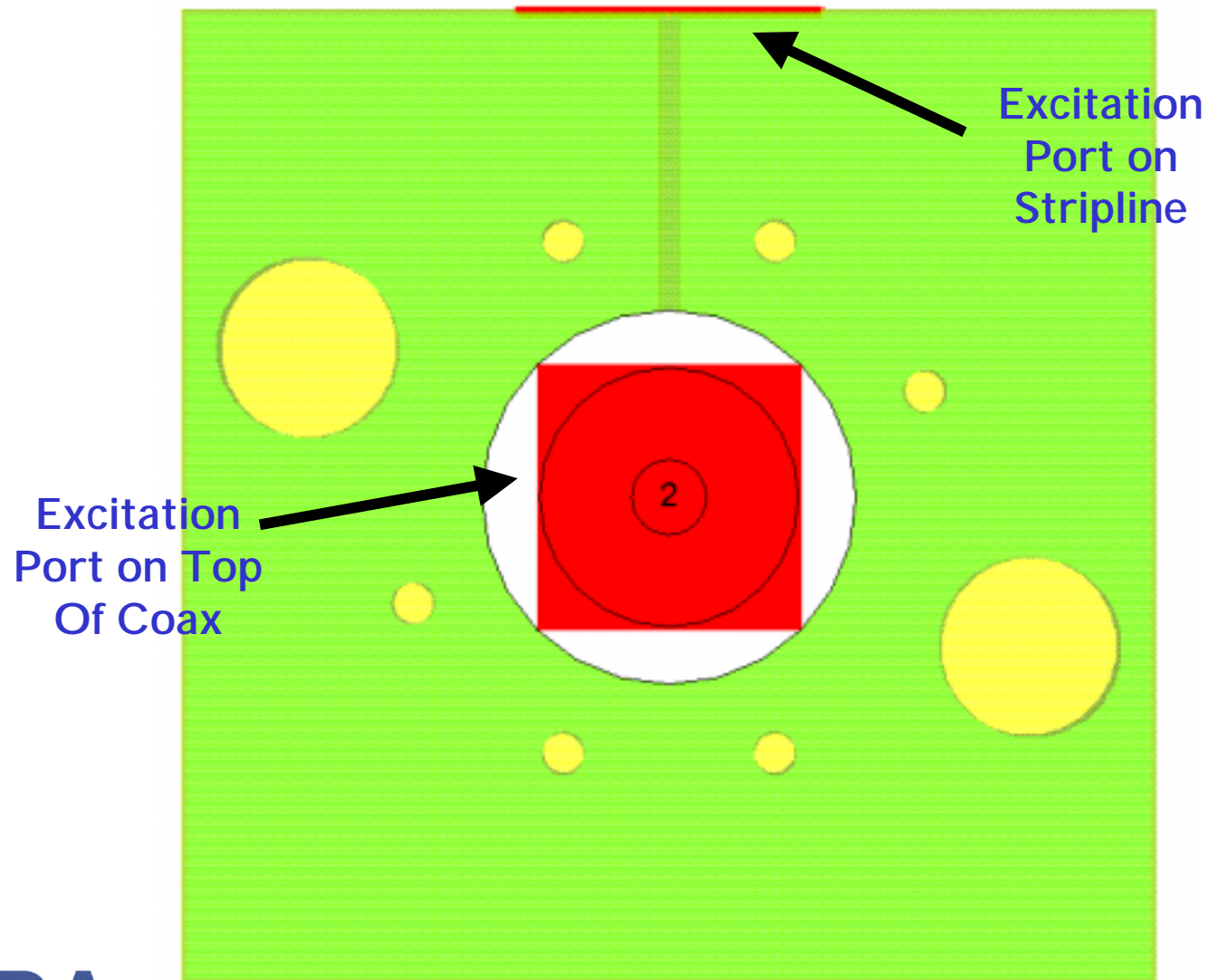
# Original SMA Launch Perspective View



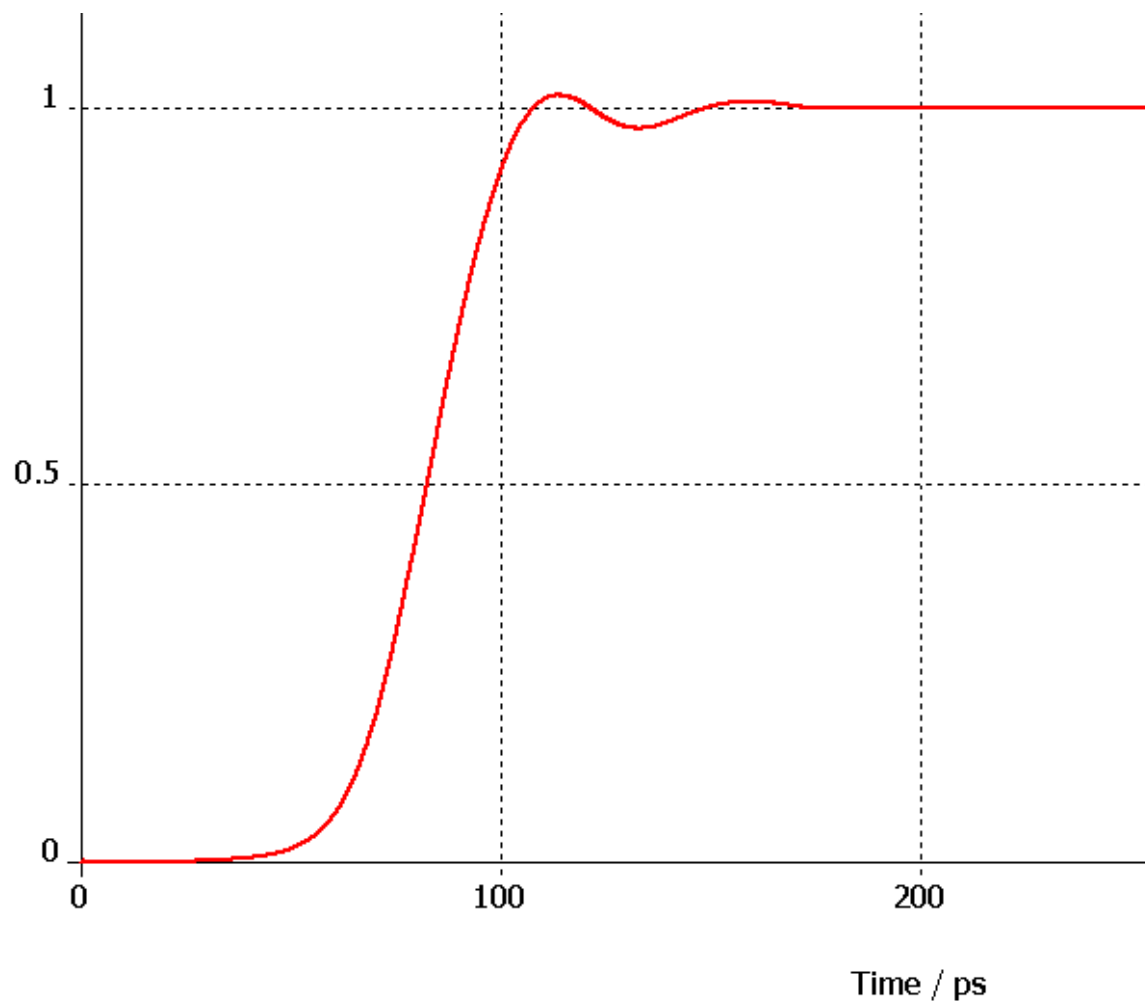
# Original SMA Launch Side View



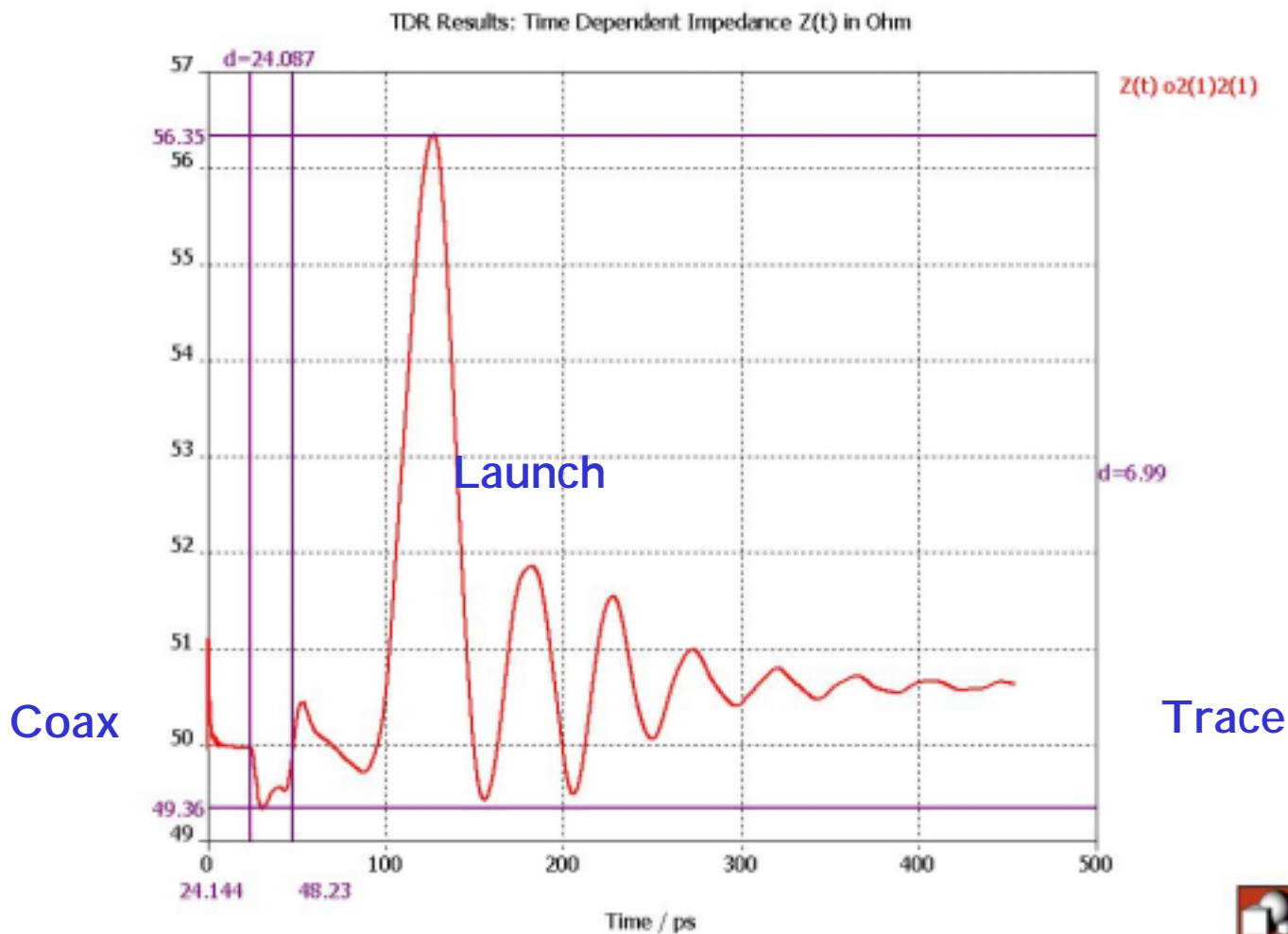
# Original SMA Launch Top View



# TDR Excitation Waveform



# Simulated SMA Launch

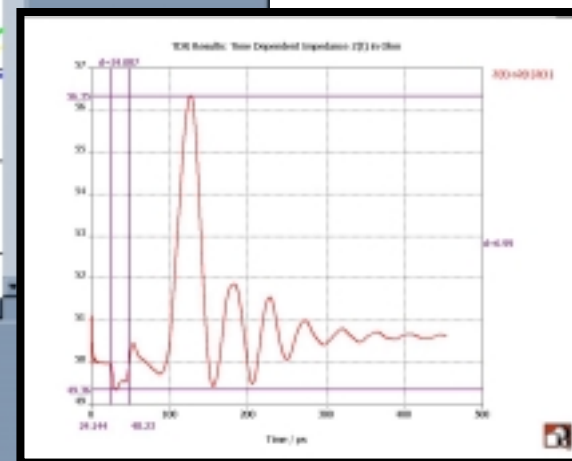
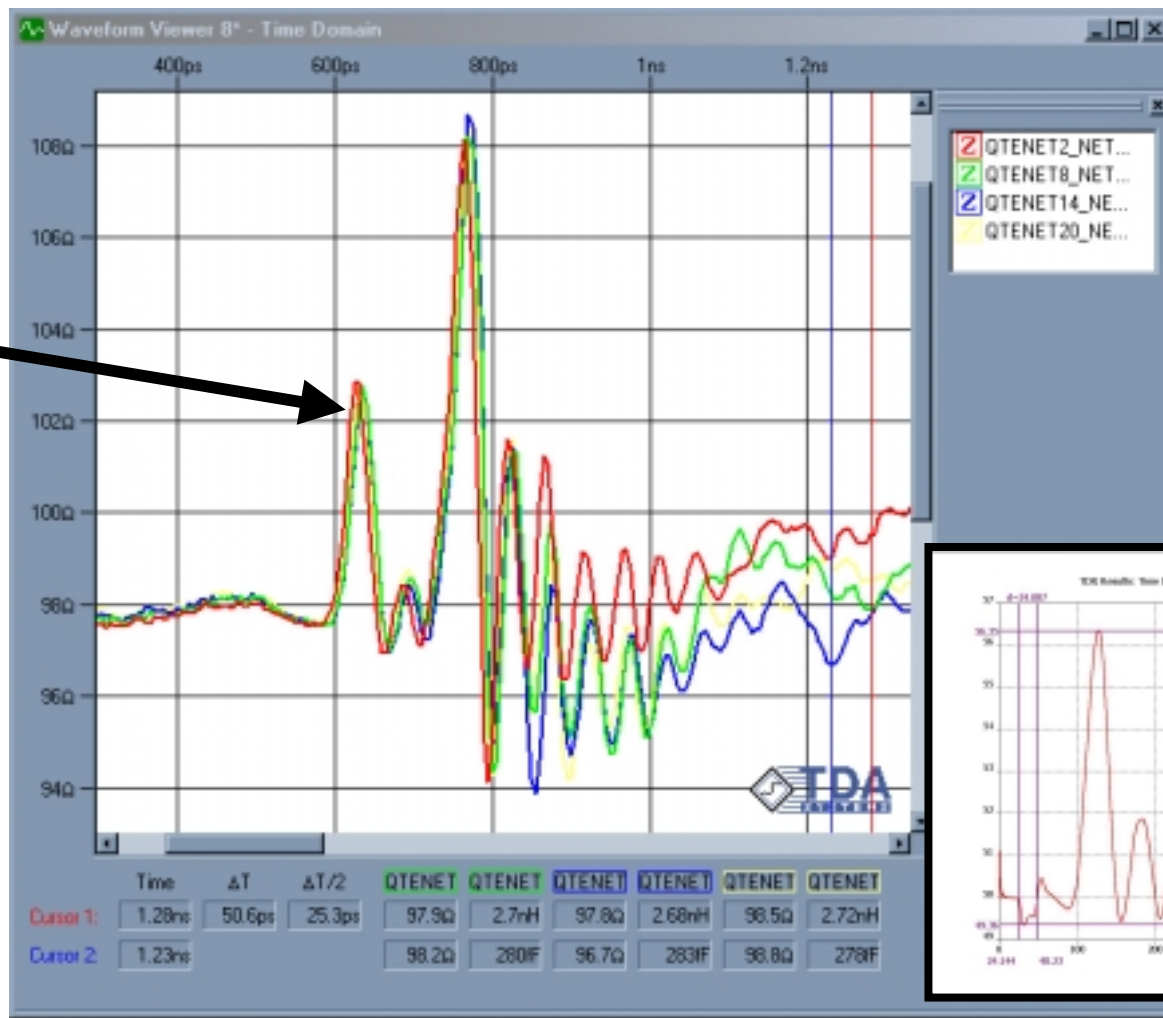


# Measured TDR Data

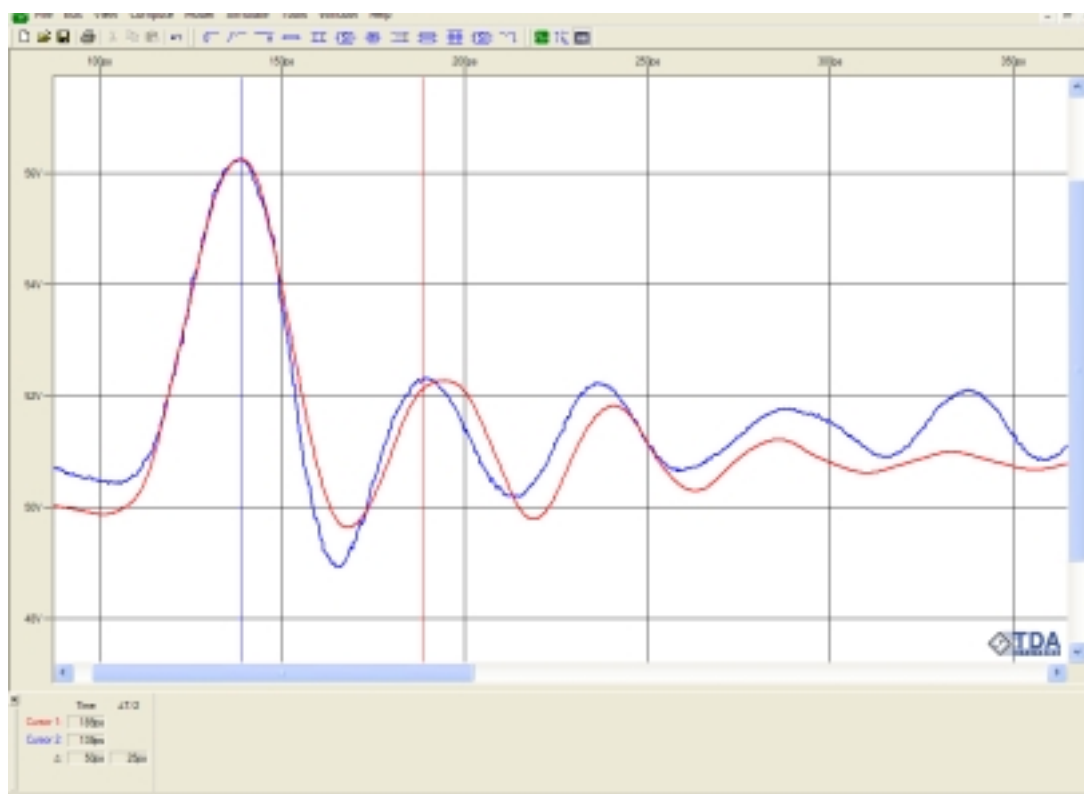
Cable to SMA transition



All other features seen in simulation are substantially the same.

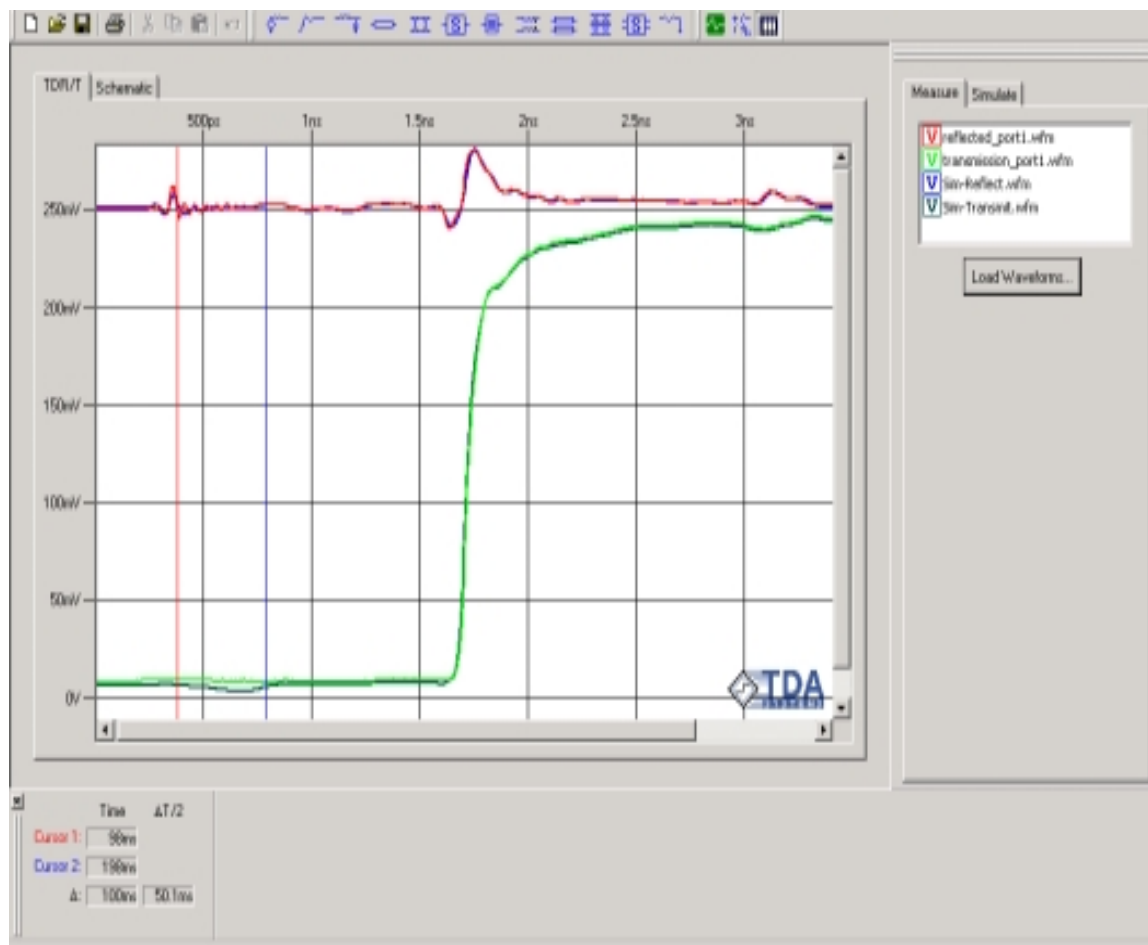


# Modeling Correlation with Topological TDR Measured Model



Excellent correspondence of 23 GHz resonance of improved launch using both 3D EM solver and measure-based model methods overlay against each other.

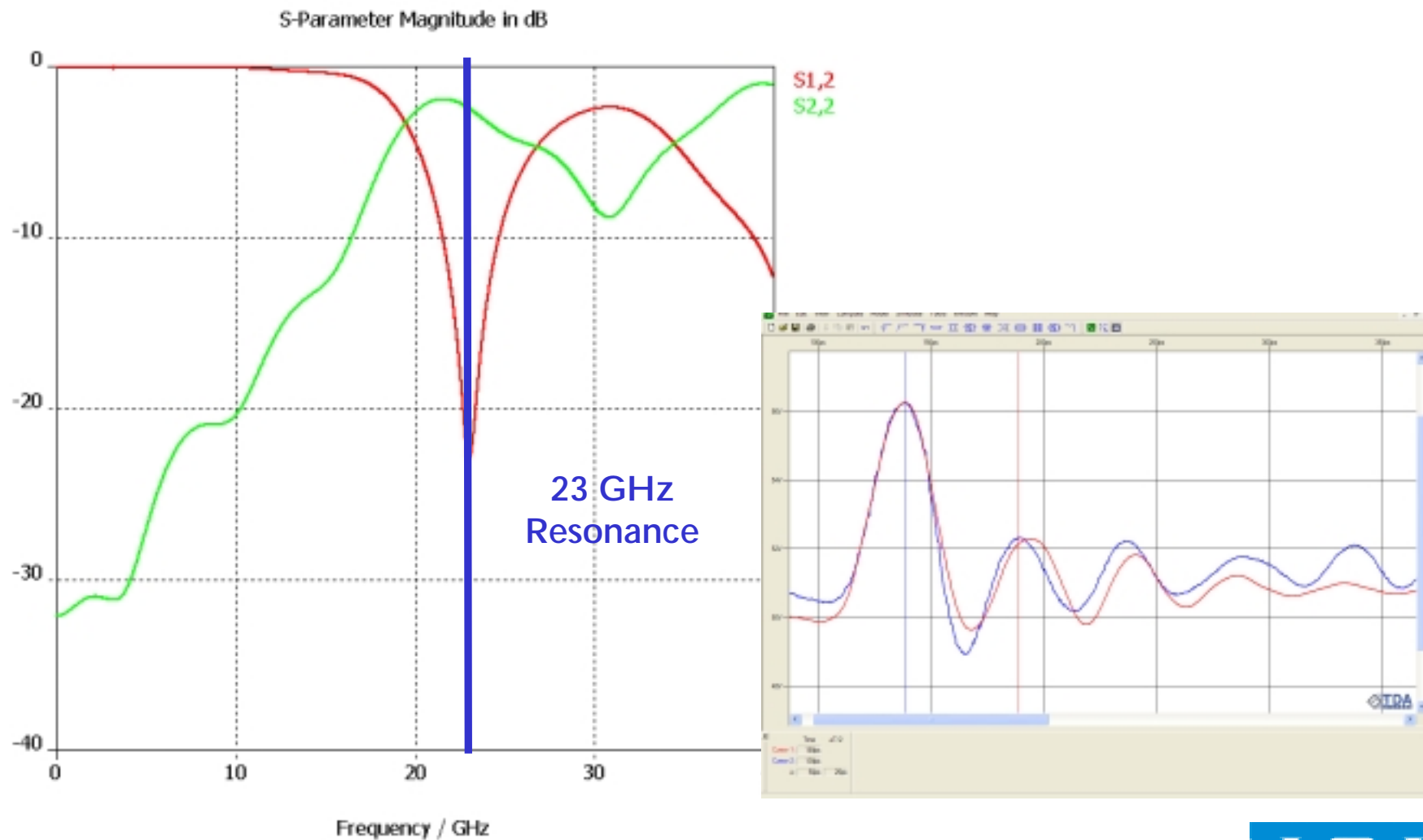
# Behavioral Model of Launch, Board, and Connector.



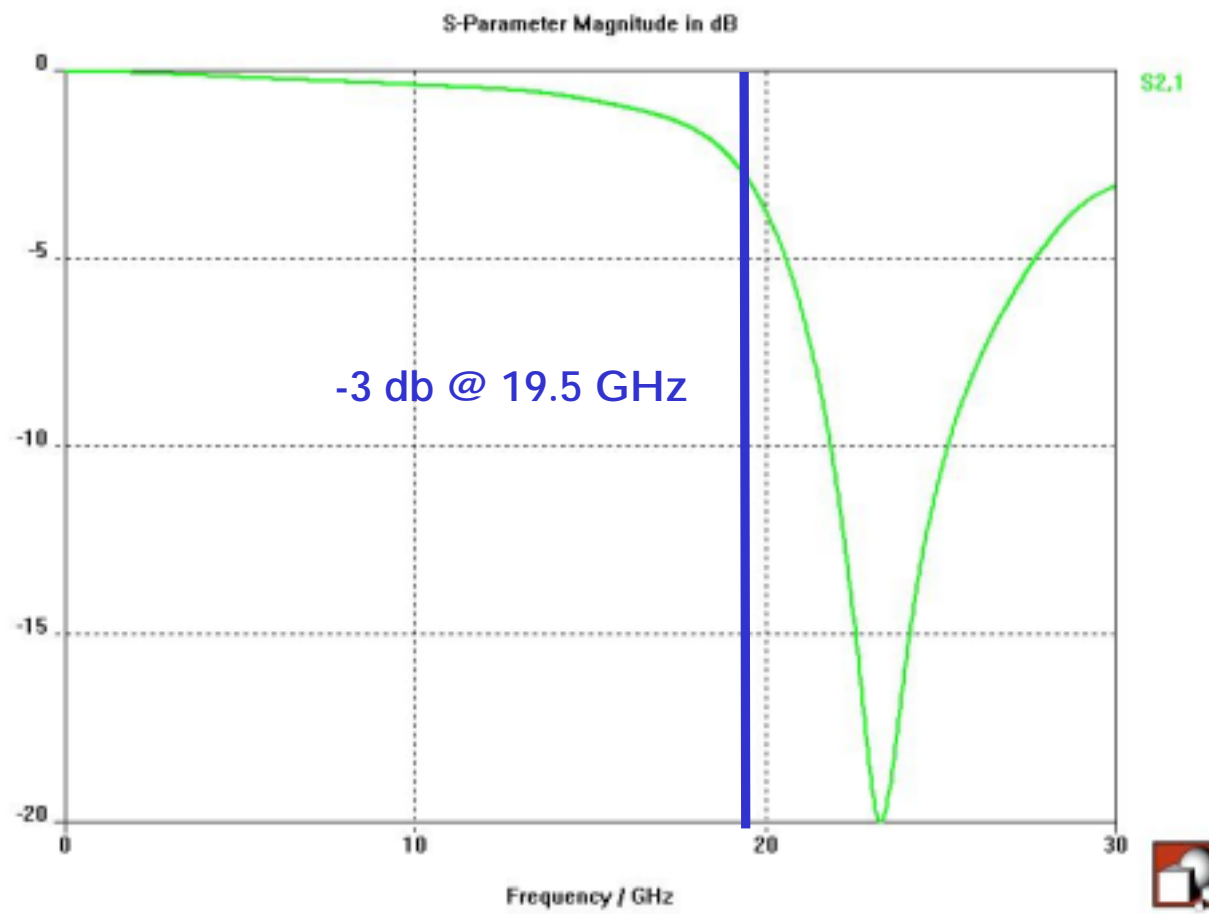
The extracted SPICE-compatible model consists of 100 poles/zeros.

Green and blue trace overlay exactly such that measured data and simulation results are exact correspondence for software generated model.

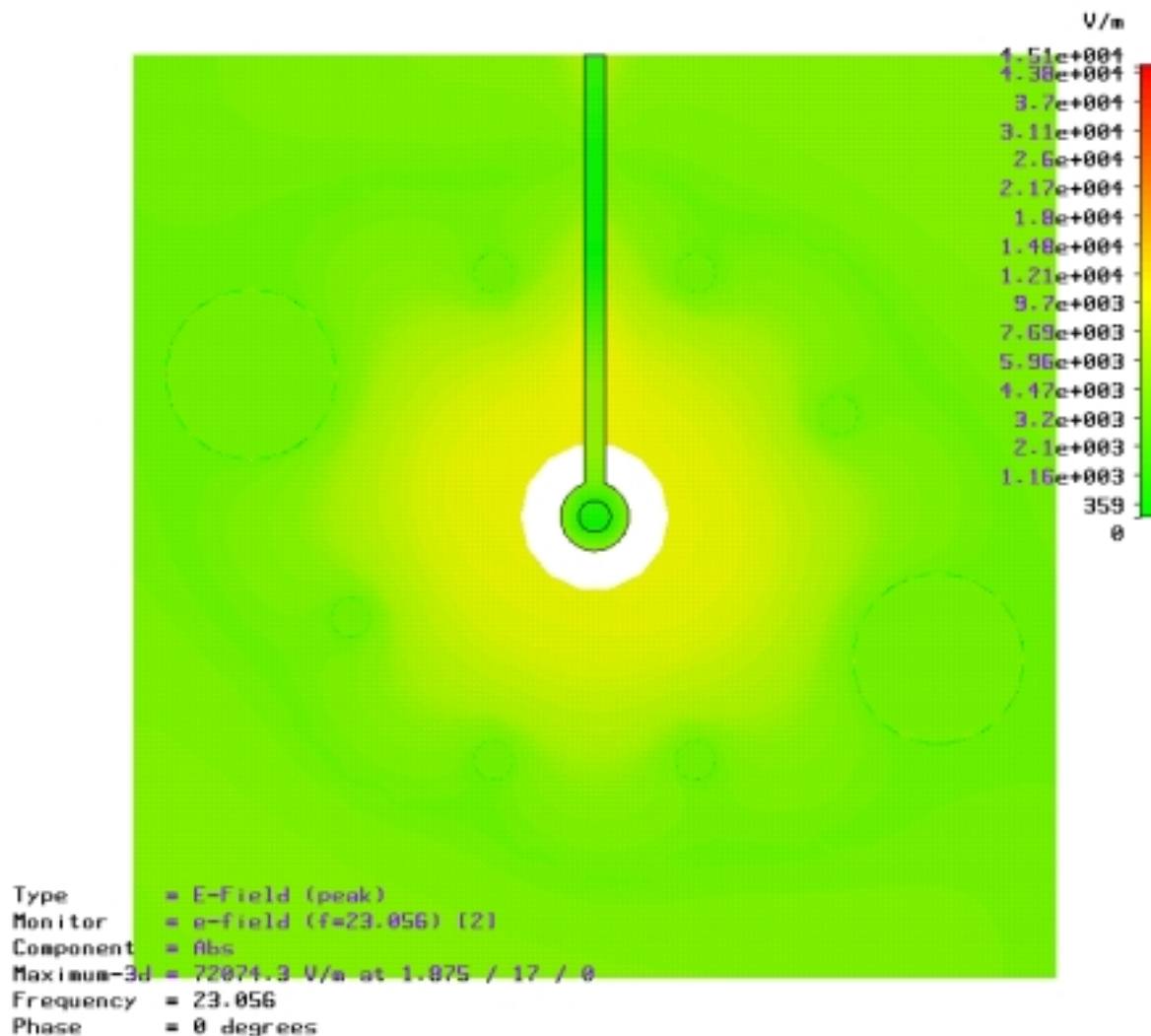
# Simulated S11, S21 Original SMA Launch Pattern



# Simulated Insertion Loss Original SMA Launch Pattern



# Field Pattern @ 23GHz

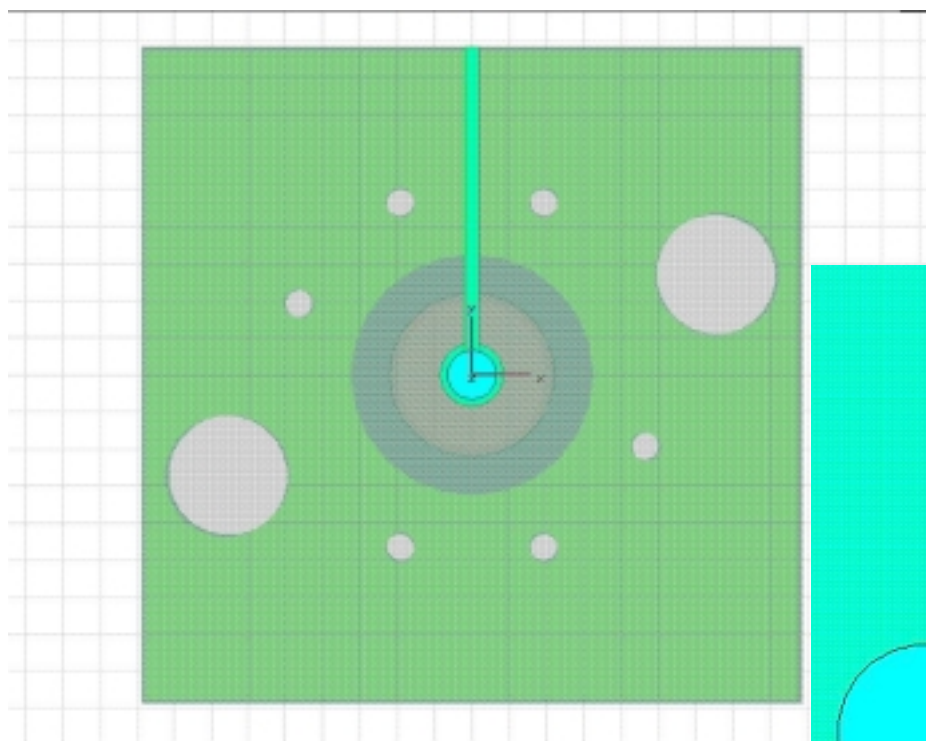


## Optimization Procedure

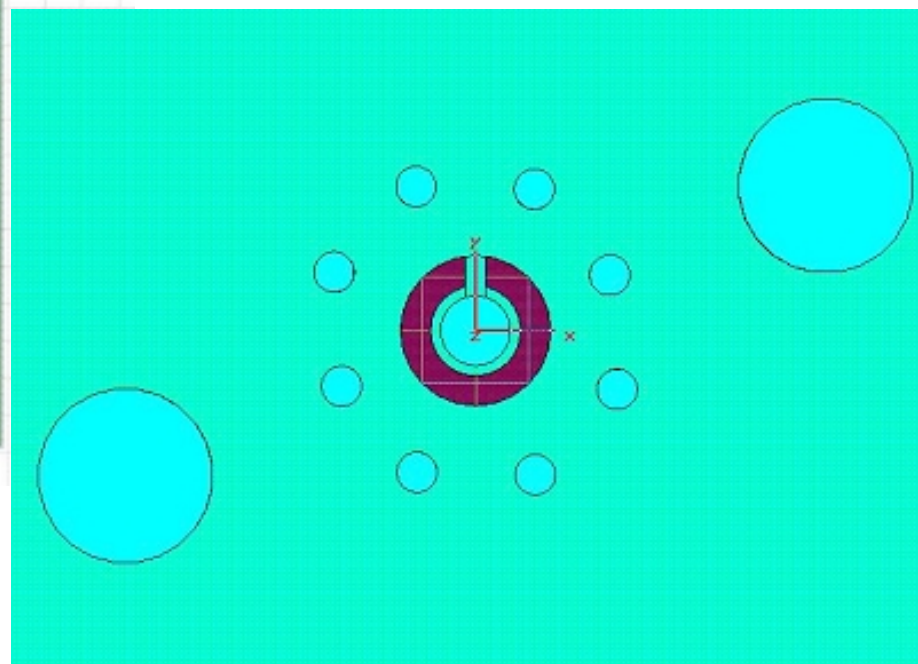
- Optimization was performed with the following steps:
  - All elements of the launch pattern were parameterized.
    - Ground via location
    - Antipad hole sized per layer
  - Solver was configured to perform multiple optimization runs with minimization of return loss (S11) as the optimization criteria.
  - Wait ... wait ... wait ....
    - Actual optimization can be performed in several hours of run time.
      - Much less than the time to enter and parameterize the model!



# Original vs. Optimized SMA Launch

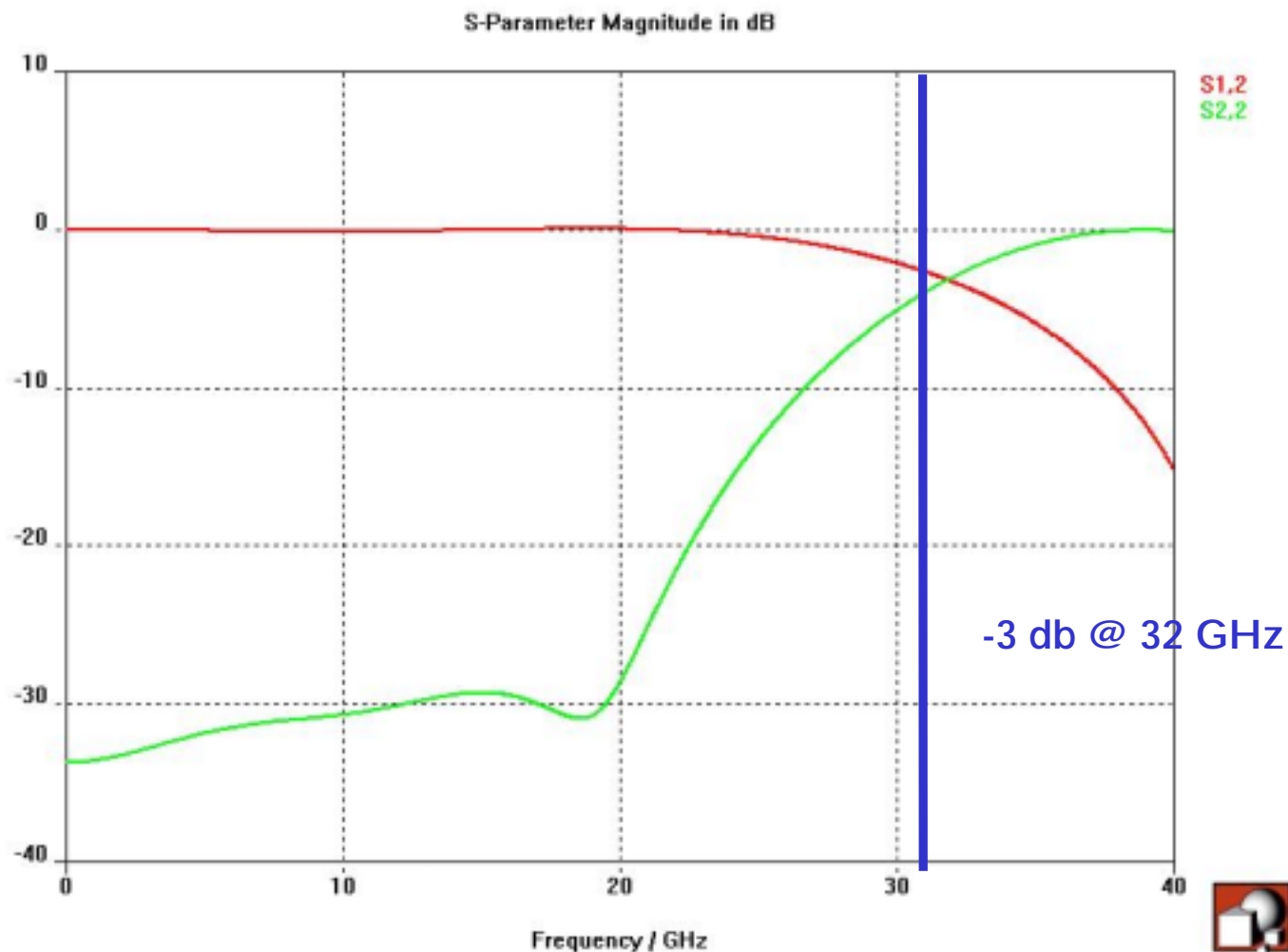


Original

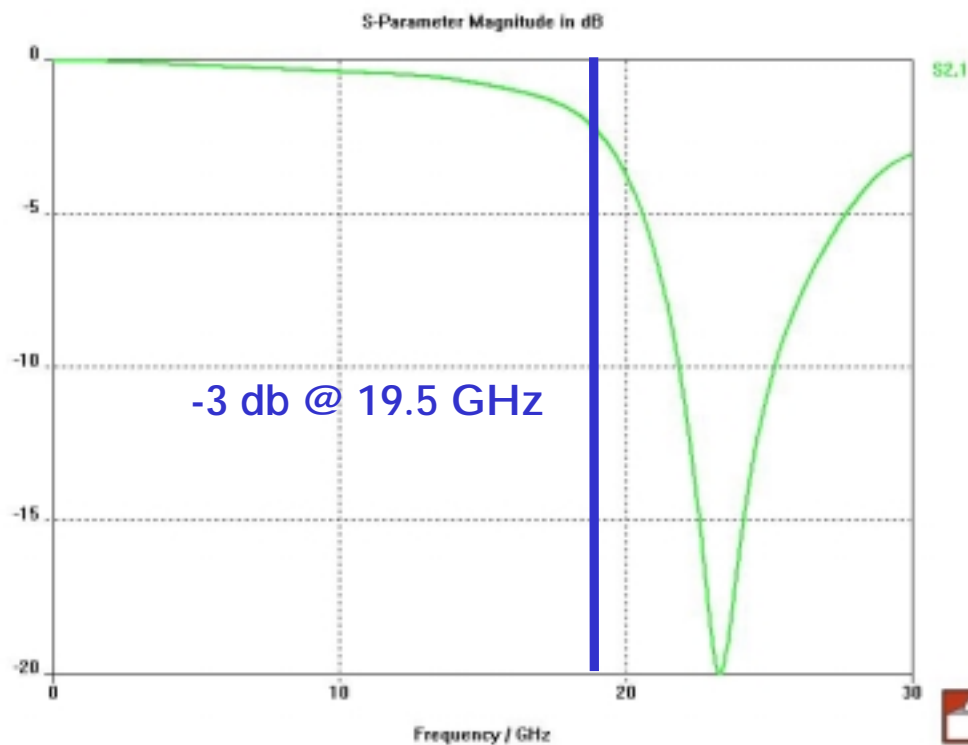


Optimized

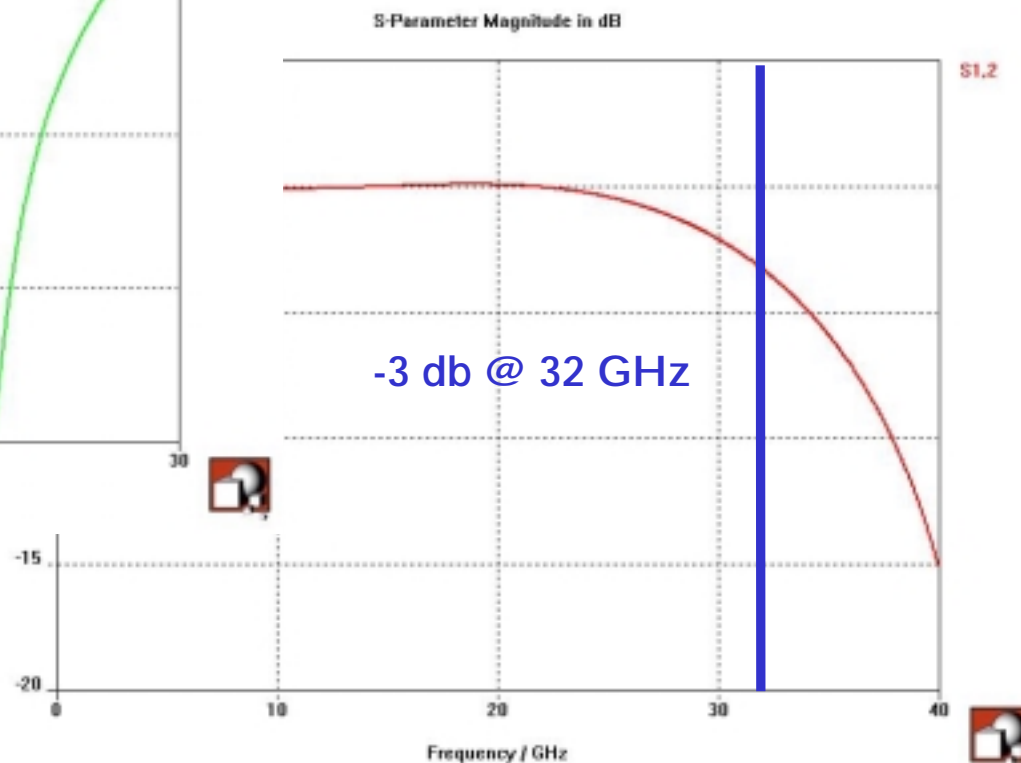
# Optimized SMA Launch Insertion Loss and Return Loss



# Original vs. Optimized Insertion Loss



Original



Optimized

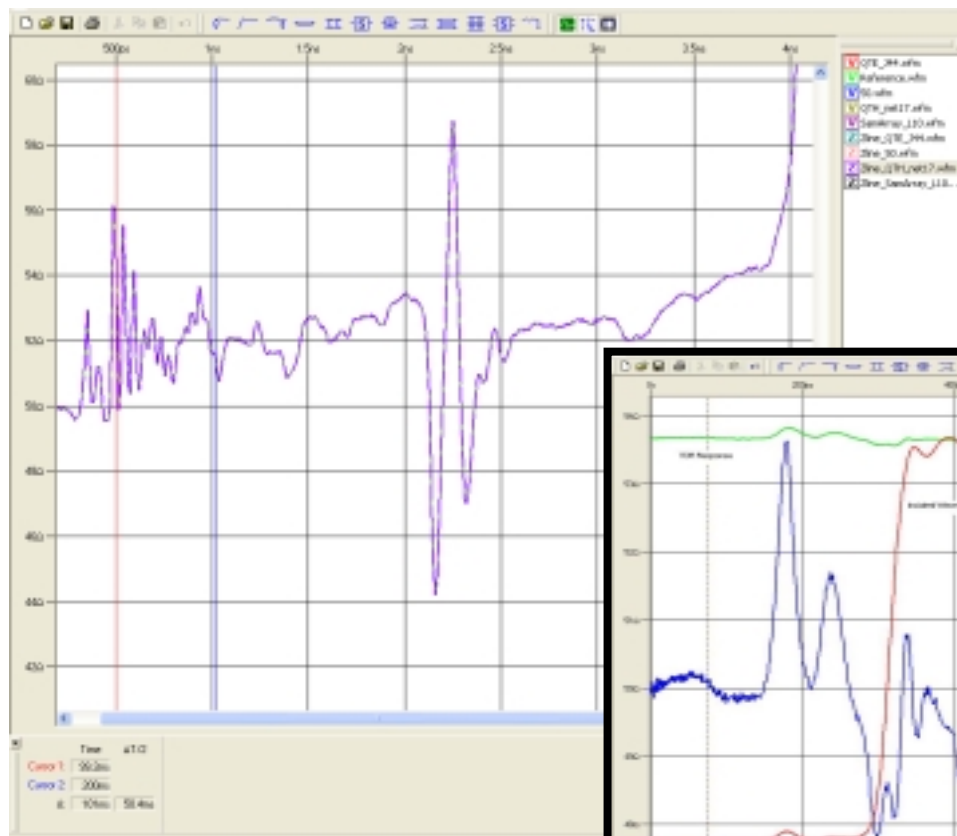


# Original Launch vs. Optimized Launch

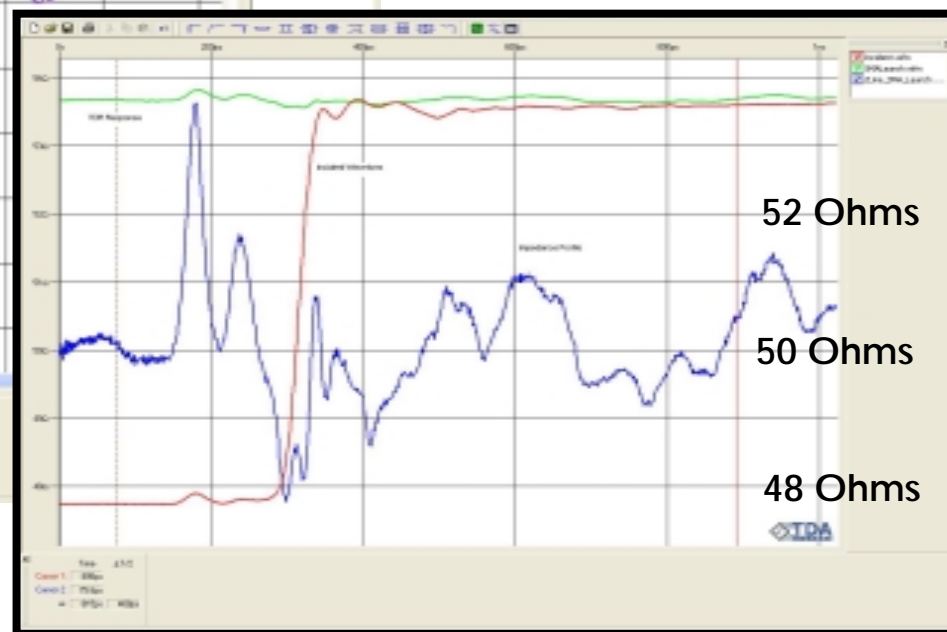
56 Ohms

50 Ohms

44 Ohms



Original



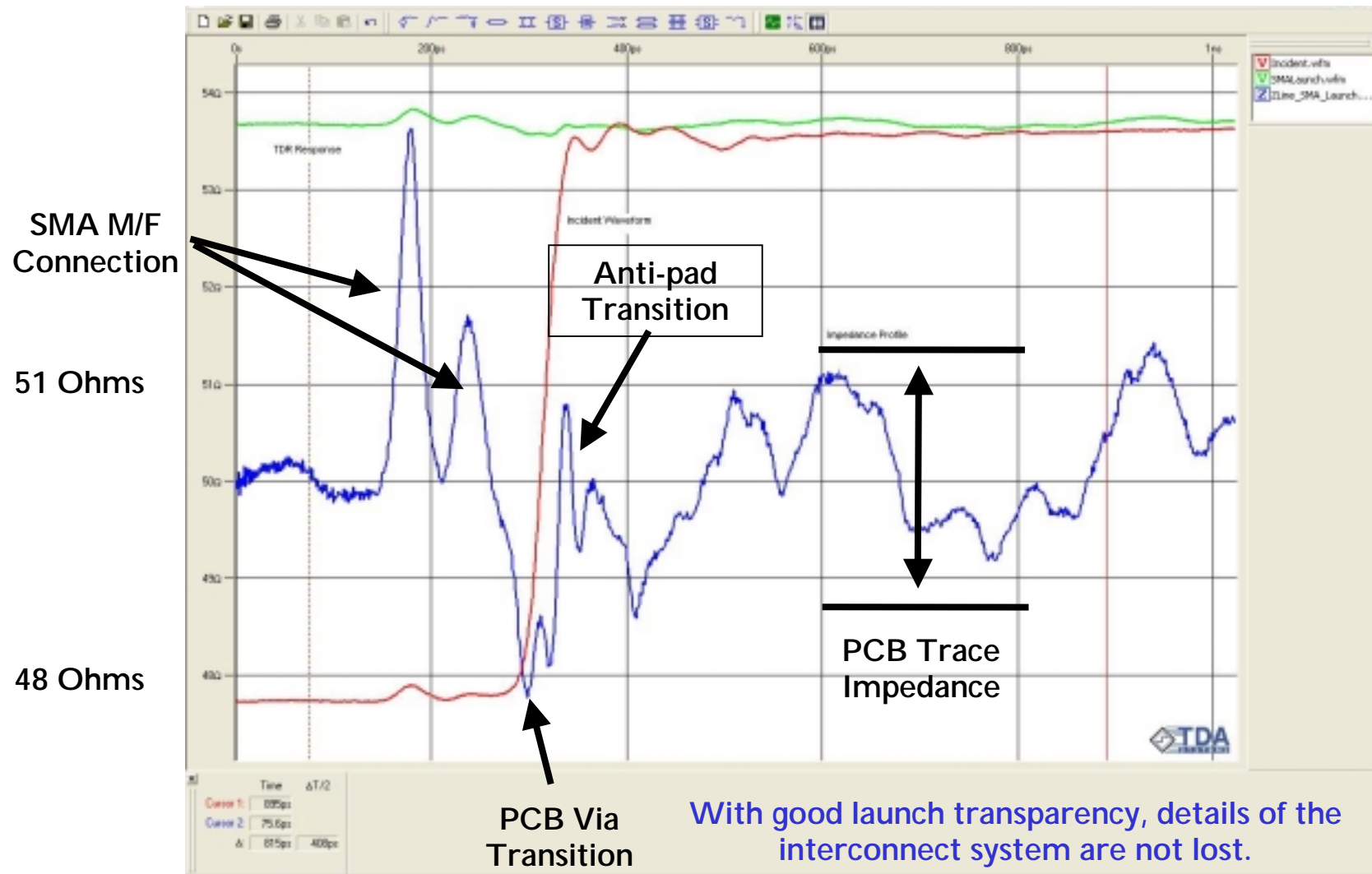
Optimized



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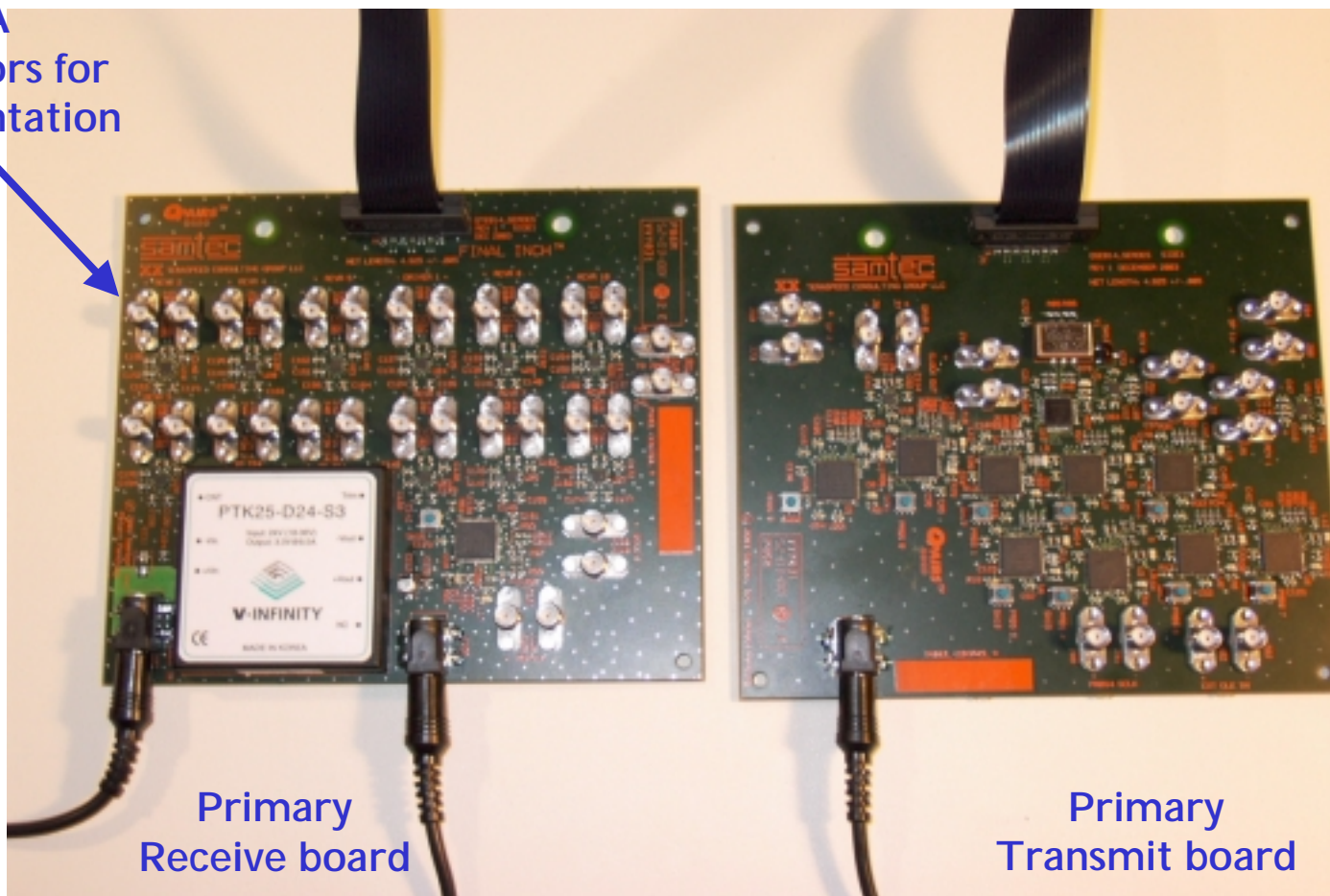
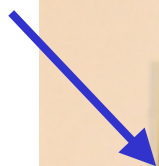


# Optimized SMA Launch



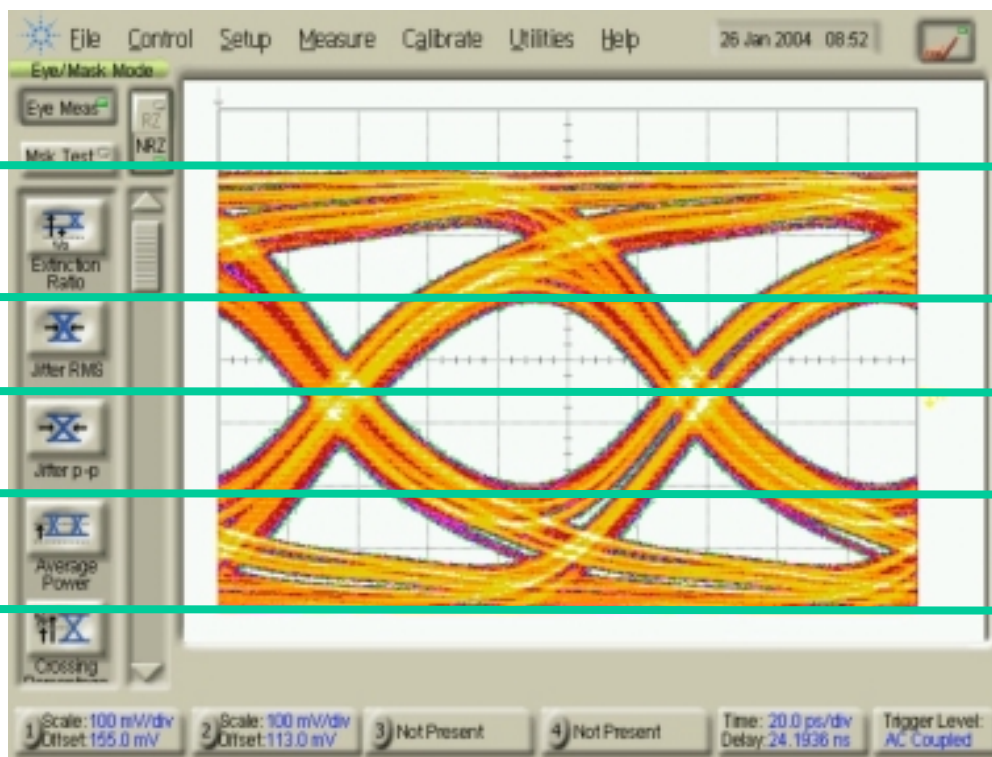
# QTE/QSE 10 Gbps Serdes Demonstration Board

SMA  
Connectors for  
Instrumentation

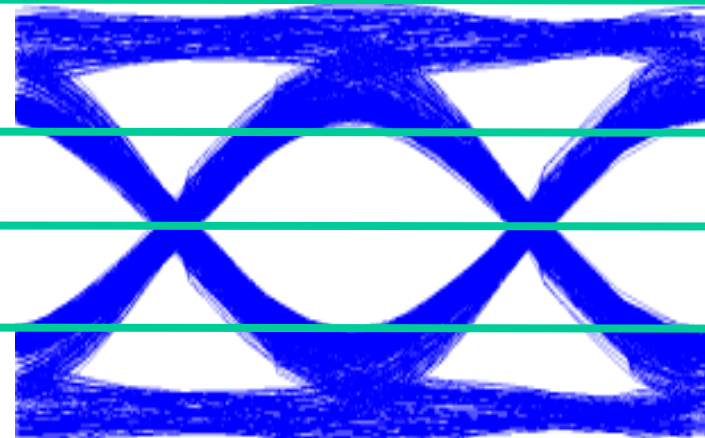


Bi-directional transmit and receive boards shown with Twin-ax cable attached.

# Measurement vs. Simulation



PRBS 7 Measurement



PRBS 7 Simulation of Modeled Interconnect w/o Driver

PRBS pattern as transmitted through Samtec QTE/QSE connectors and 10" of FR4 trace and 2 SMA.  
(9.95 Gbps actual data rate)

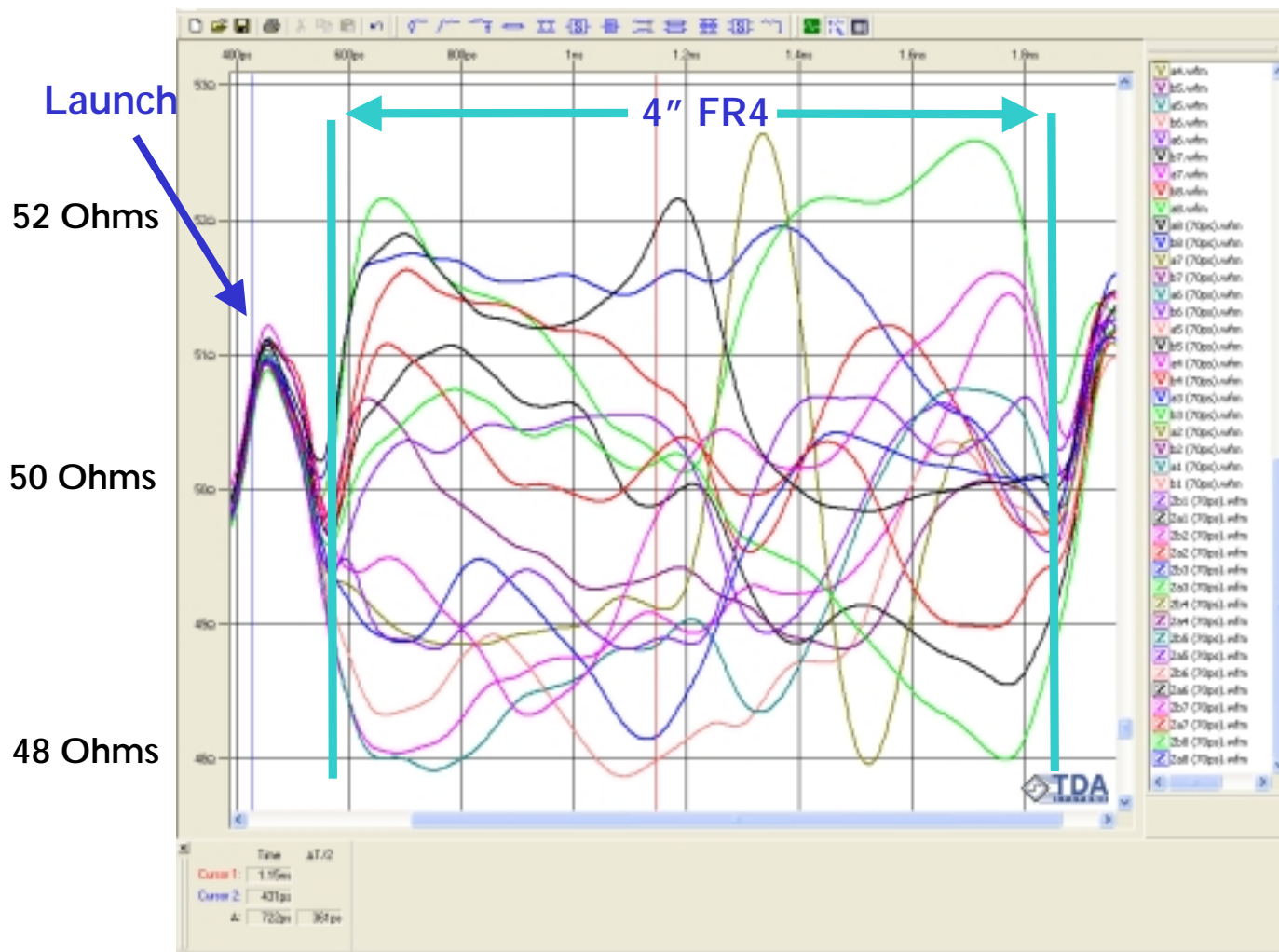
Measurement differences due to additional loss and jitter in MAX3952 driver (9ps deterministic jitter).



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# Measurement of 11-mil Microstrip Through Test Traces

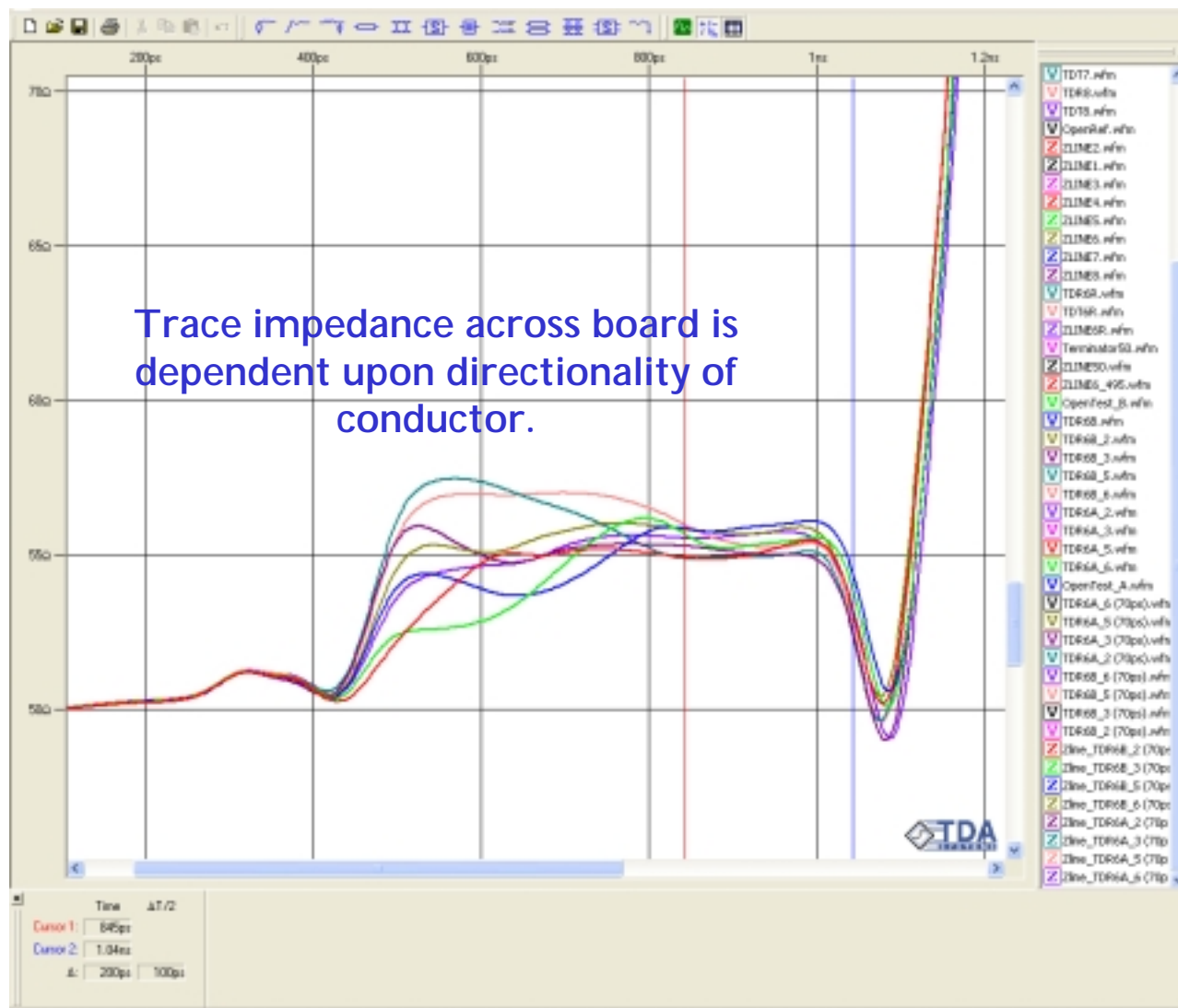


Precise launch allows accurate measurement of +/- 4% impedance variation across 16 different boards fabricated at the same time.

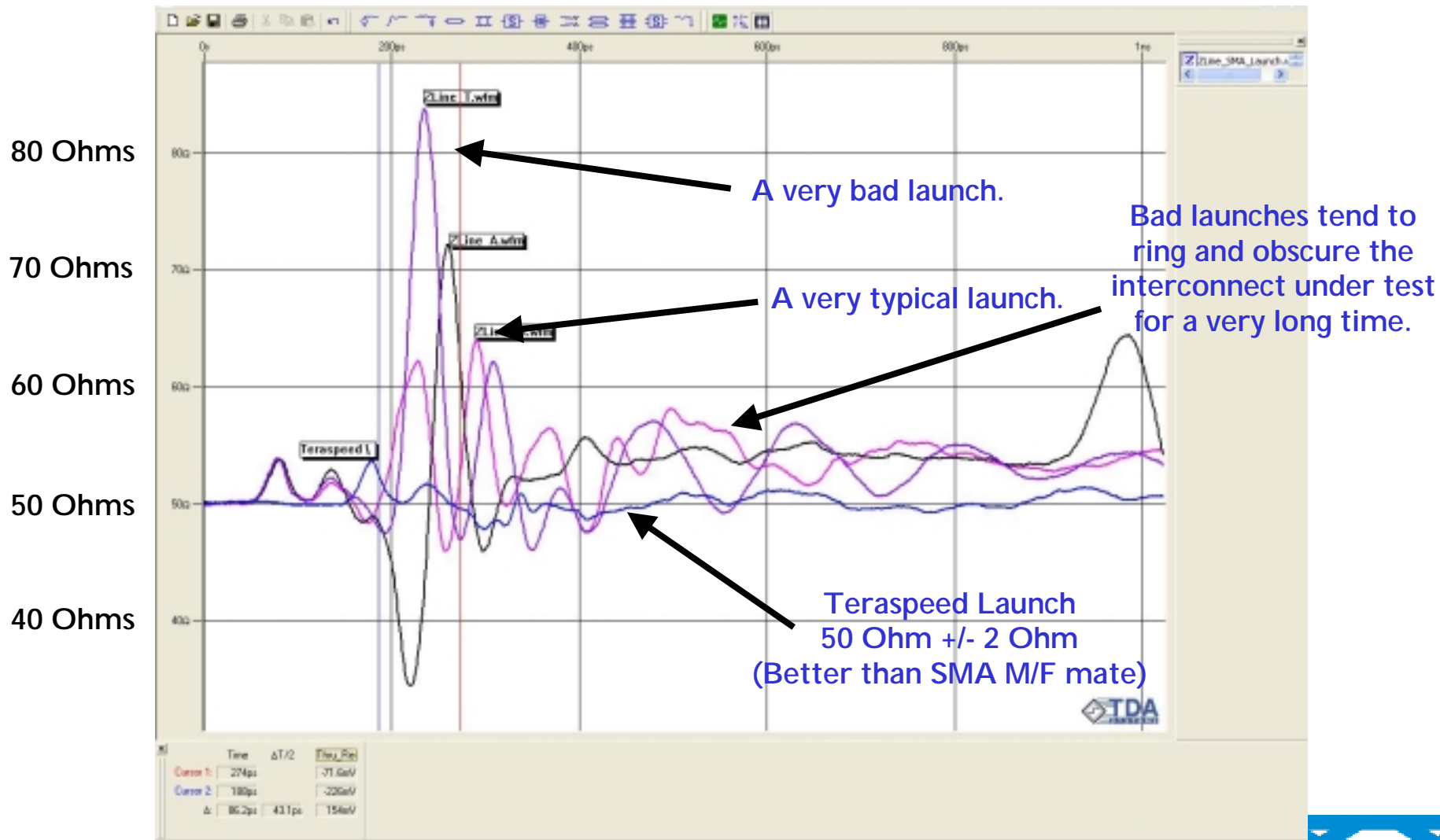
Note the variation in impedance



# Trace Directionality



# There's No Such Thing As A Free Launch



## TDR Measurement Bandwidth

- A 26 GHz SMA has an effective risetime of

$$t_{\text{rise (SMA)}} = .35/26 \text{ GHz} = 13.5 \text{ ps}$$

- With a Picosecond Pulse Labs 9 ps TDR pulse.

$$t_{\text{rise (system)}} = (t_{\text{rise (A)}})^2 + (t_{\text{rise (B)}})^2$$

$$t_{\text{rise (system)}} = (9\text{ps})^2 + (13.5 \text{ ps})^2$$

$$t_{\text{rise (system)}} = 16.2 \text{ ps}$$

Effective Measurement  
Bandwidth

21.5 GHz



## For More Information

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