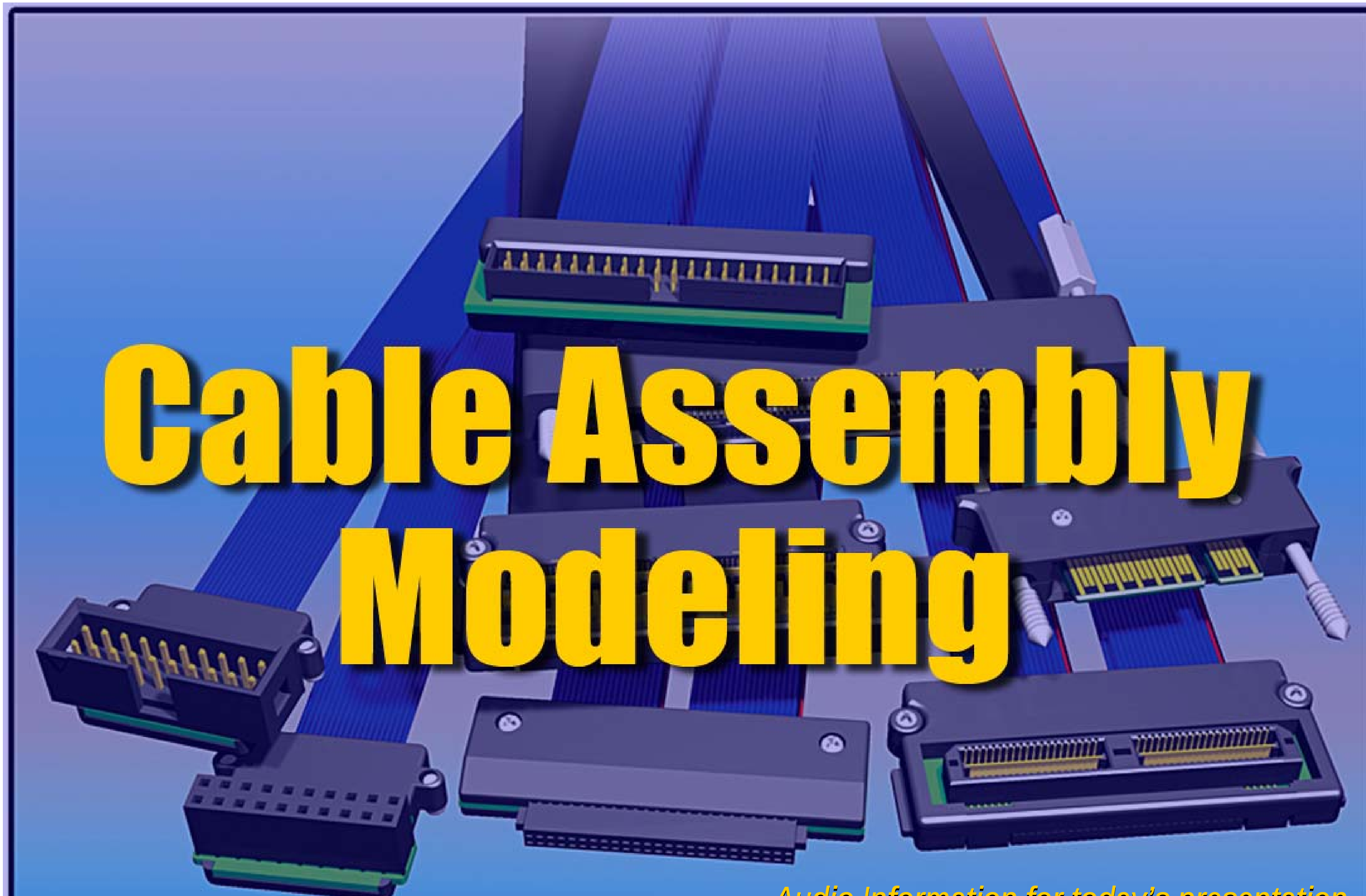
Cable Assembly Modeling



Audio Information for today's presentation

- Dial: 1-800-944-8766 (US)
- Dial: 1-317-713-0002 (Outside of US)
- Use Conference Code 61969

Cable Assembly Models for SPICE Simulation

June 29, 2006

11:00am EST

Duration: 1 hour

Outline

- Motivation for Developing Cable Assembly Models
- Lossy Transmission Lines
- Developing the Cable Assembly Model
- Using the Cable Assembly Model
- Useful Resources

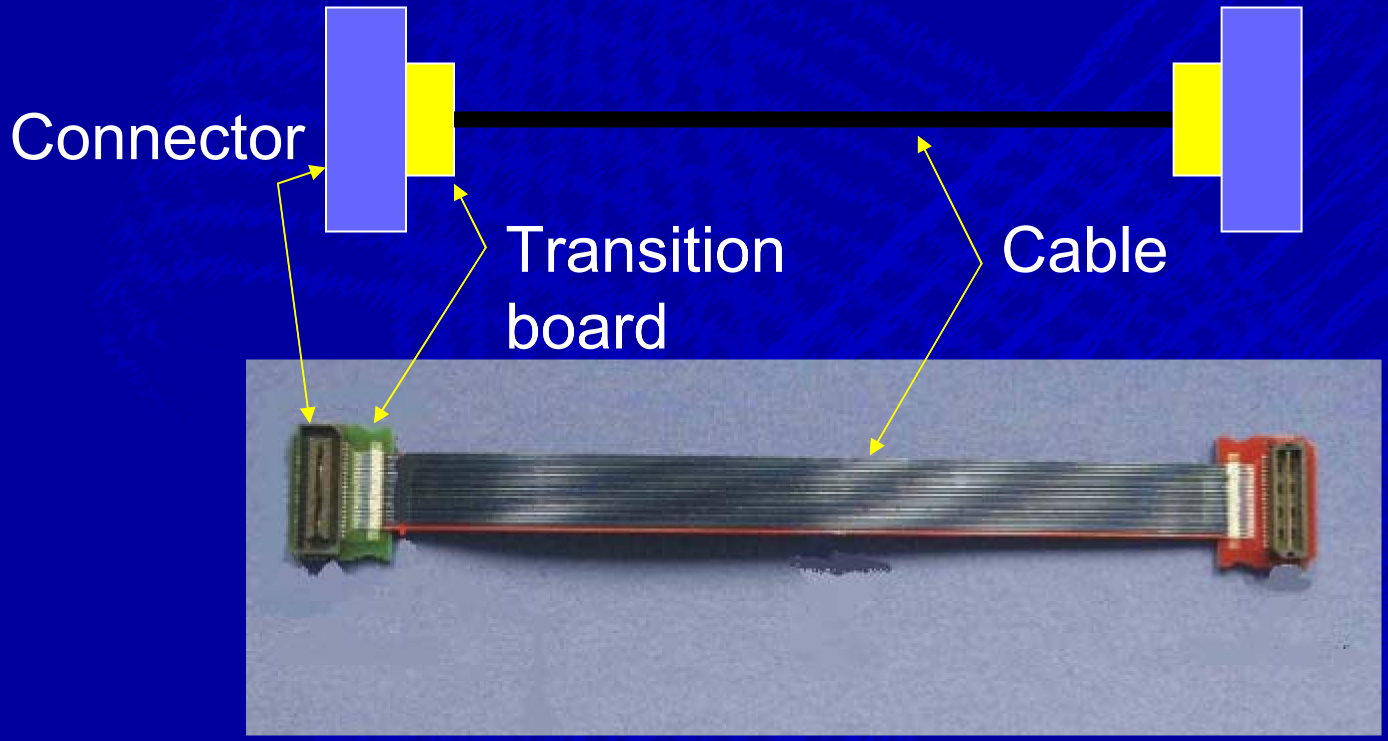
Motivation for Developing Cable Assembly Models

- **Our Customers Request Them!**
  - Emphasis is on Customer Service [easy]
    - We logged 1,500 SI service requests in 2005
  - Requests are for SPICE, IBIS or S-Parameter models of connectors and cable assemblies

Motivation for Developing Cable Assembly Models

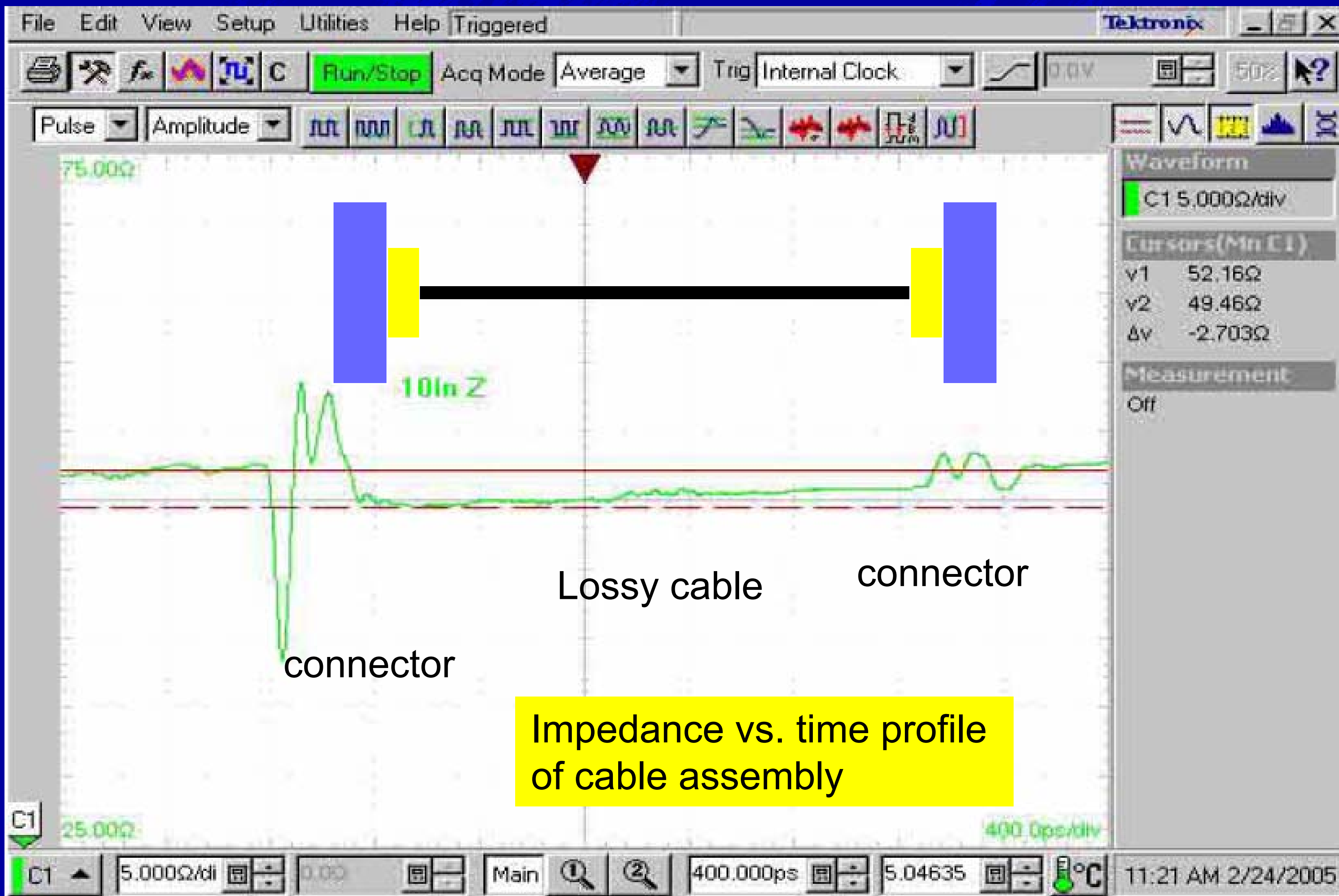
- **Integral to Design Decisions**
  - What AWG cable is required?
  - What length cable will work?
    - What is the frequency response?
    - What does the eye pattern look like at “x” Gbps?

Developing the Cable Assembly Model



- **The cable assembly does not always have a transition board, but it will always have a transition area from cable to connector**

Developing the Cable Assembly Model



Developing the Cable Assembly Model

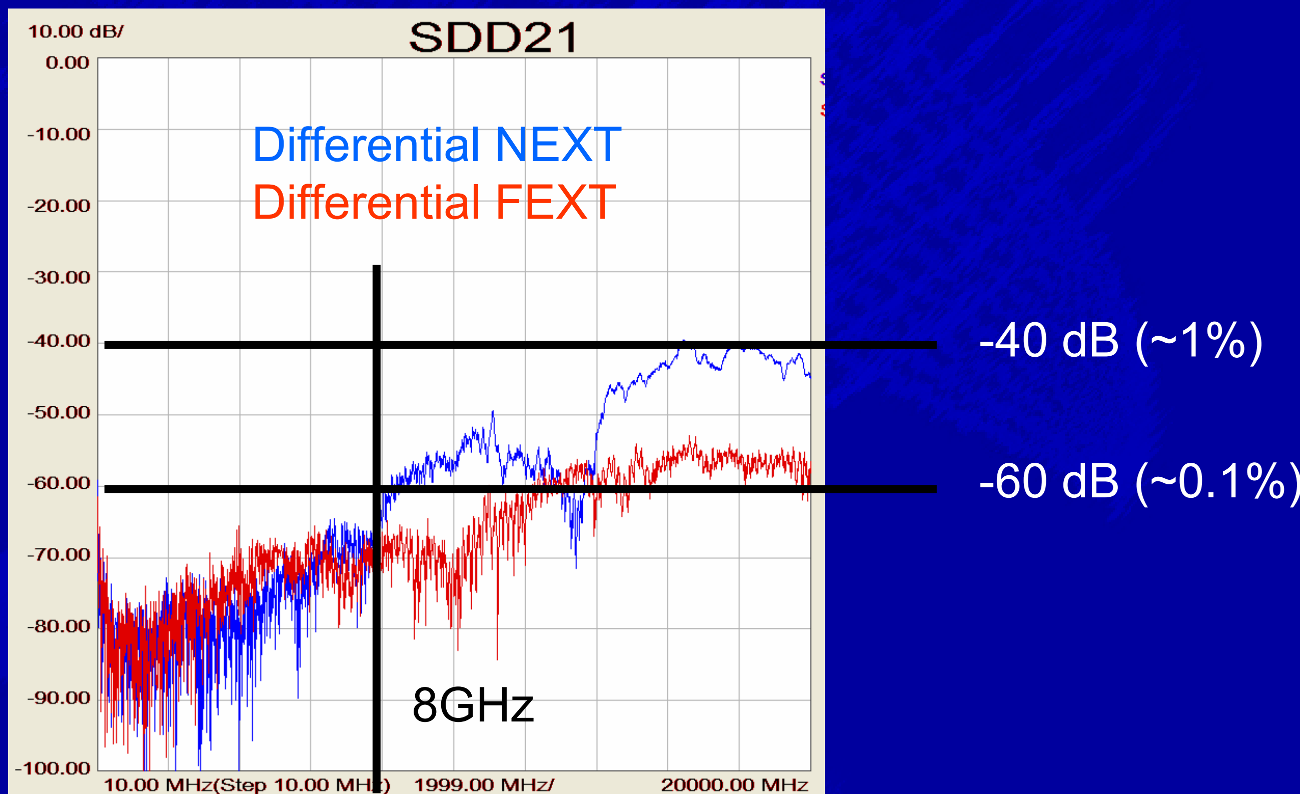
- **Approach - Collection of models**
  - Raw cable
  - Connectors
  - Transition/paddle boards
- **As opposed to a measured S-Parameter library which is not length scalable, modular, or useable in generic SPICE**

Developing the Cable Assembly Model

- **Assumptions**
  - Valid for risetimes of 50 ps or slower
    - Determined by the complexity of paddleboard and connector model
  - Crosstalk in the cable is zero

Developing the Cable Assembly Model - Raw Cable

- **Assumptions**
  - No crosstalk in the cable



Measured differential crosstalk in 30AWG ribbonized twinax

Lossy Transmission Lines

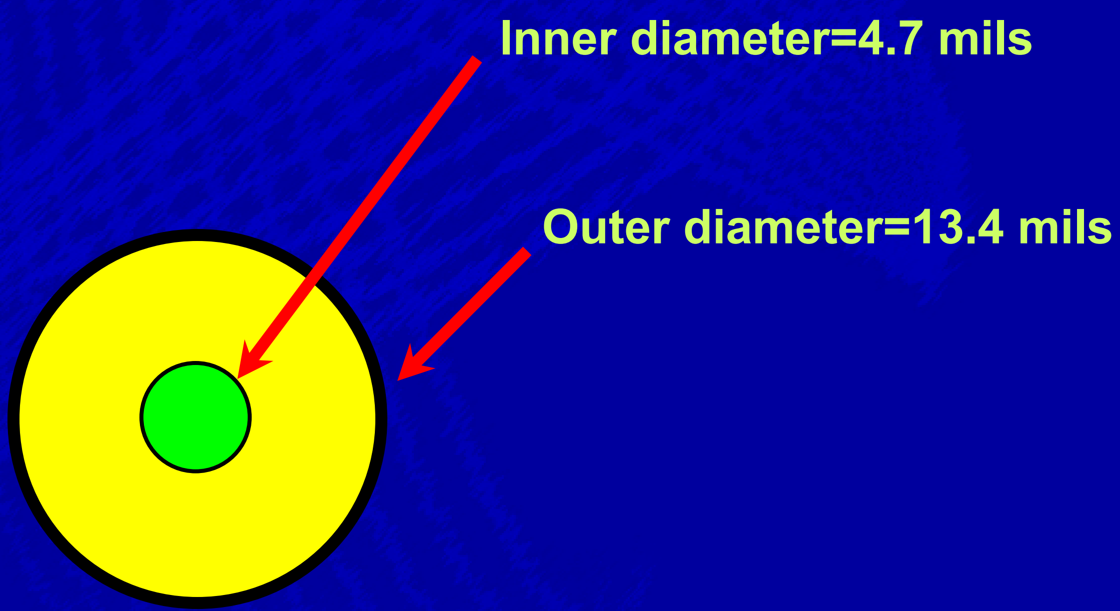
- **Lossless transmission line**
  - Impedance $$Z_0 = \sqrt{\frac{L}{C}}$$
  - Prop Delay $$t_{pd} = \frac{d\sqrt{\varepsilon_r}}{c}$$
  - Output Risetime $$t_{out} = t_{in}$$
- **Lossless transmission lines are well described by simple equations**

Lossy Transmission Lines

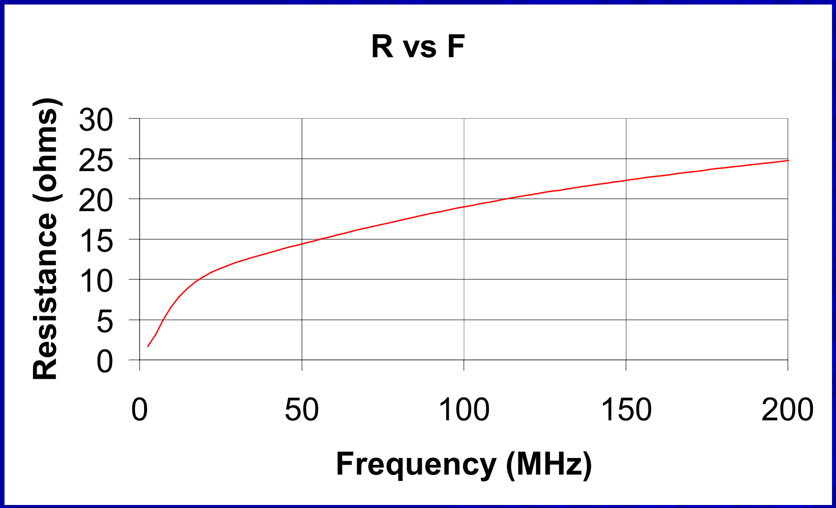
- **Lossy transmission line** **(actually the low-loss approximation)**
  - Impedance $$Z_0 = \sqrt{\frac{R + j\omega L}{G + j\omega C}}$$
  - Group Delay $$GD = \frac{d\varphi}{dt}$$
  - Step Response Time $$t_r \approx \frac{0.35}{BW}$$
- **Lossy transmission lines are much more complex to describe with simple equations in the time domain. Low loss approximations are the normal.**

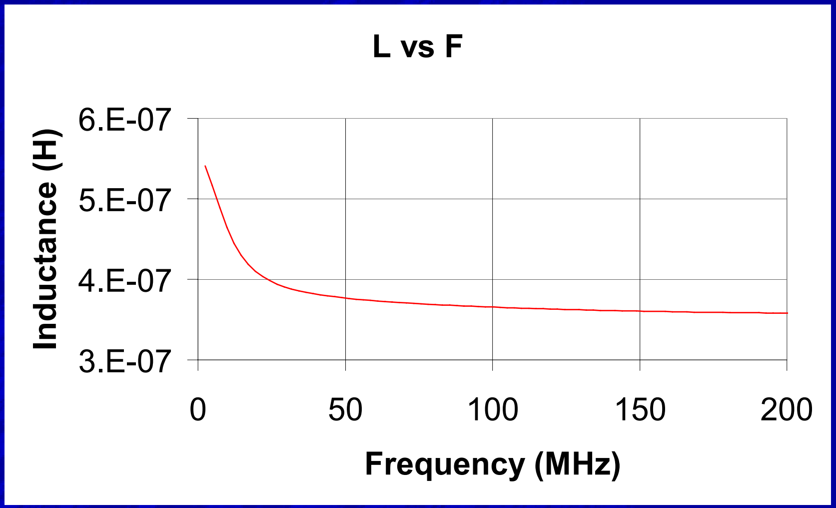
Lossy Transmission Lines

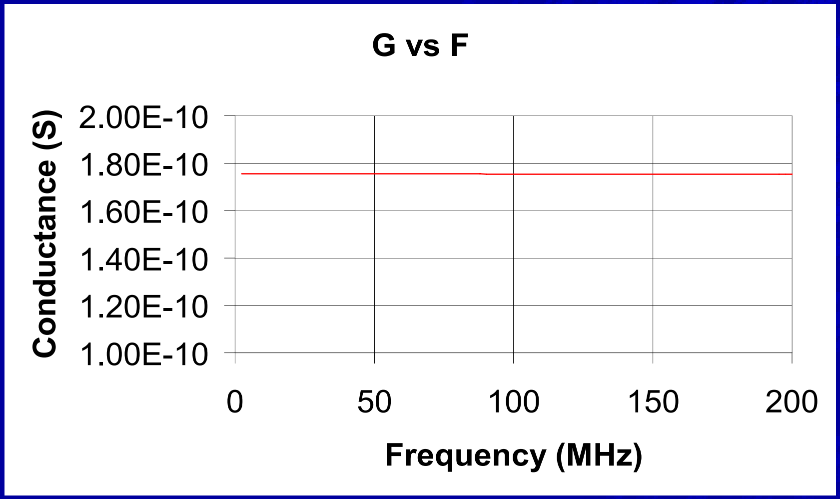
- To illustrate lossy cable behavior, consider a 38 AWG Coax
- Extract the RLGC parameters for this cable using IConnect

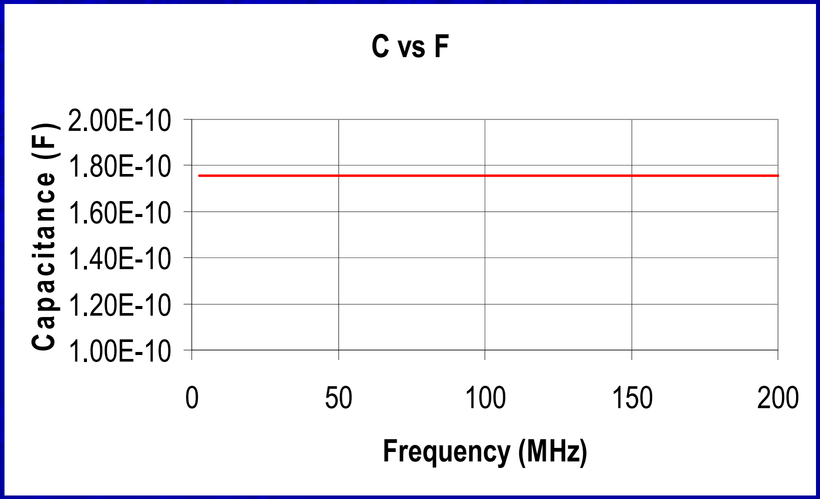


RLGC Behavior for 38 AWG Coax Cable



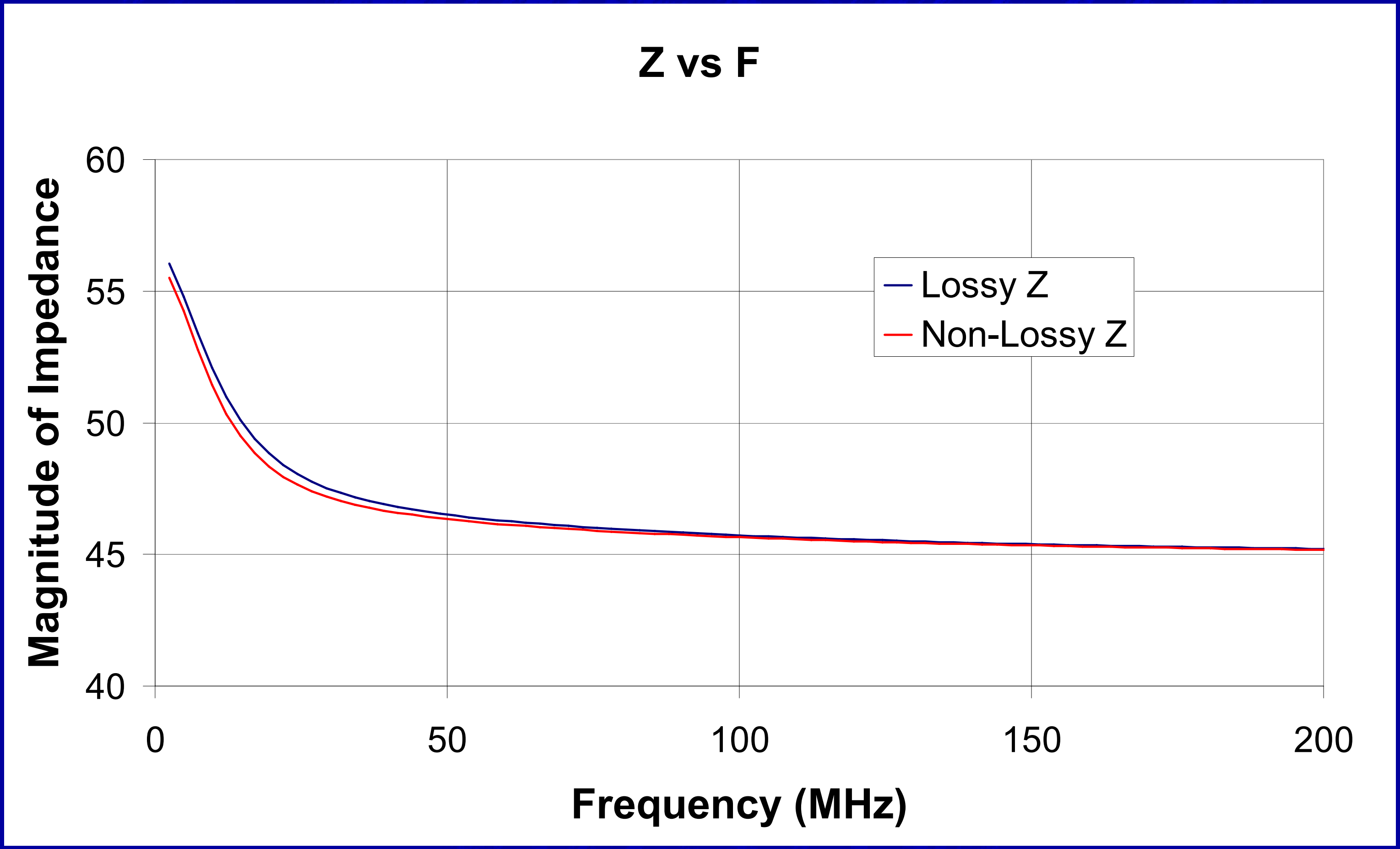






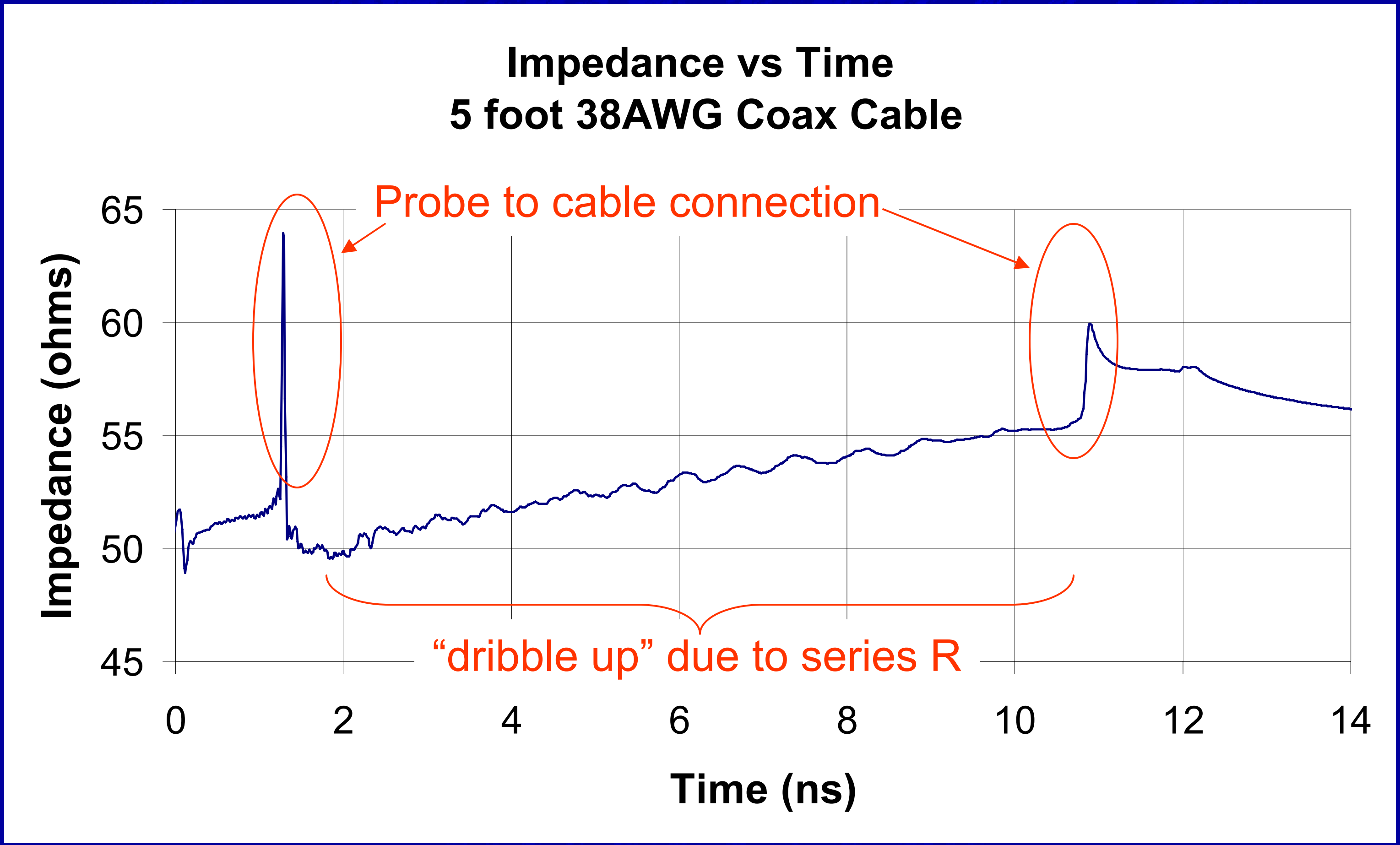
Lossy Transmission Lines

- **Characteristic Impedance**



Lossy Transmission Lines

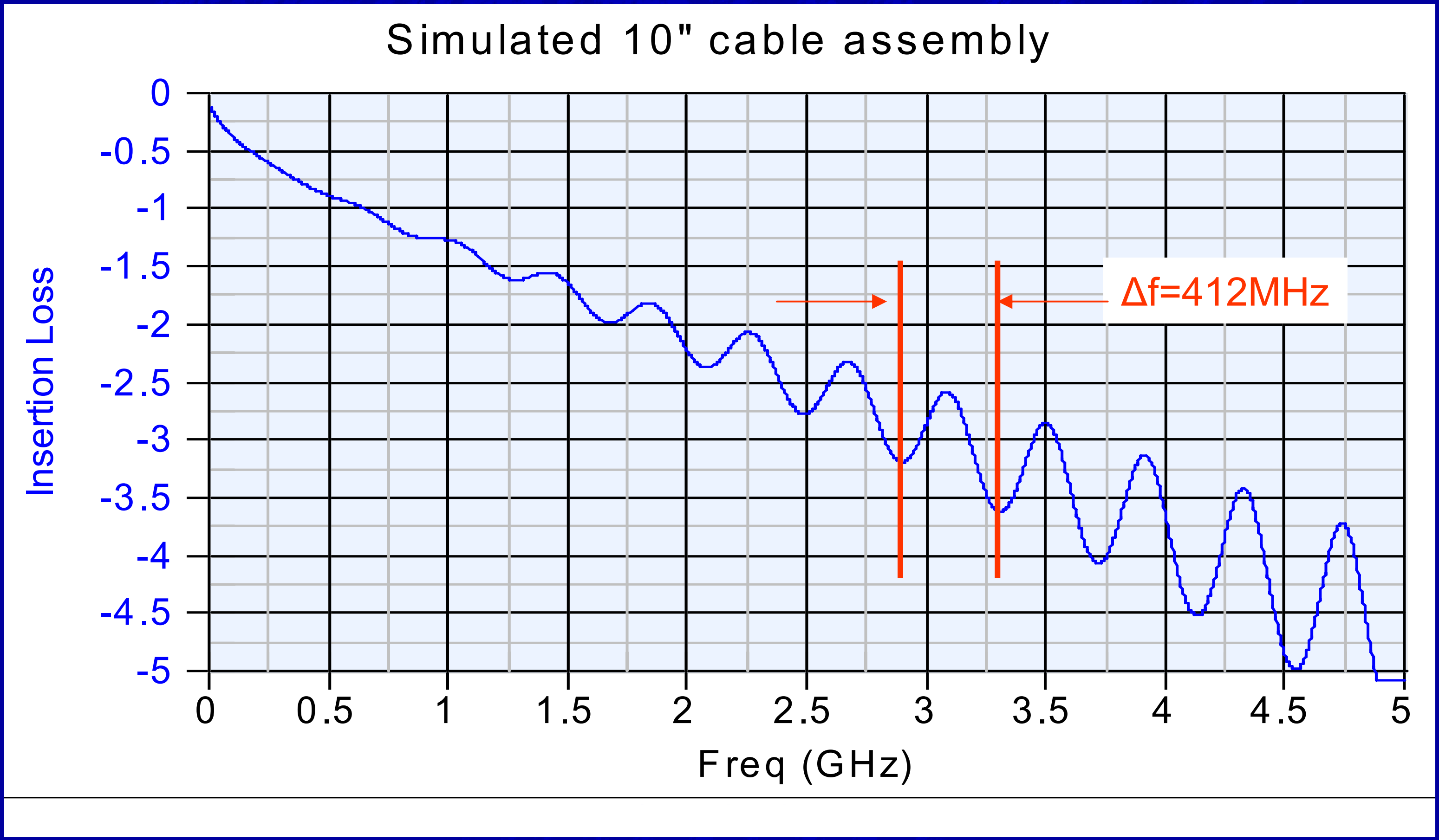
- TDR profile showing lossy response



Lossy Transmission Lines

- **Summary**
  - R and L change (significantly at lower frequency)
  - Characteristic Impedance varies with frequency
    - Higher at low frequency
    - Skin effect cause R and L to vary
    - Change in L with frequency dominates characteristic impedance behavior
  - Resistance causes “dribble up” on TDR profile

Resonance Effects and Length

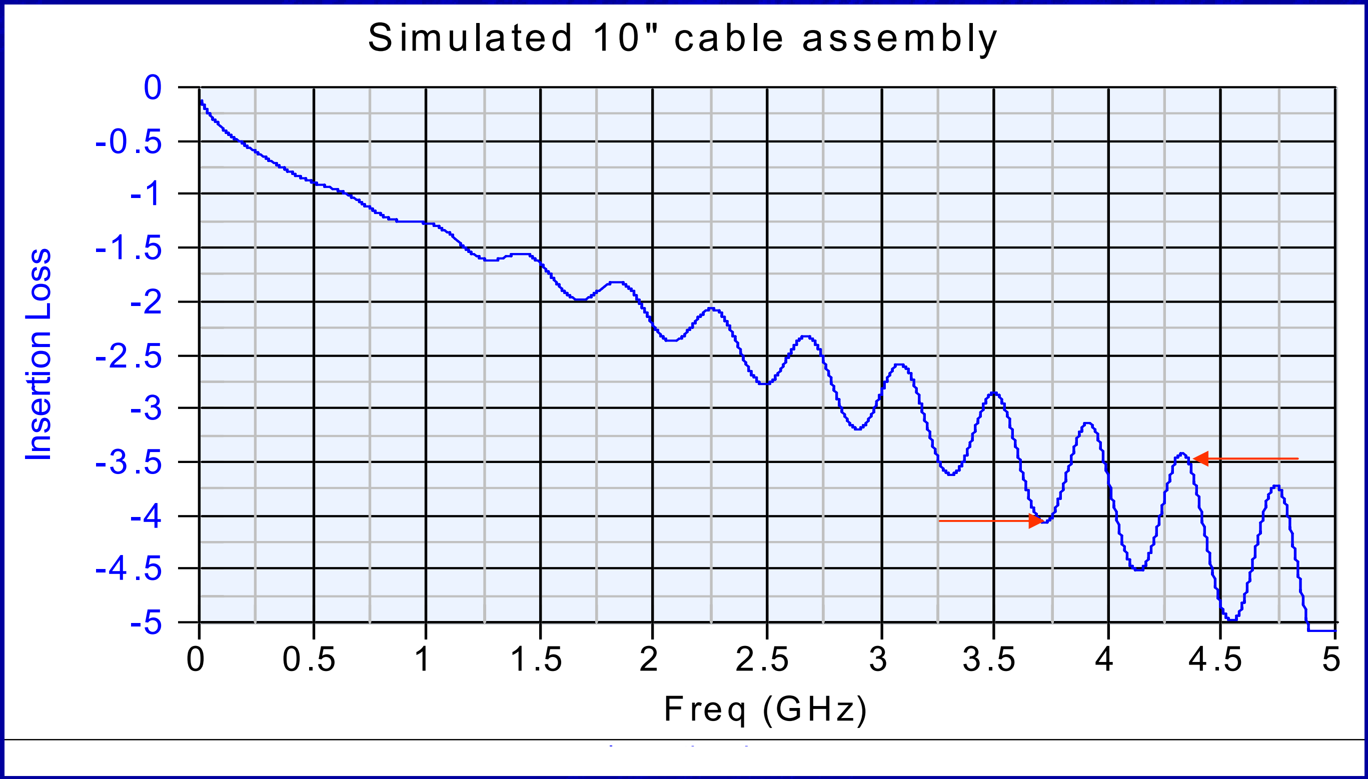


Resonance Effects and Length

- **Impedance mismatch from connectors cause ripple in the insertion loss profile at $l=\lambda/2$**
- **For a 10”cable assembly with $\varepsilon_r=2$, $\Delta f=V_p/\lambda$**
  - ε_r =relative dielectric constant
  - V_p=phase velocity
  - λ=wavelength
  - Δf=frequency spacing between nulls in insertion loss profile
- **Δf=412 MHz (refer to previous slide)**

Resonance Effects and Length

- Resonance effects tend to be more pronounced in low loss (short) cable assemblies
- Explains why cable assembly loss can be greater at lower frequency
- A length scalable model allows users to easily investigate resonance behavior



S-Parameters

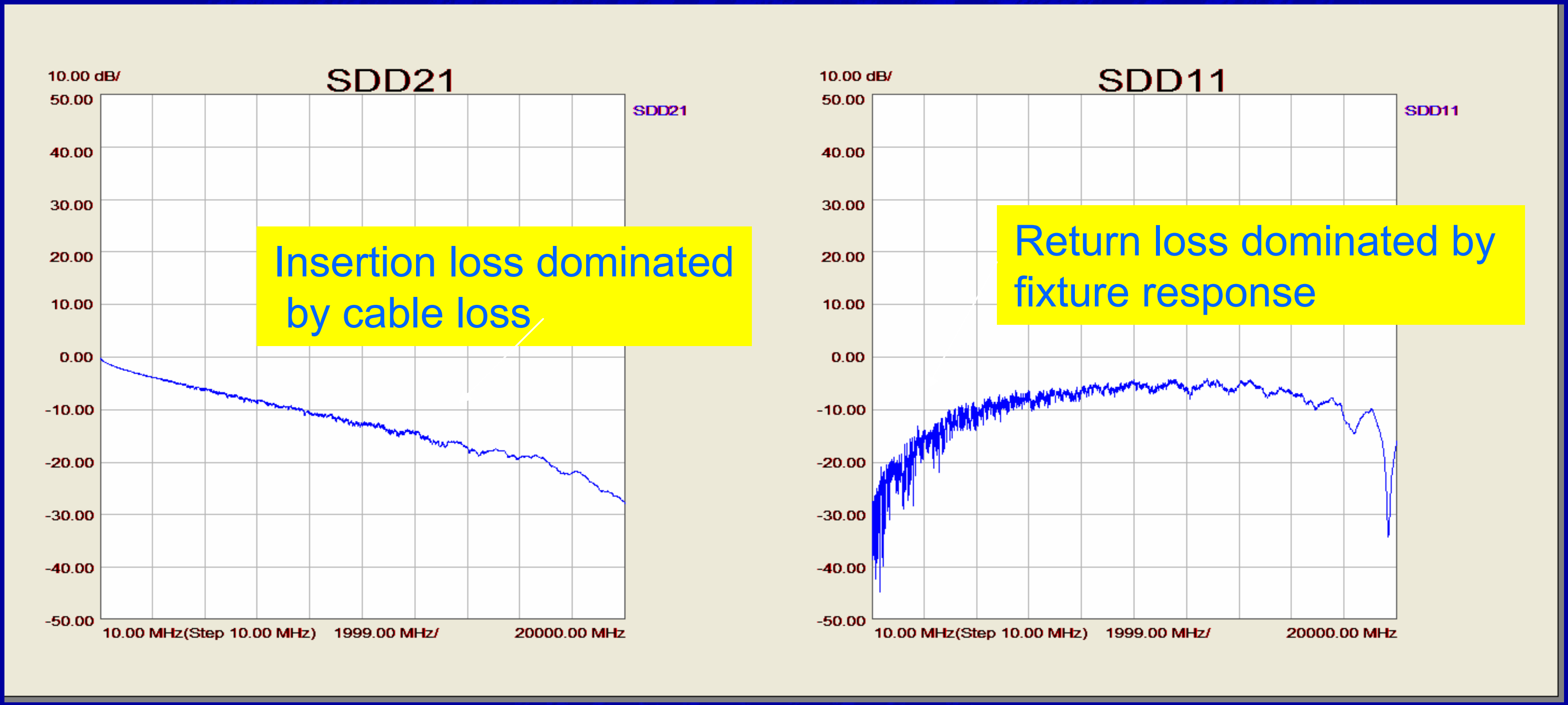
- **Measurement based model can be developed with frequency domain tools**
  - Vector Network Analyzer
    - Export a Touchstone model (S-Parameters)
    - De-embed fixturing effects
  - HSPICE can operate with Touchstone models
    - Reasonable simulation times
- **But care must be taken using S-Parameters in a time domain simulation…**

S-Parameters

- **Passivity**
  - Passive network cannot show energy gain
  - Passivity violations not uncommon when de-embedding test board effects
- **Causality**
  - Output response vs. prop delay
  - Kramers-Kronig Relationship (loss tangent must change with frequency for broadband simulations)
  - Dielectric modeling becomes involved
- **Symmetry**
  - For a 2 port network, S21=S12
  - VNA Calibration errors can result in asymmetric behavior

Real Data Response

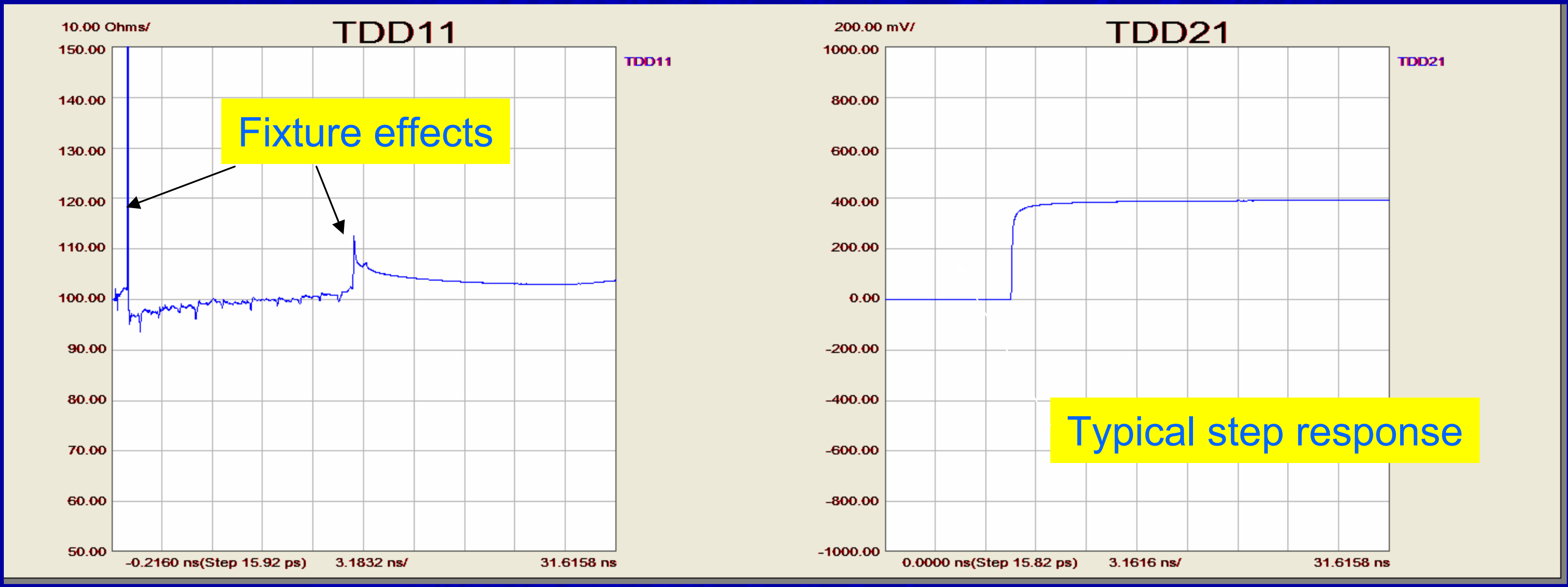
- **30 AWG Twinax with test fixtures**
  - 10MHz-20GHz, 10MHz step



Differential insertion and return loss from measurements

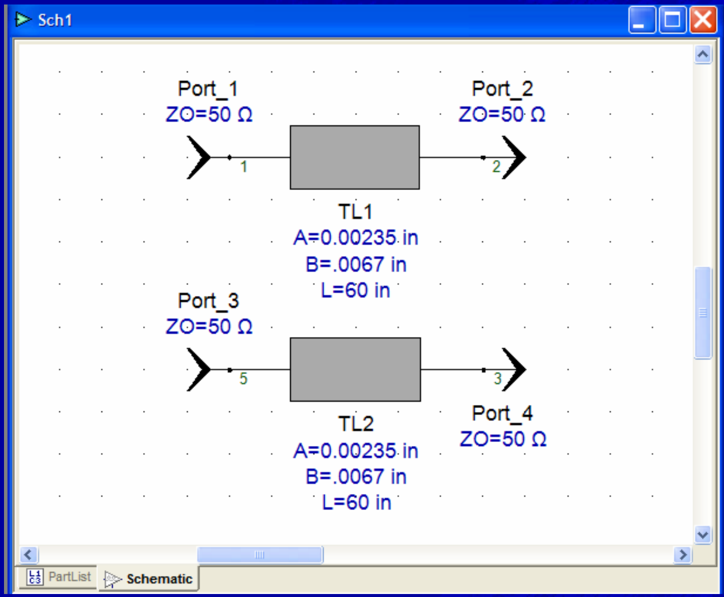
Real Data Response

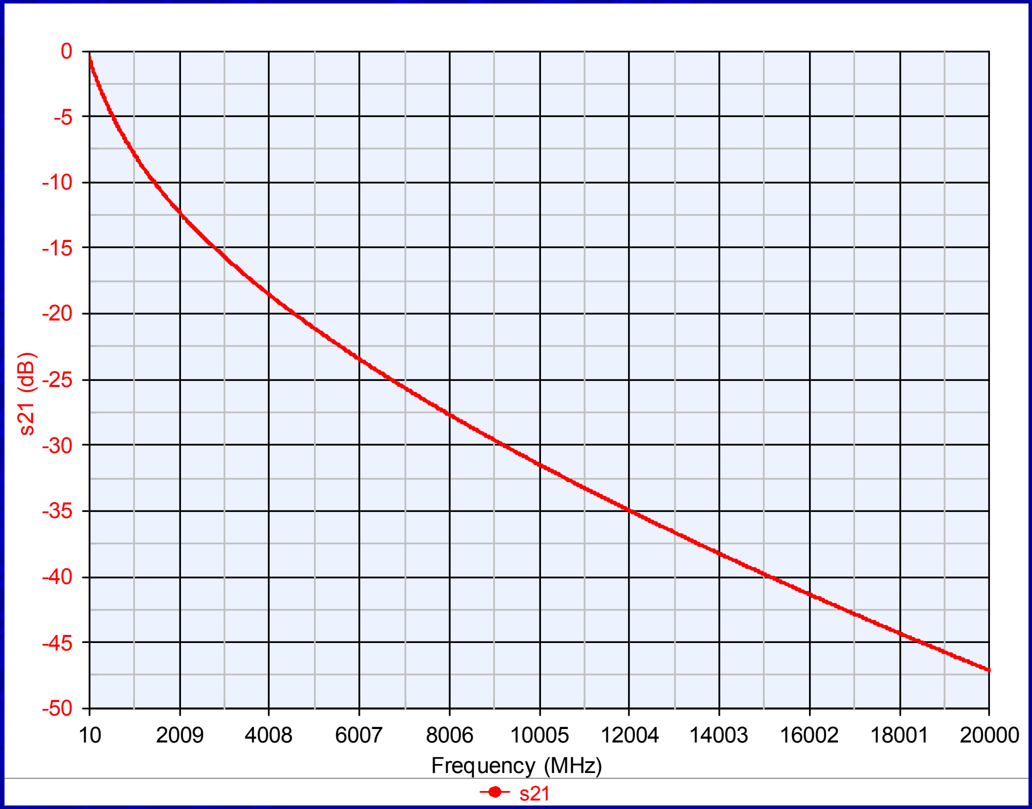
- **30 AWG Twinax with test fixtures**
  - 10MHz-20GHz, 10MHz step



Differential impedance and transmission response transformed from measurements

Consider a Simulated Cable Response (Genysis CL1 Model)

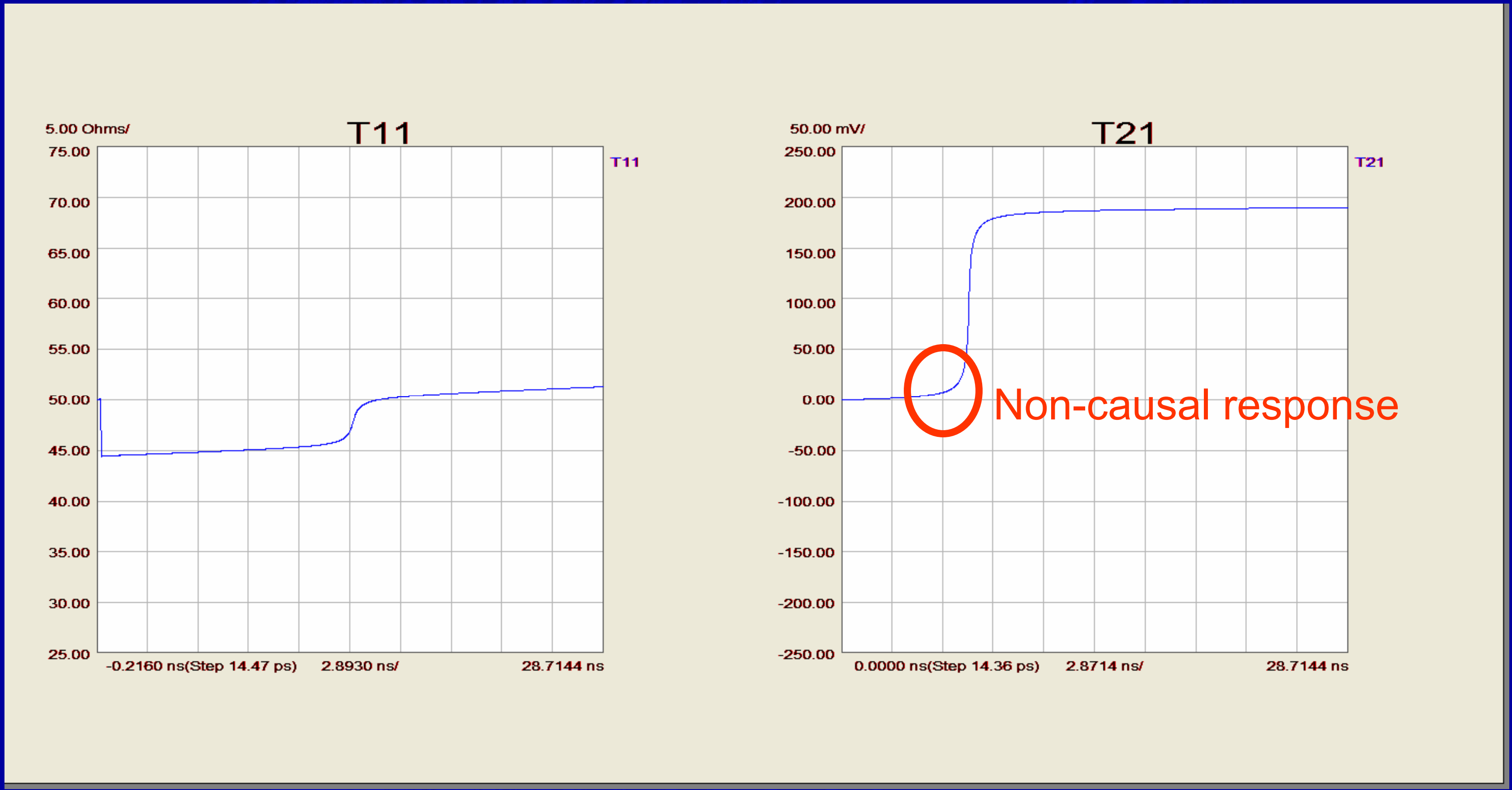




10 MHz-20GHz, 10 MHz step, 2000 points

Dielectric constant =2, loss tangent 0.002

Transform the Simulated Frequency Domain Response to the Time Domain using PLTS



10 MHz-20GHz, 10 MHz step, 2000 points
Dielectric constant =2, loss tangent 0.002

Very reasonable looking S-Parameters can be non-causal!

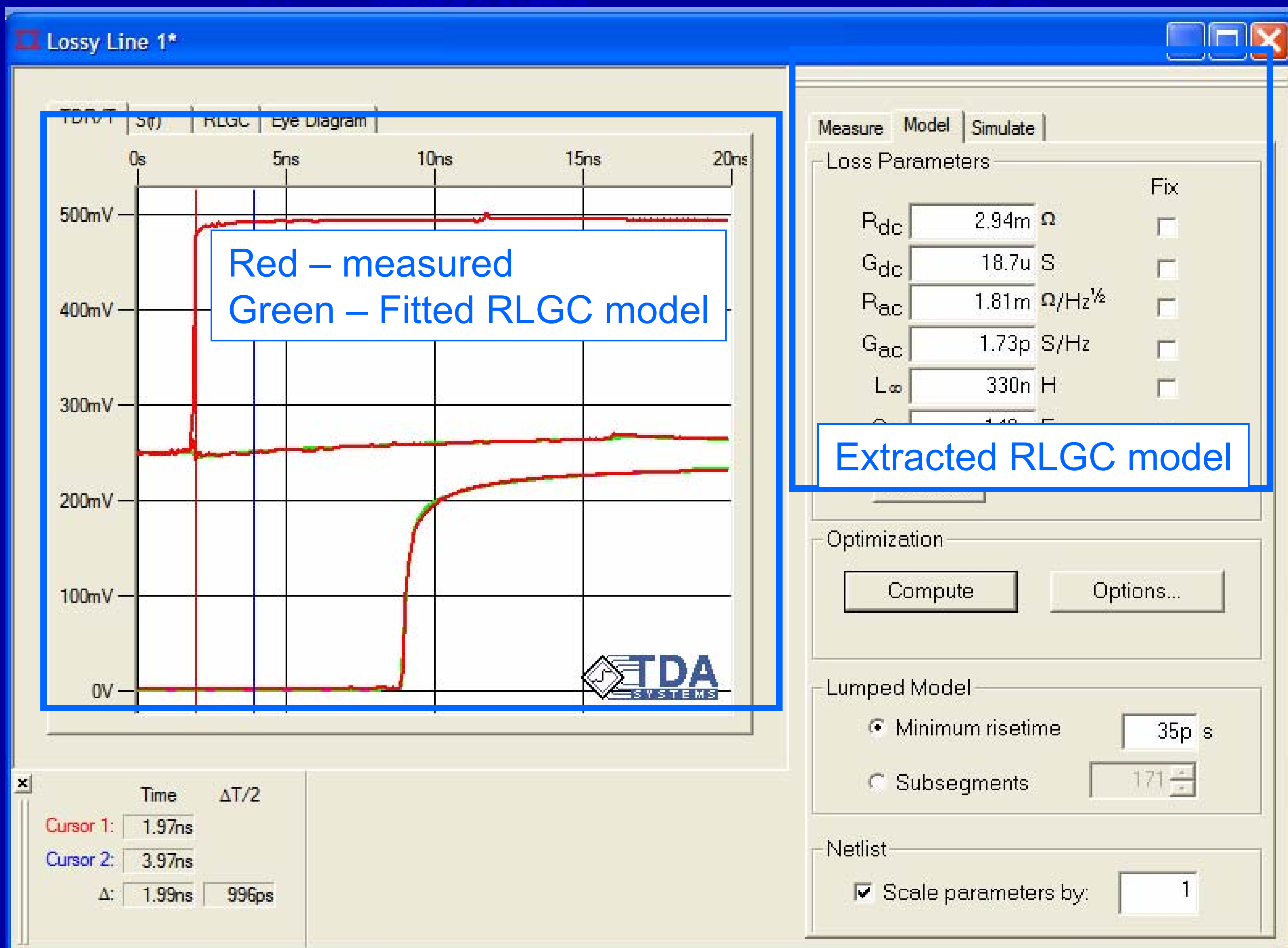
Summary on S-Parameters

- **S-Parameter files can have problems**
  - Accuracy of de-embedding
  - Causality problems with some simulation tools
  - Symmetry issues

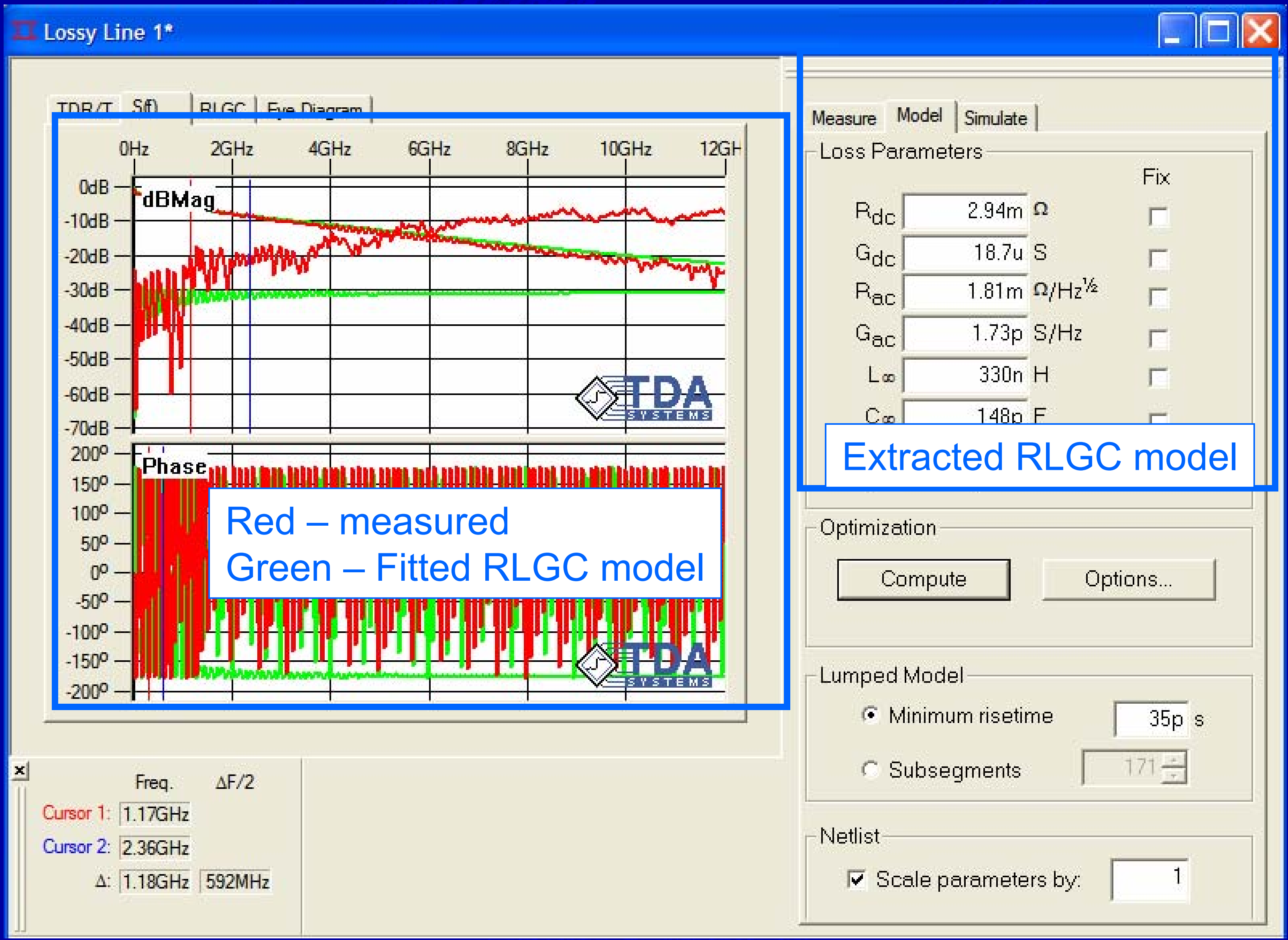
Extracting a Lossy Cable Model with IConnect

- **Tektronix IConnect and MeasureXtractor**
- **Why we use IConnect?**
  - IConnect has a “lossy line model” which fits an RLGC model to the measured data
  - Model parameters can be manually or automatically adjusted
  - Resultant model is “well behaved” in HSPICE
  - Model extracted from measured data

Extracting a Lossy Cable Model with IConnect



Extracting a Lossy Cable Model with IConnect



Using the Cable Model

- **Simulation times for lossy transmission lines can be extensive…**
- **Consider a lossy transmission line extracted from measurements using TDA IConnect**
- **We have several model types we can consider**
  - W-Element
  - S-Parameters
  - Ladder Network
- **Which one should we use?**

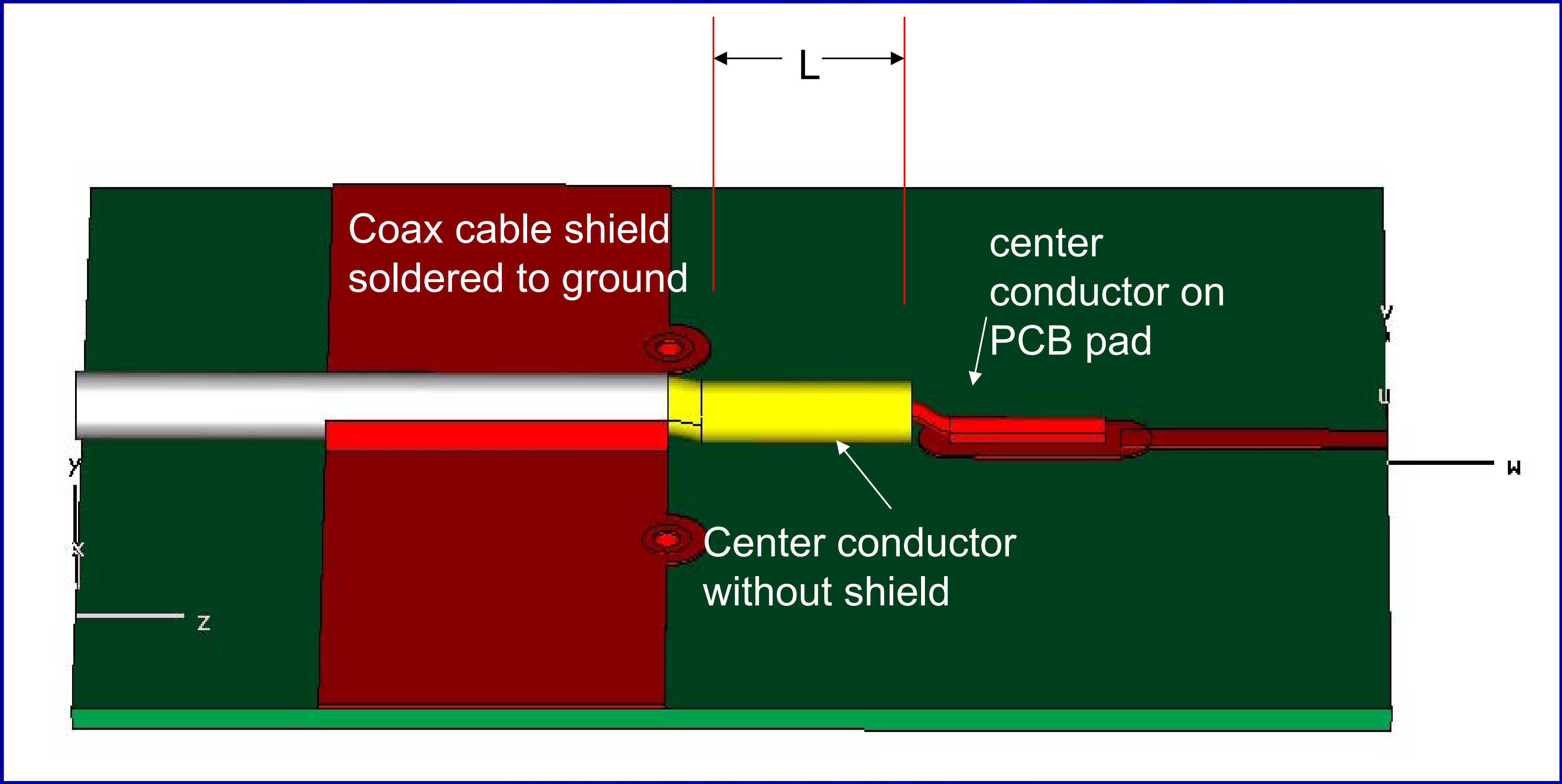
Using the Cable Model

- **Simulation Details**
  - 5 foot length of 30AWG Twinax cable
  - Model derived from measurements using TDA IConnect
  - 1 psec step time and 20 nsec simulation time (20K time steps)
  - Pentium IV processor, 2.8GHz clock speed
- **W-Element (HSPICE) – 18.64 seconds**
- **S-Parameter (HSPICE) – 21.36 seconds**
- **Ladder Model (HSPICE) – 3567 seconds (~1 hour)**
  - While ladder model will run in Generic SPICE, it will take a long time

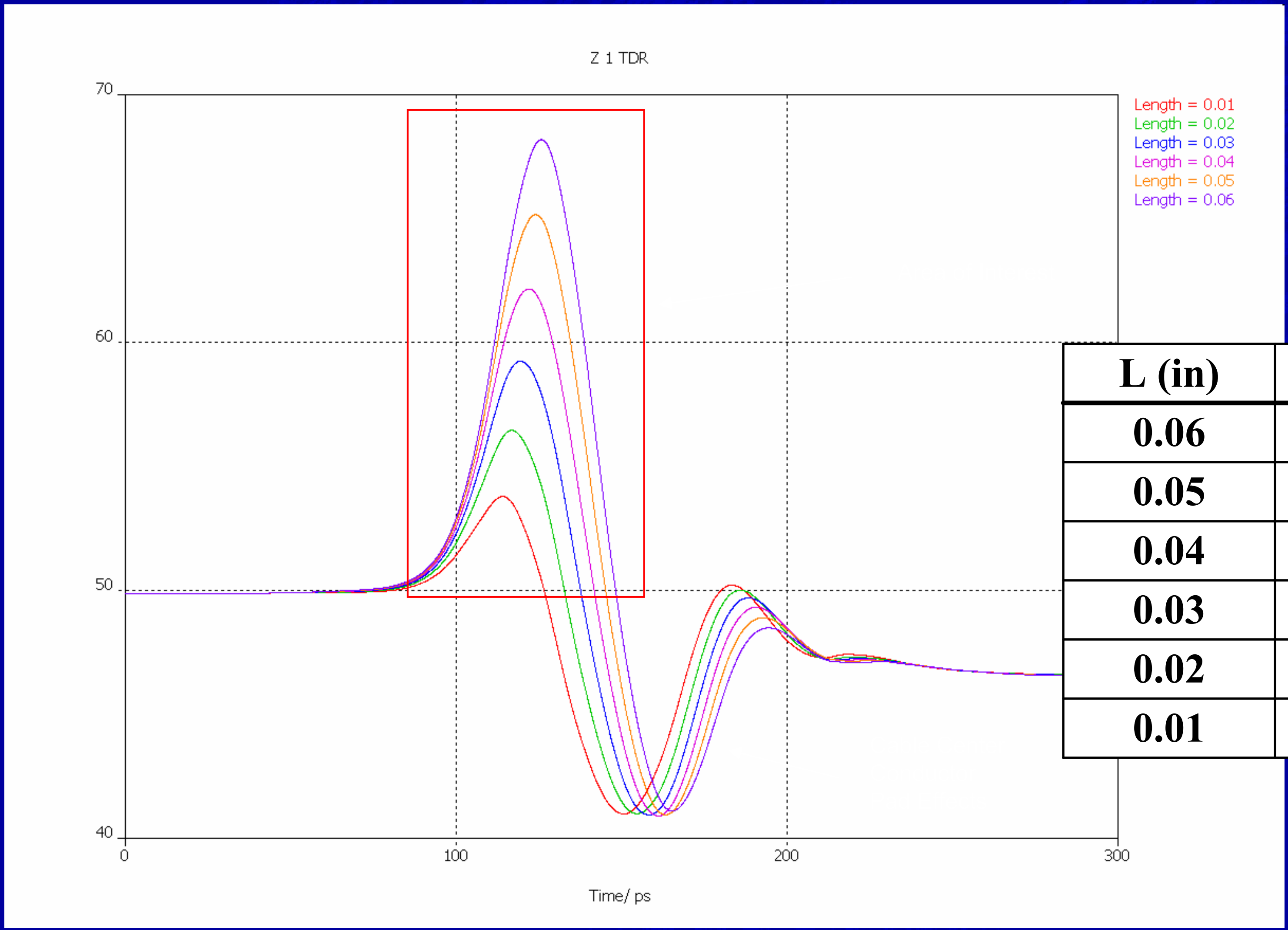
Cable Assembly Model

- **Connector and paddle board models developed using 2D FEA approach**
  - Valid for structures with minimal or well understood 3D effects
  - Yields passive, causal circuit which simulates well in SPICE
- **Cable termination response dominated by termination board**
  - Inductive effect as center conductor leaves the Coax shield
  - Capacitive effect as center conductor solders to pad on termination card

CST Microwave Simulation of Coax Cable Termination



CST Microwave Simulation Results – Coax Cable Termination

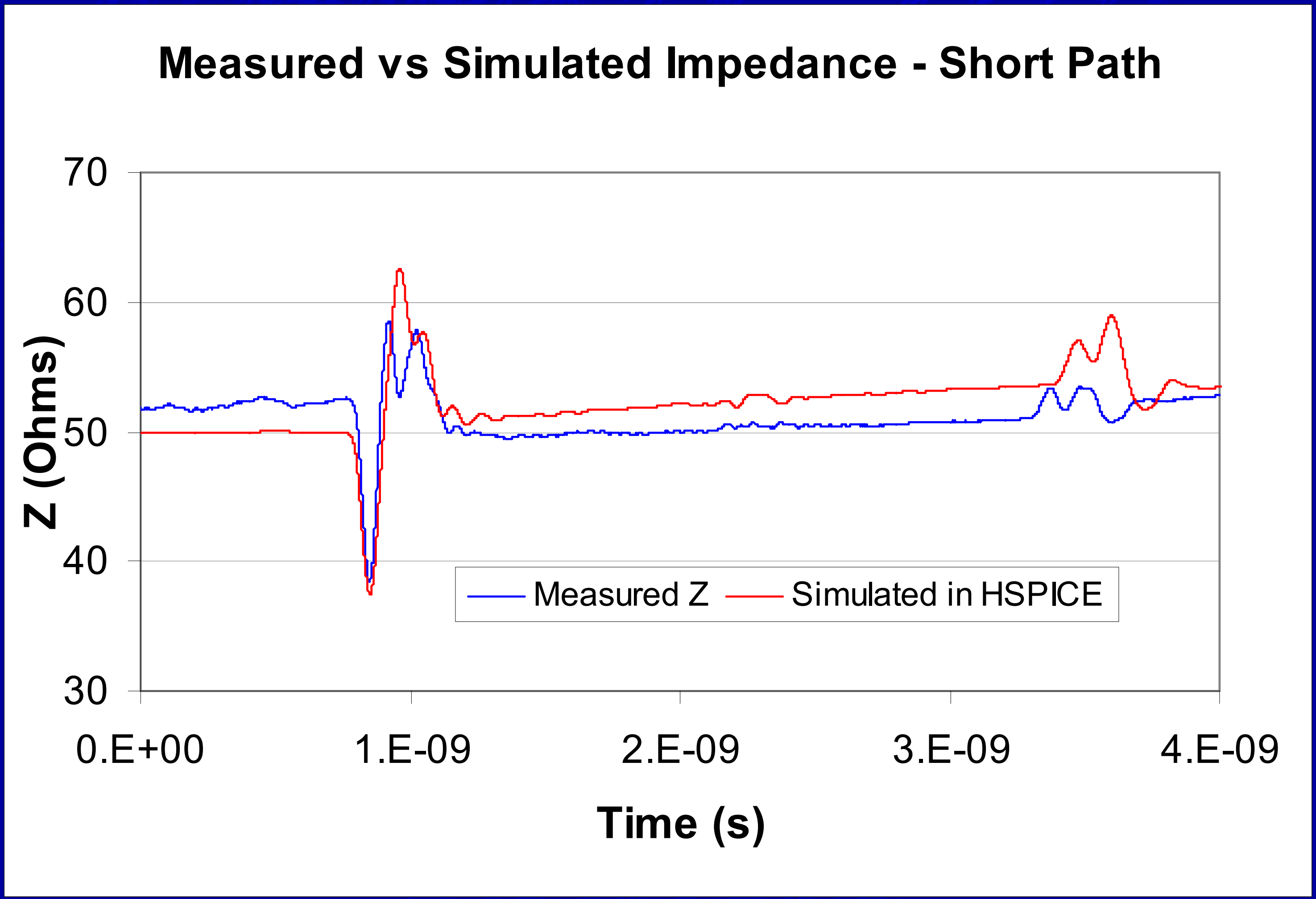


L (in)	Z(t) (Ω)
0.06	68.2
0.05	65.2
0.04	62.1
0.03	59.3
0.02	56.5
0.01	53.8

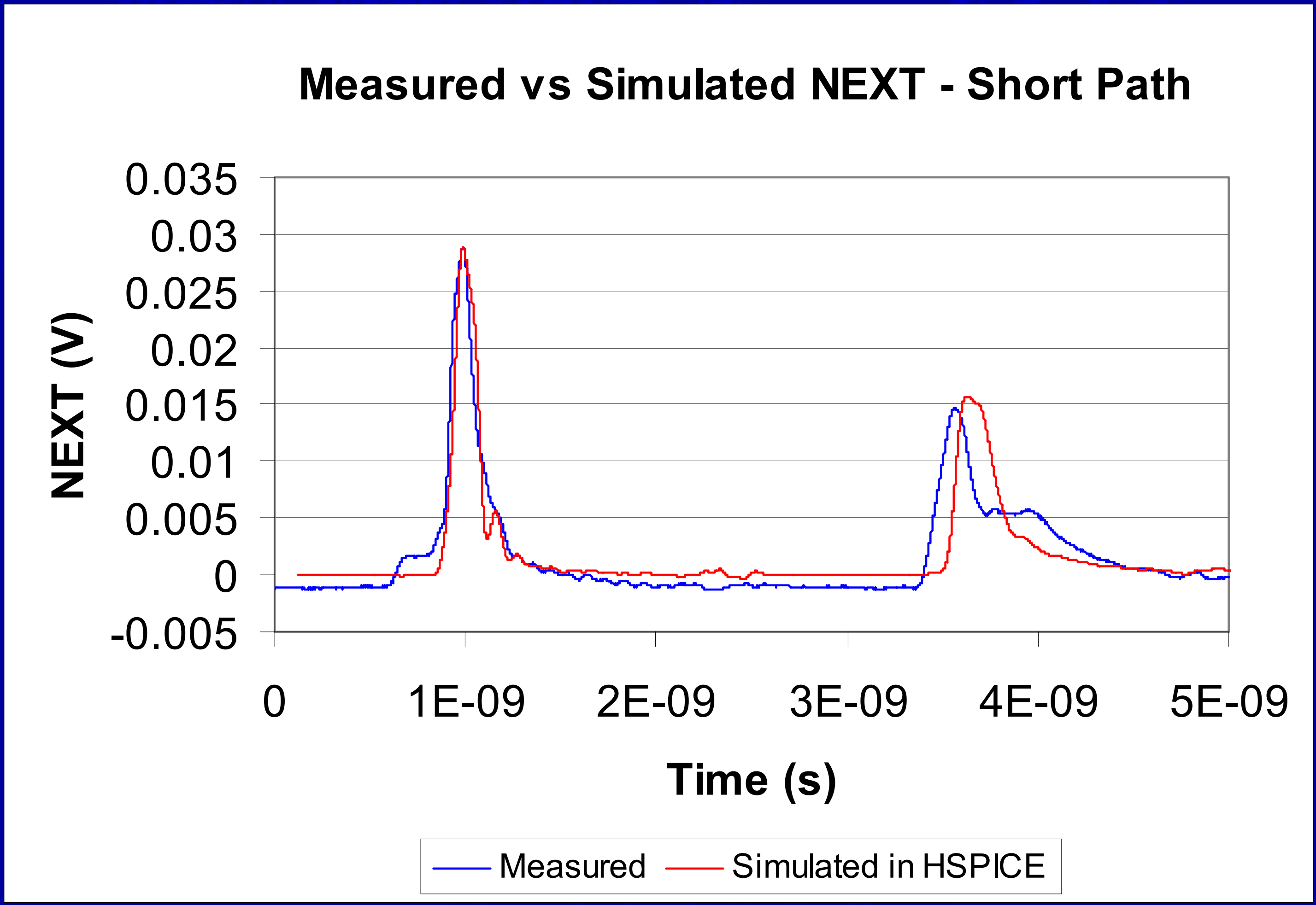
Using the Cable Assembly Model

- **Typical Assembly Model**
  - Two connector sub circuits with 20 inputs/outputs
  - Two transition board sub circuits with 20 inputs/outputs
  - 20 lossy cable sub circuits
- **A Readme file which describes**
  - How to vary the cable length
  - Pin mapping
- **Test Circuits**
  - S-Parameter simulation
  - Step response simulation for impedance/TDR data

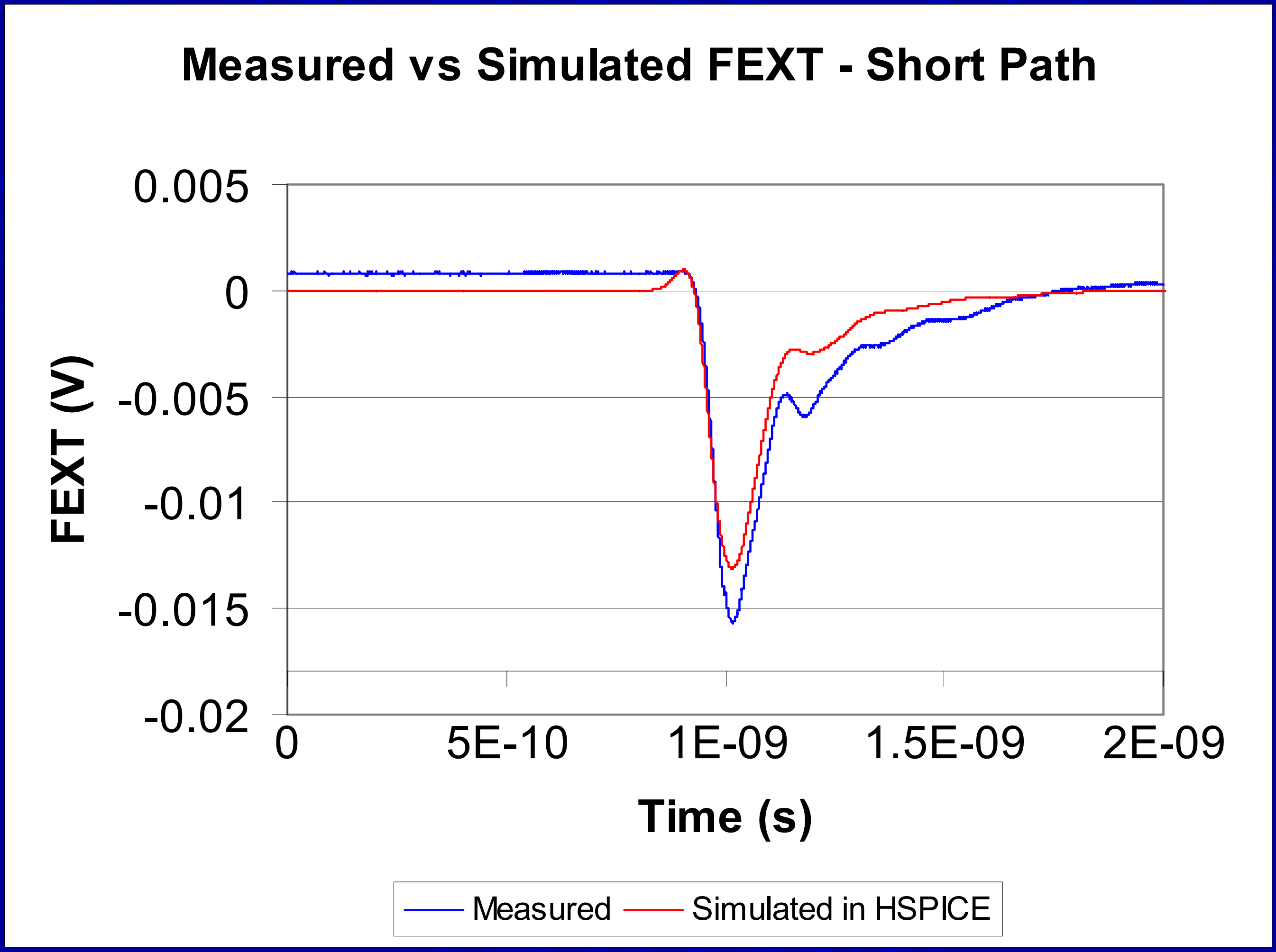
Impedance (risetime=100ps)



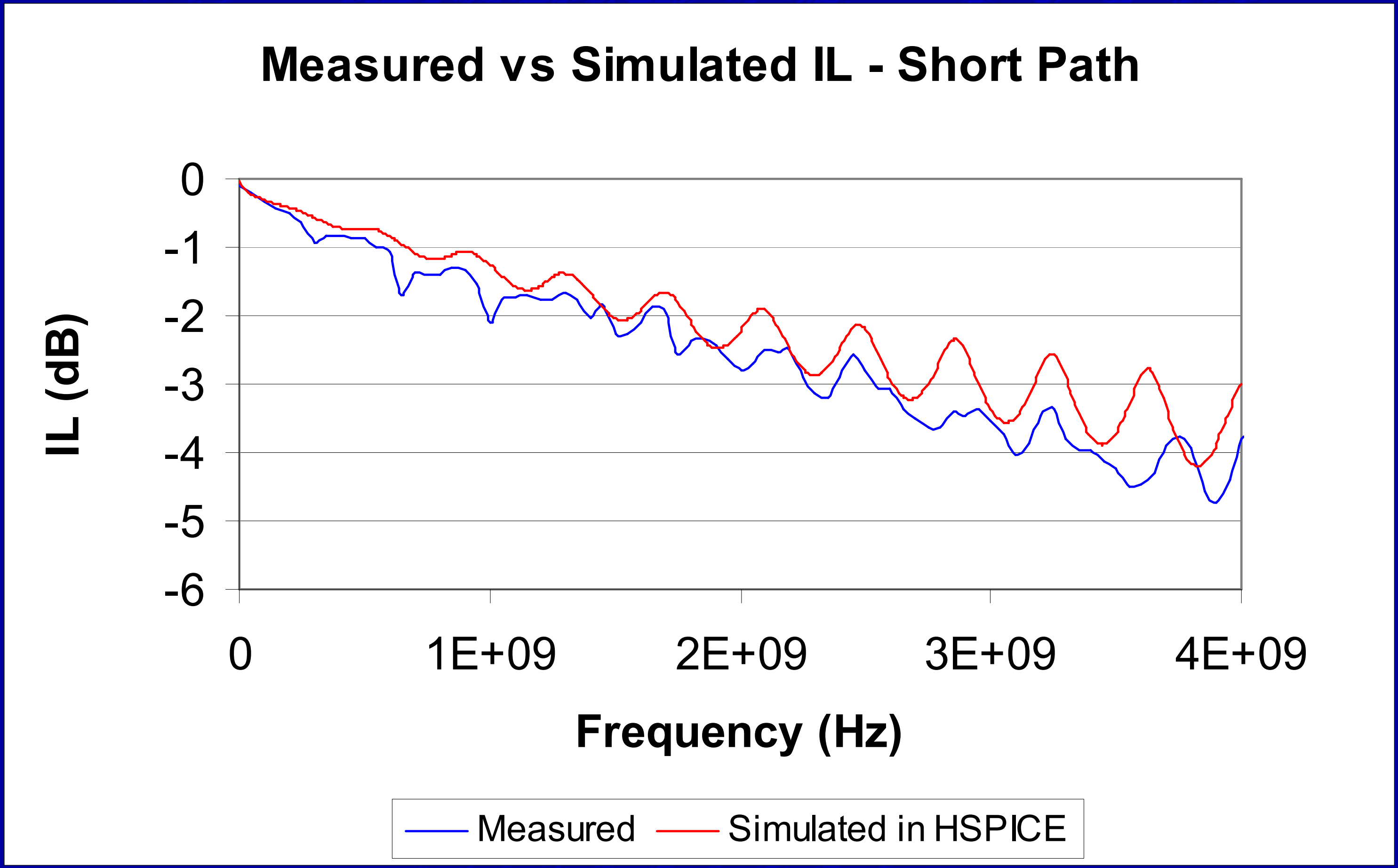
Near End Crosstalk (risetime=100ps)



Far End Crosstalk (risetime=100ps)



Insertion Loss



Summary

- **Models available for download** **http://www.samtec.com/signal_integrity/testing_and_simulation/spice_models.asp**
- **Presently have HSPICE models; other formats to follow**
- **Model accuracy generally within 5% compared to measured data**
- **Models run in HSPICE**
  - With easy to follow syntax
  - Simple sub circuit calls
  - Simulation time ~10 minutes for 20 pair cable assembly

Useful References

- **Samtec Technical Papers**
  - http://www.samtec.com/reference/articles/white_papers.asp
- **Lossy Transmission Lines**
  - Johnson and Graham – High Speed Signal Propagation – Advanced Black Magic
- **Model Extraction via Measurements**
  - http://www2.tek.com/cmswpt/tifinder.lotr?cn=interconnect+software&lc=EN
  - http://www.home.agilent.com/agilent/facet.jspx?c=152771.i.3&to=79830.g.0&cc=US&lc=eng&sm=g

Thank You and Questions

- For additional questions regarding the information contained in today's presentation, please contact our Signal Integrity Group at: sig@samtec.com

- For a copy of today's presentation, please contact us at: ewebinar@samtec.com