Rev. 1/20/2003

Lossy Line Simulation and Analysis

Dima Smolyansky

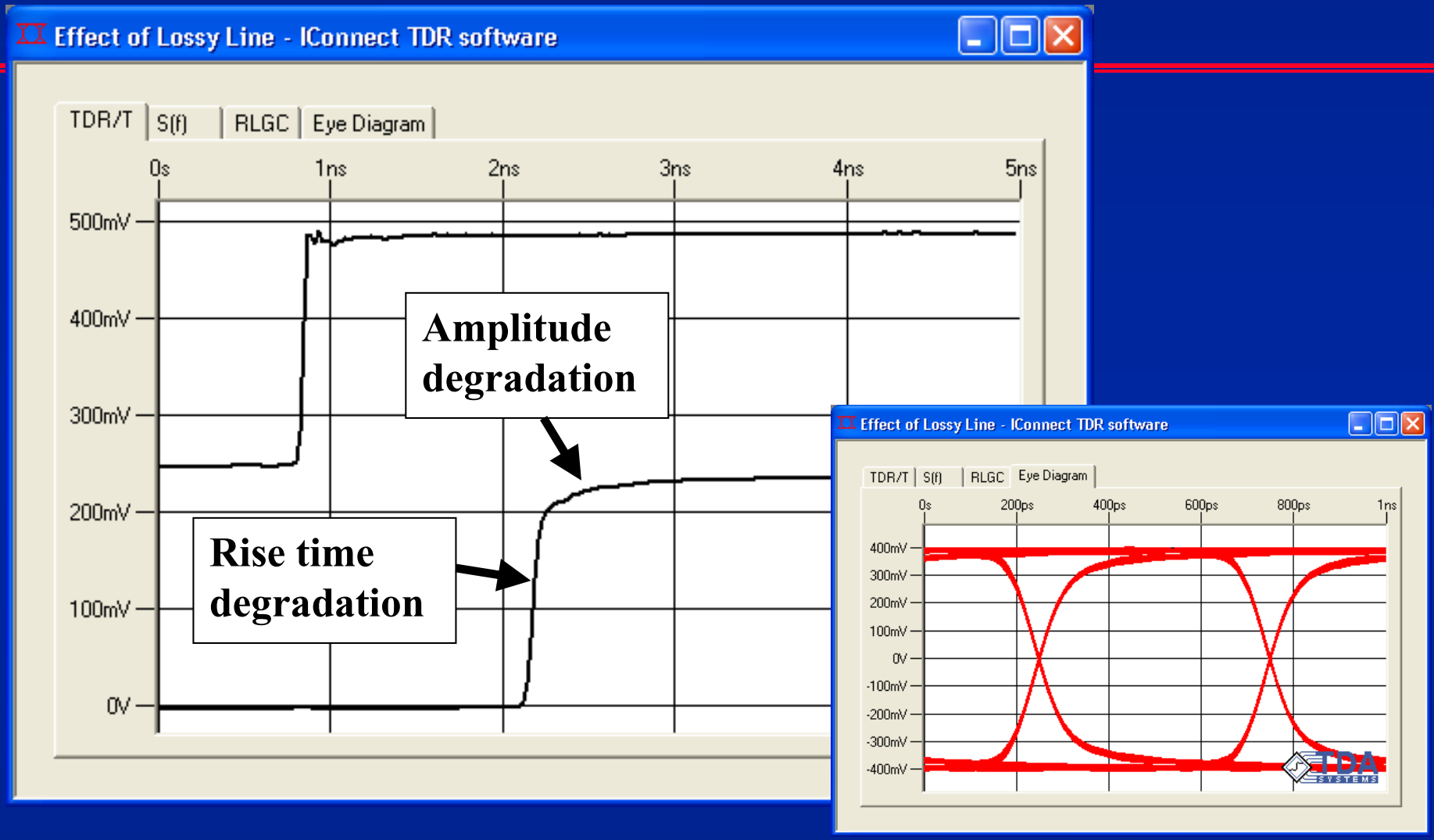
TDA Systems, Inc.

www.tdasystems.com

Based on a paper at Printed Circuit Design Magazine, March 2003

The Interconnect Analysis Company™

Effect of Losses



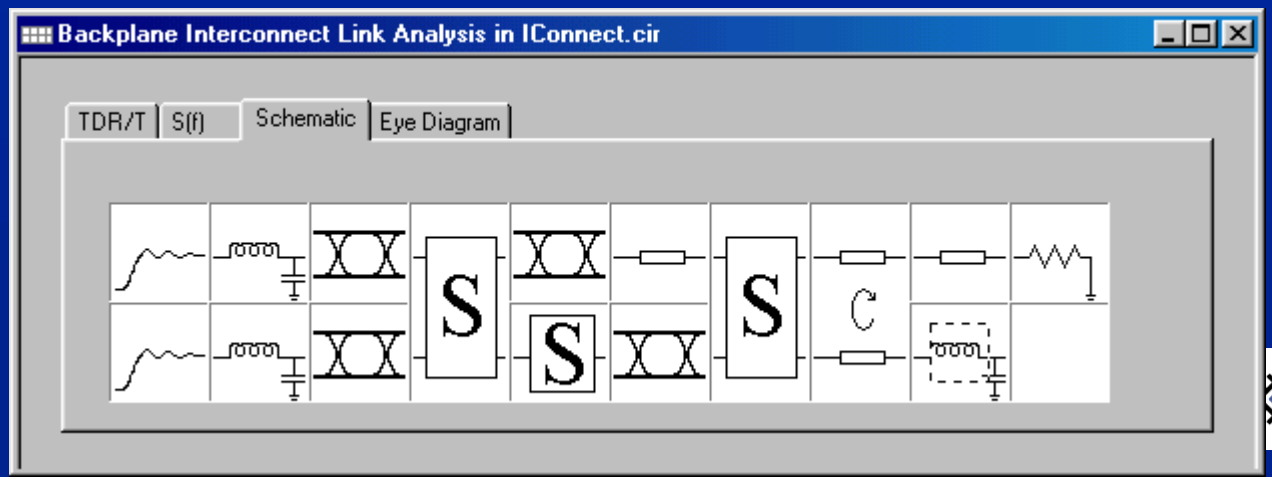
The Interconnect Analysis Company™

Lossy Line Simulation Approaches

- S-parameters
- Parametric models
- RLGC tables
- Behavioral model

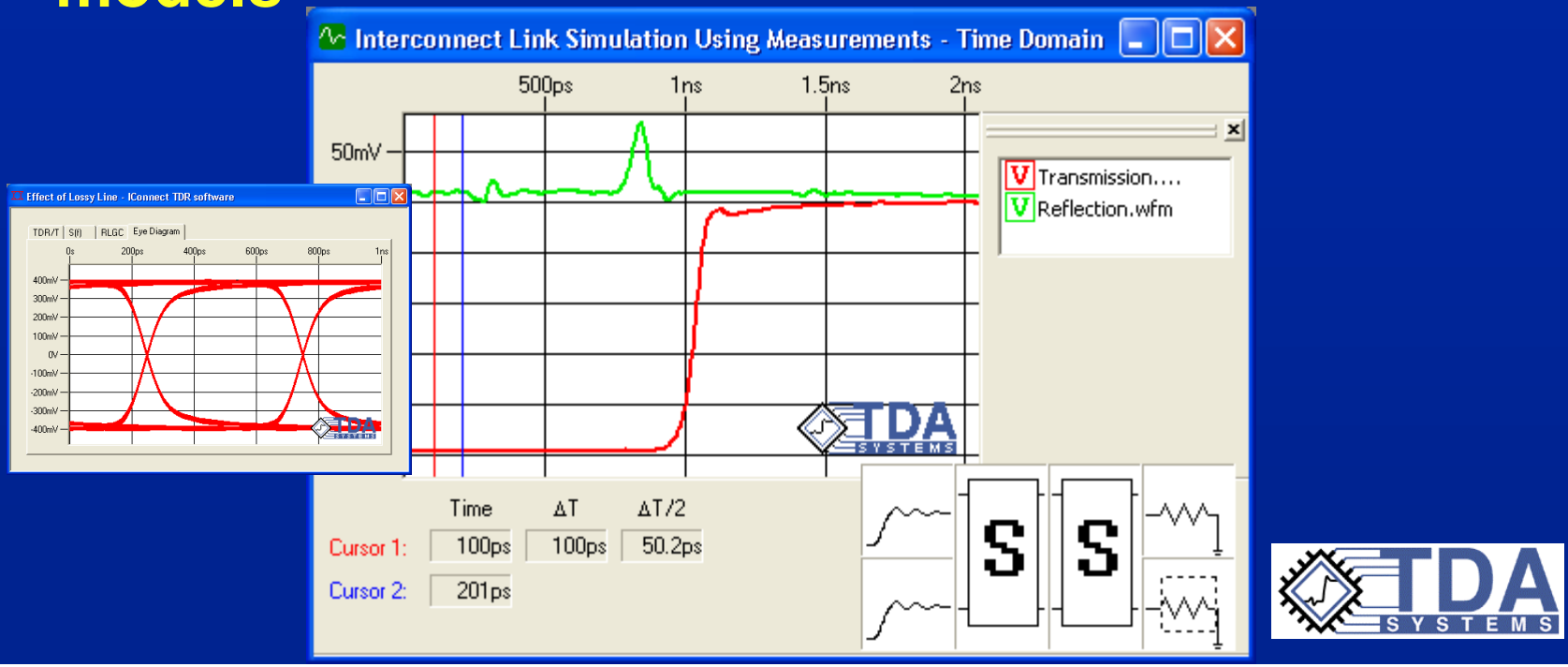
Using S-parameters in Simulation

- Tried and true approach in microwave design
  - Used in linear or small-signal regime
  - Skip the modeling, save the time!
- SPICE just begins to support it
  - Need to use in non-linear regime
  - Accuracy yet unknown



TDA's Interconnect Link Simulator

- Use *TDR/T or S-parameter data in simulations*
  - Quickly predict eye diagram, jitter, losses, crosstalk, reflections, ringing
  - Efficiently validate analytical and field solver models



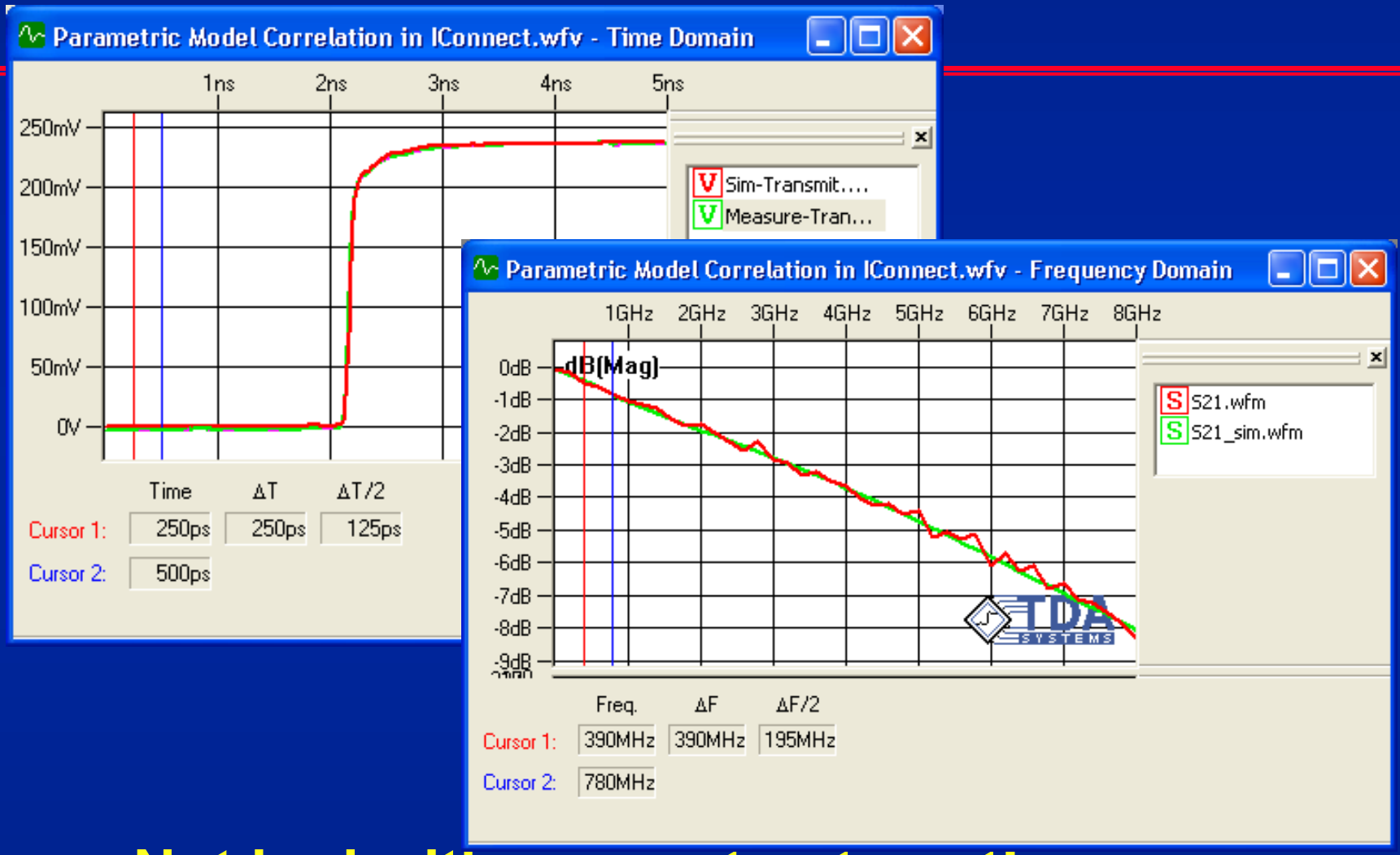
Parametric Models

- Parametric model make specific assumptions
- Example: the hailed and hollered W-element…

$$R(f) = R_{DC} + R_{AC}\sqrt{f} \qquad G(f) = G_d \cdot f$$

  - Accuracy – depends on who you talk to
  - Clearly, dielectric loss simulation is not perfect
- Speed and efficiency – very good
- Pre-defined assumptions make it easy to extract the accurate model from measurement

TDA Modeling Experience with W-element



- **Not bad with proper treatment!**

Frequency Tables

- Better accuracy than parametric
- Slower simulation time
- More difficult to extract accurately
- Example: TDA extraction

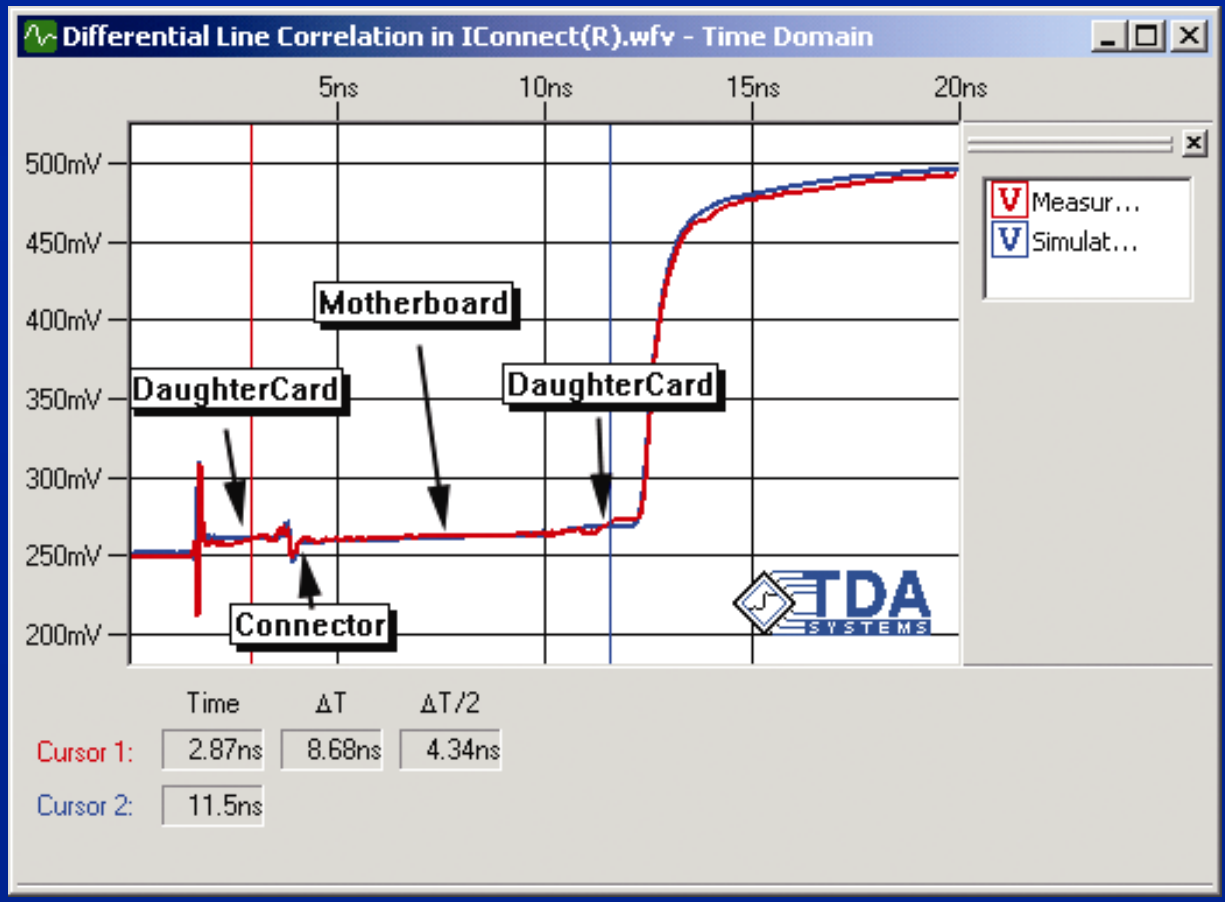
Frequency	R	L	G	C
0.0000E+00	7.8700E-01	6.9960E-08	2.2100E-09	2.9339E-11
4.1100E+07	8.0822E-01	6.9670E-08	1.9028E-04	2.7912E-11
8.2200E+07	8.1517E-01	6.9648E-08	4.0699E-04	2.7574E-11
1.2300E+08	8.2057E-01	6.9639E-08	6.0625E-04	2.7339E-11
…	…	…	…	…
8.1000E+09	1.0588E+00	6.9605E-08	3.9807E-02	2.5401E-11
8.1400E+09	1.0596E+00	6.9605E-08	4.0027E-02	2.5398E-11
8.1800E+09	1.0604E+00	6.9605E-08	4.0247E-02	2.5395E-11
8.2200E+09	1.0612E+00	6.9605E-08	4.0467E-02	2.5392E-11
…	…	…	…	…

Behavioral Modeling

- Different algorithms are available
- Can achieve exact correlation between model and measured data
- Simulation tends to be slower for large interconnect structures
  - Lumped element approach is the only approach where *passivity* can be ensured

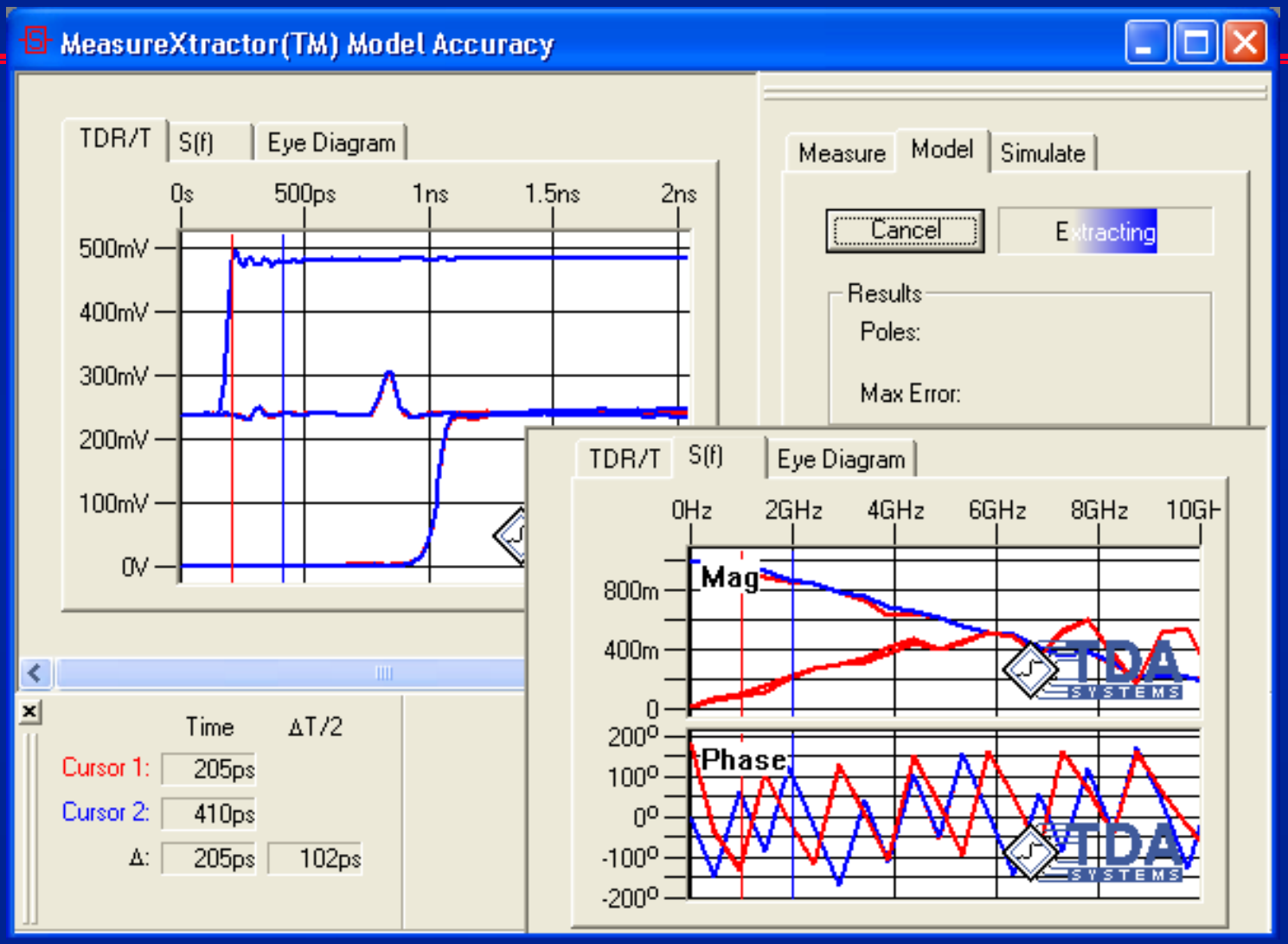
TDA Experience: Parametric Behavioral

- **Convert mathematically exact skin effect and dielectric loss into behavioral model**



TDA SYSTEMS

TDA Experience: MeasureXtractor™



The Interconnect Analysis Company™

TDA SYSTEMS

Summary

	Advantages	Disadvantages
S-parameters	Exact representation of frequency dependent behavior. Measurement data is used directly in simulations.	Requires forced linearization of inherently non-linear transmitter and receiver. Not effective for large backplane-style system simulations.
Parametric model	Simulates quickly and efficiently Can be efficiently extracted from measurements. Accuracy is sufficient for most applications.	Parametric assumptions do not always hold. Accuracy of simulating parametric models in current SPICE implementations is moderate.
RLGC tables	More accurate than parametric models.	Without the parametric model assumptions, could not be extracted from measurement directly. Results in longer simulation times. Simulator interpolation between and extrapolation beyond frequency points can result in stability and passivity issues.
Behavioral modeling	Exact if implemented properly; effectively, an S-parameter substitute. Models include other features embedded into the transmission line structure, such as vias or connectors.	Results in longer simulation times. Passivity, stability, and causality of models must be ensured.