S-Parameters for Model Extraction to 50 GHz
Problems, pitfalls, and lessons learned

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Problems with Model Data

- Passivity
  - Passivity is an indication of error in the measurements or modeling approach used.
  - Any passivity "fix" moves the errors into an acceptable region.
  - Sometimes the "fix" is as simple as concatenating with additional lossy models and resampling.
- Causality
  - Major causality issues require measurement/models to be recreated.
  - Minor causality issues (< 1% of pulse height) can be effectively ignored.
- Good data, poor data, and just plain bad data
  - Measurement return loss variations obscure the actual data.
    - Variations must either be removed mathematically, or used up to the obscuring artifacts.

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Problems with Simulation

- Frequency to Time Domain Conversion
  - Tricky, tricky, tricky
  - FD step size must accommodate longest time domain simulation duration
    - Rule of thumb to accommodate multiple round trips
      - Step size = (1 / 4 x channel delay)
    - 50 MHz for a 30" backplane with a 5 ns channel delay
    - Failure to do this will cause aliasing in the time domain.
  - Concatenation of FD models in time domain simulations WILL propagate errors.
    - Must be evaluated.
  - Upper frequency limit for transform needs to be evaluated for time domain accuracy
    - Is dependent on algorithms, windowing, and often secret methods for the necessary oversampling.
  - Laplace macro modeling can be used (if accurate) for comparison, since continuous functions are used.

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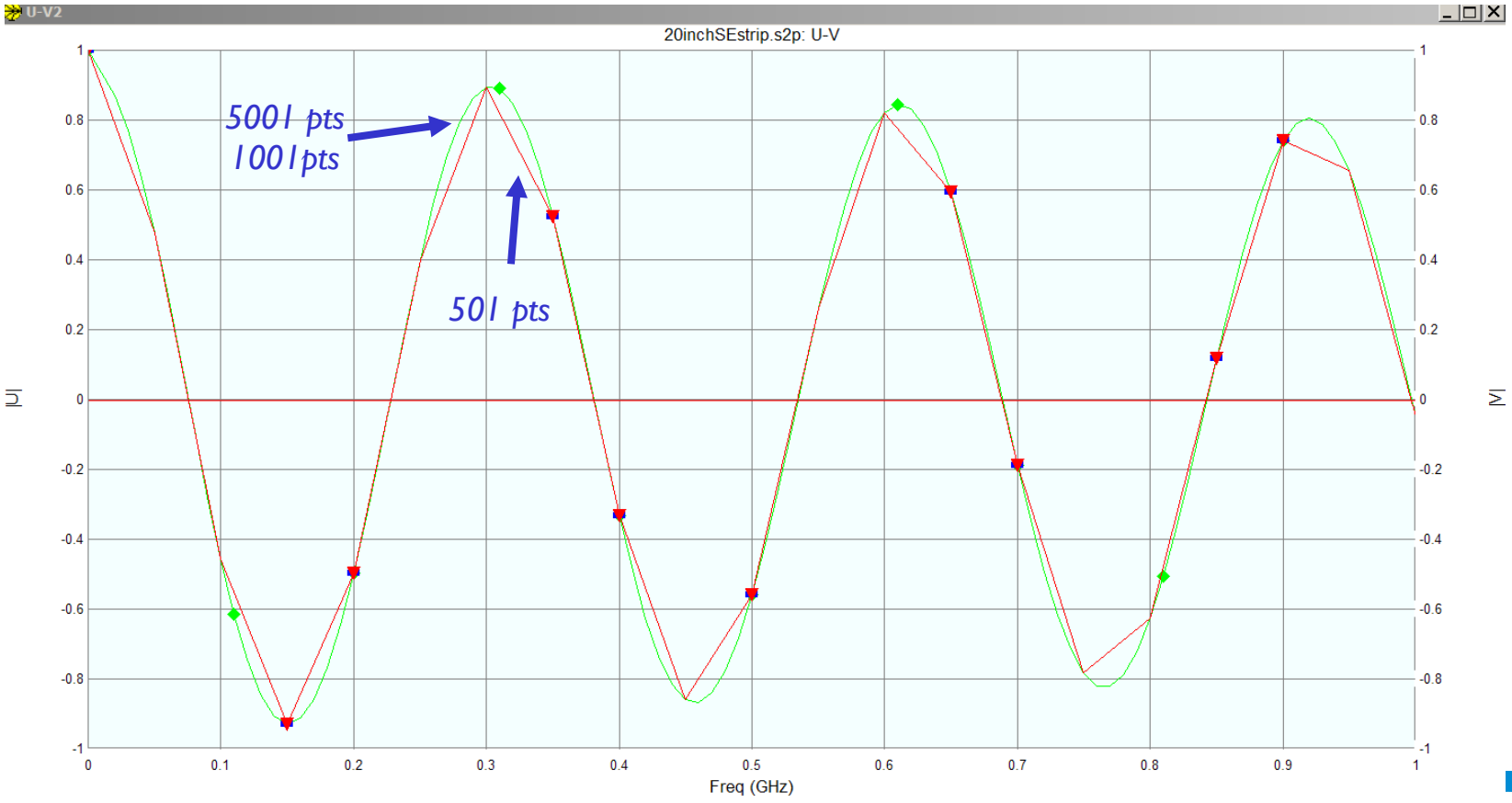
Impact of Frequency Domain Sampling Step Size



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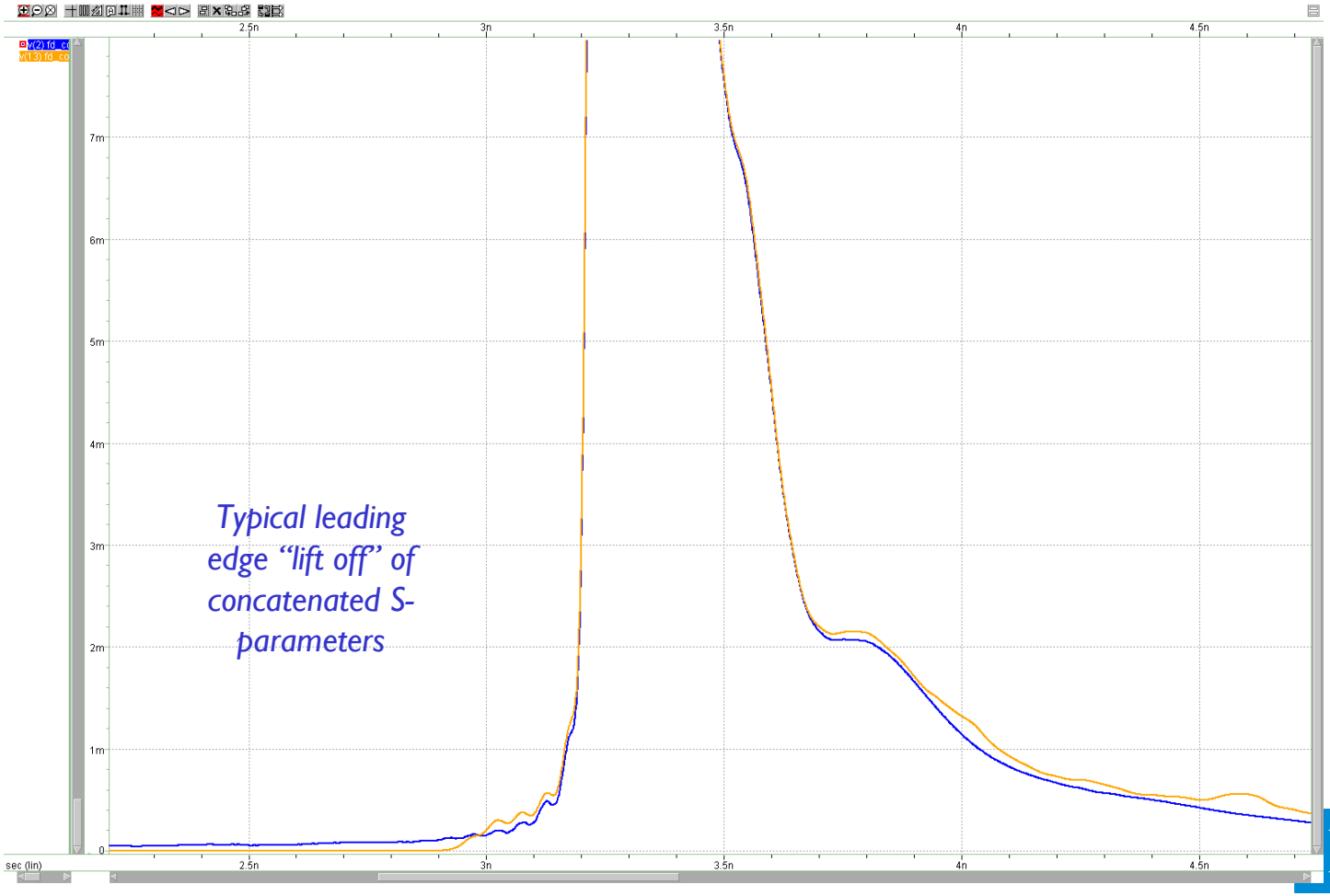
Concatenation of S-parameters in Time Domain Propagates Errors



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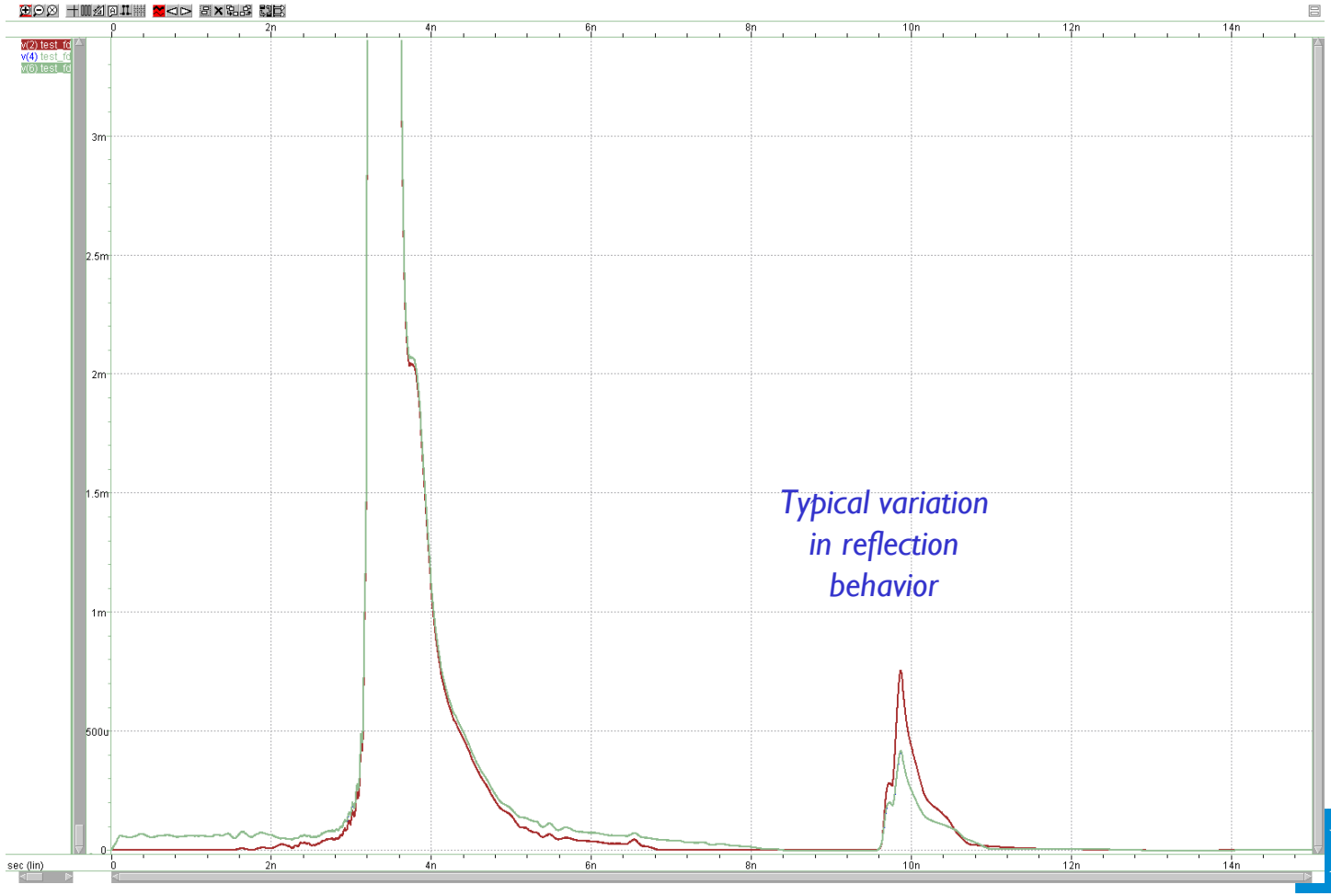

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Concatenation of S-parameters in Time Domain Propagates Errors

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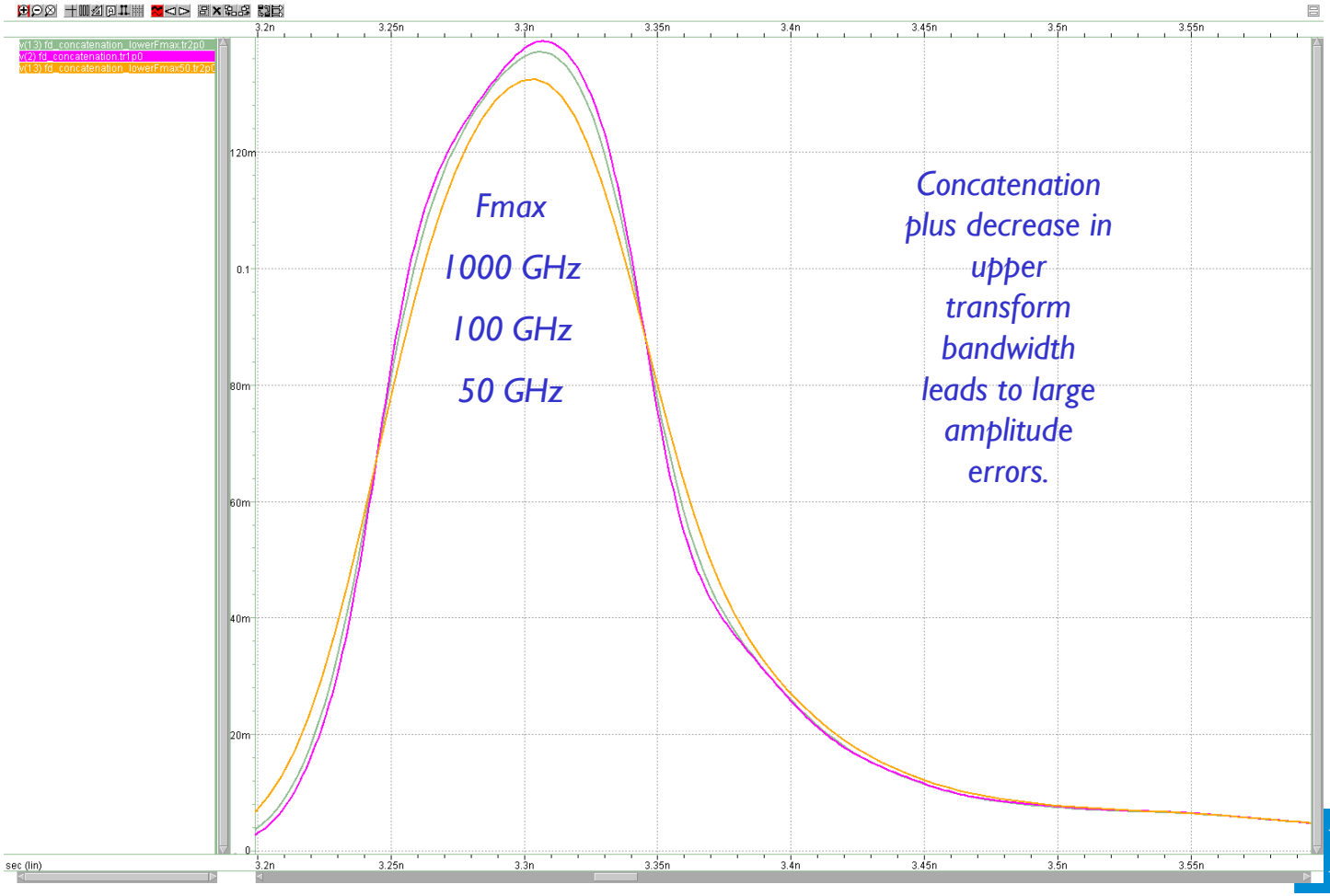
Decrease in Fmax for Frequency to Time Domain Conversion results in Large Error Propagation



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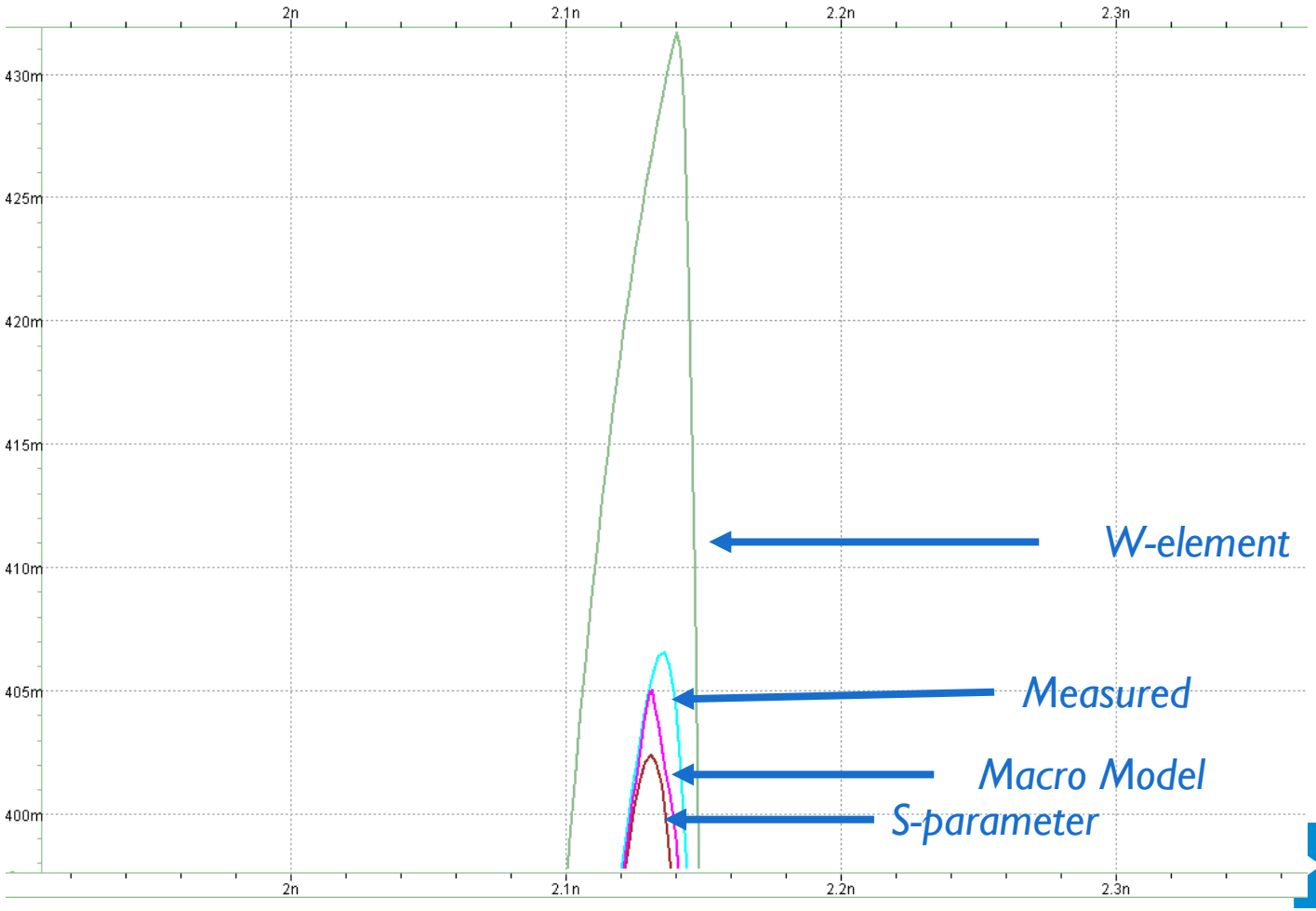
Pulse Response Measurement to Model Correlation 12” SE Trace Peak



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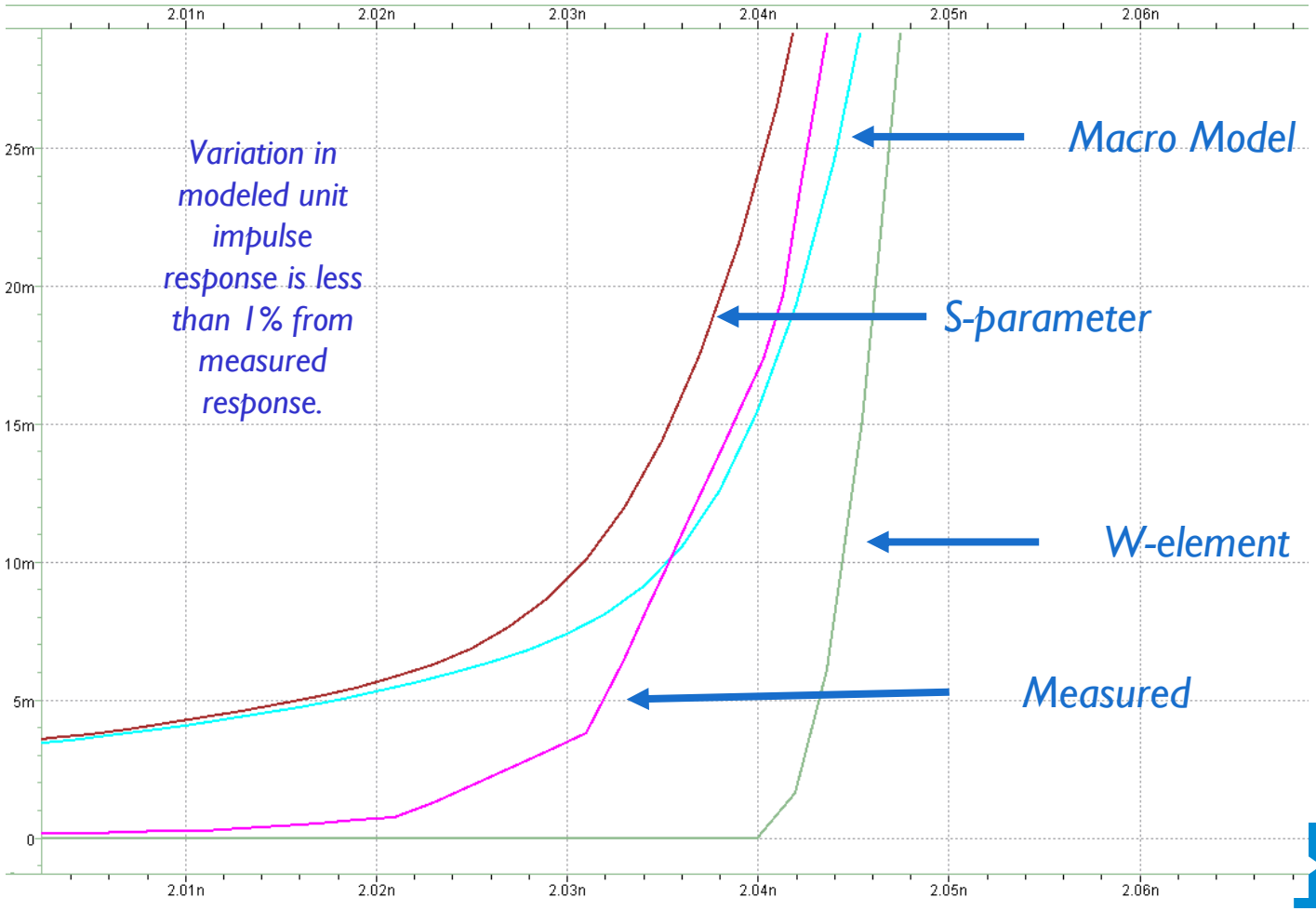
Pulse Response Measurement to Model Correlation 12” SE Trace Leading Edge



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Using Fitted T-line Modeling to Tame Problems

- For model sections that are continuous, accurate measurements can be used to extract the appropriate trace (cable) material parameters.
  - Models can be guaranteed to use realistic material models that enforce causality.
  - Limits passivity/causality issues to "other" models with smaller sections.
    - These can be measured with TRL (or other) de-embedding methods and used directly, or fit to continuous macro models.
    - Or extracted with full wave field solver methods.
- Traces and Cables
  - May be extracted and fit to proper passive/causal material models with high accuracy measurement boards.

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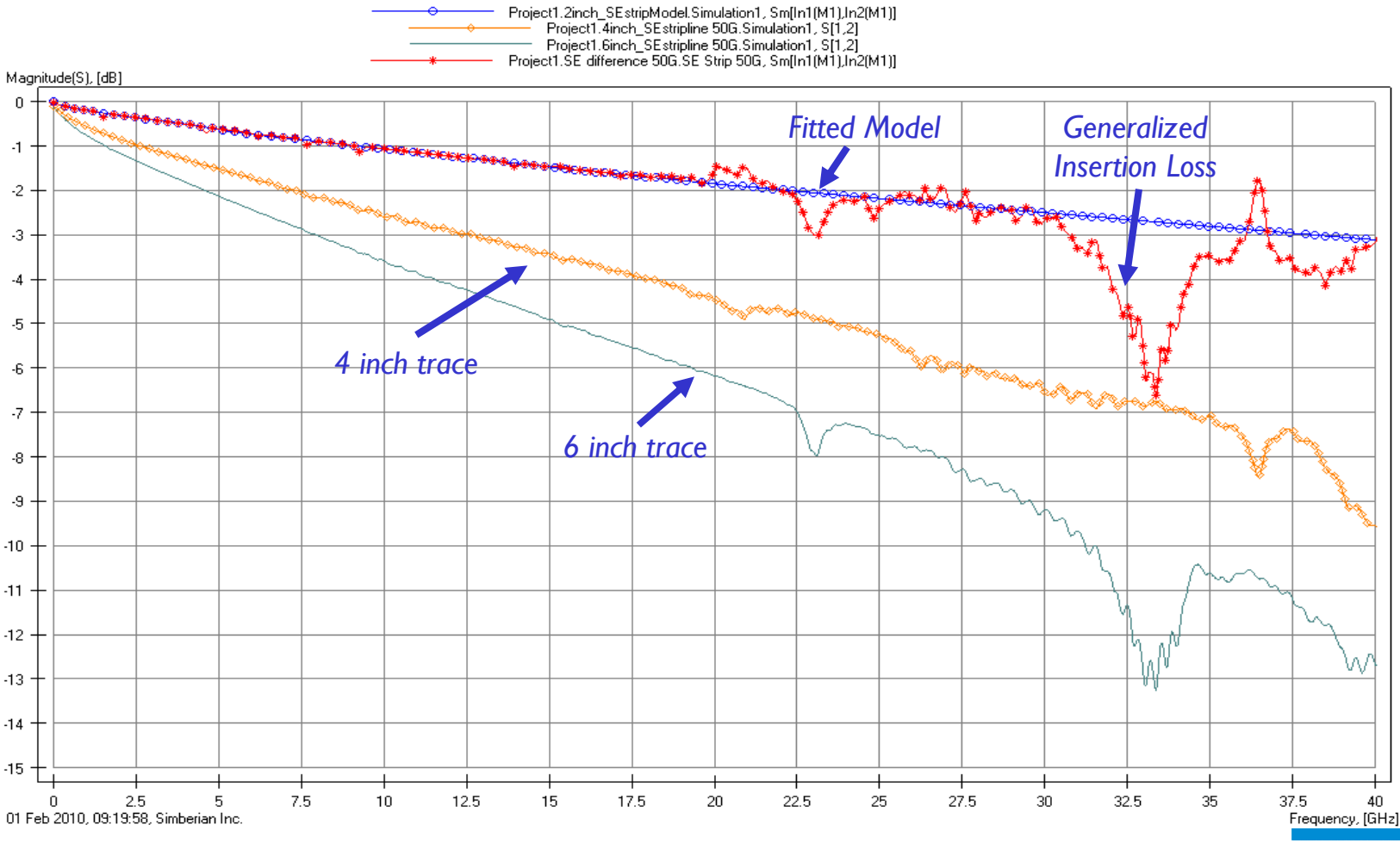
Wideband Debye (*Djordjevic-Sarkar*) Fit to Material Measurements



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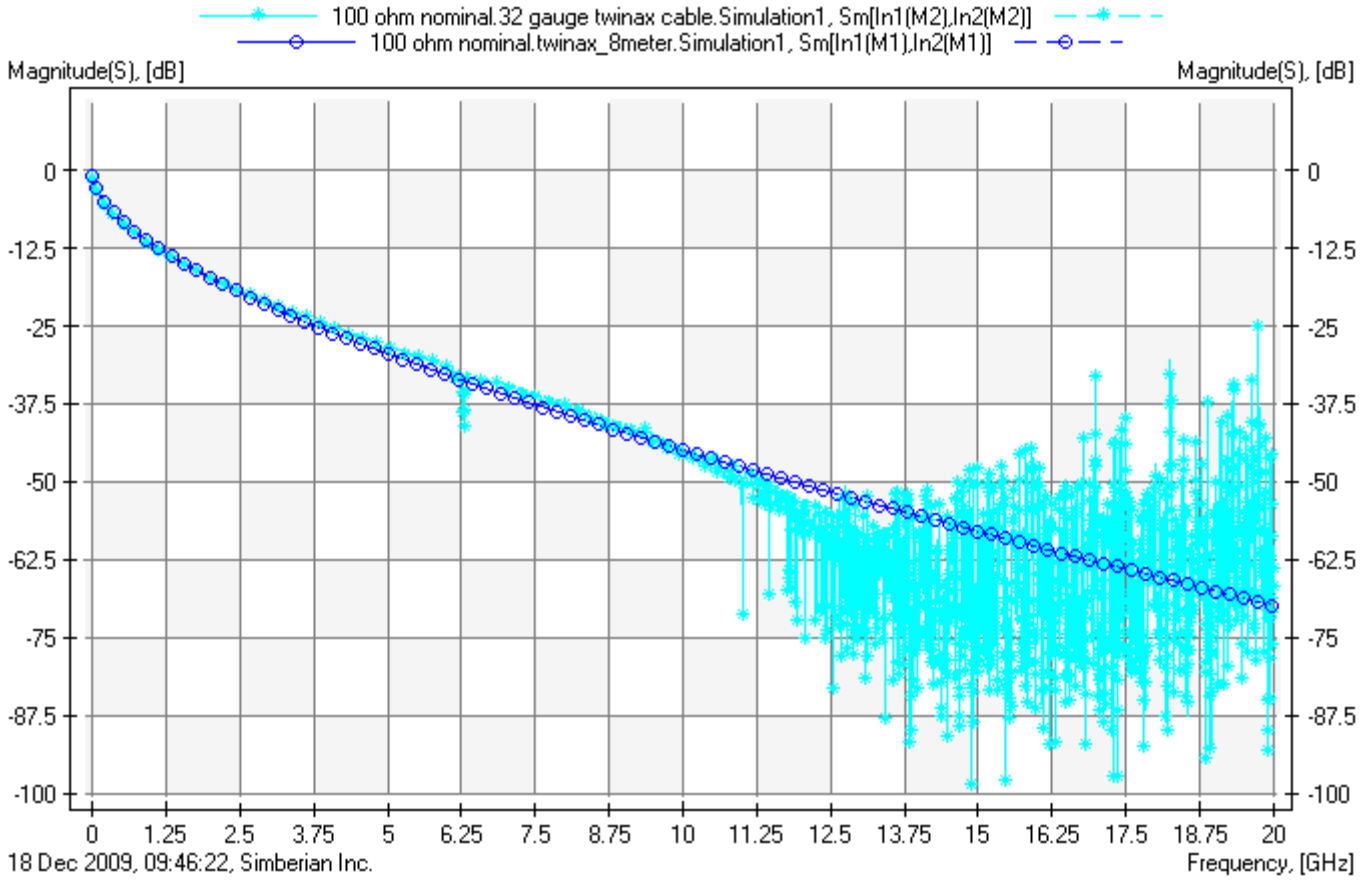
Modeling vs. Measurement Correlation of 8 Meter Cable Secton

Simberian Simbeor was used to extract generalized modal differential s-parameters (light blue) of two cables 1 meter and 9 meters long. This was used to construct a passive and causal model of the cable (dark blue).

This synthetic model may be used to create accurate models of various lengths for end-to-end simulations.



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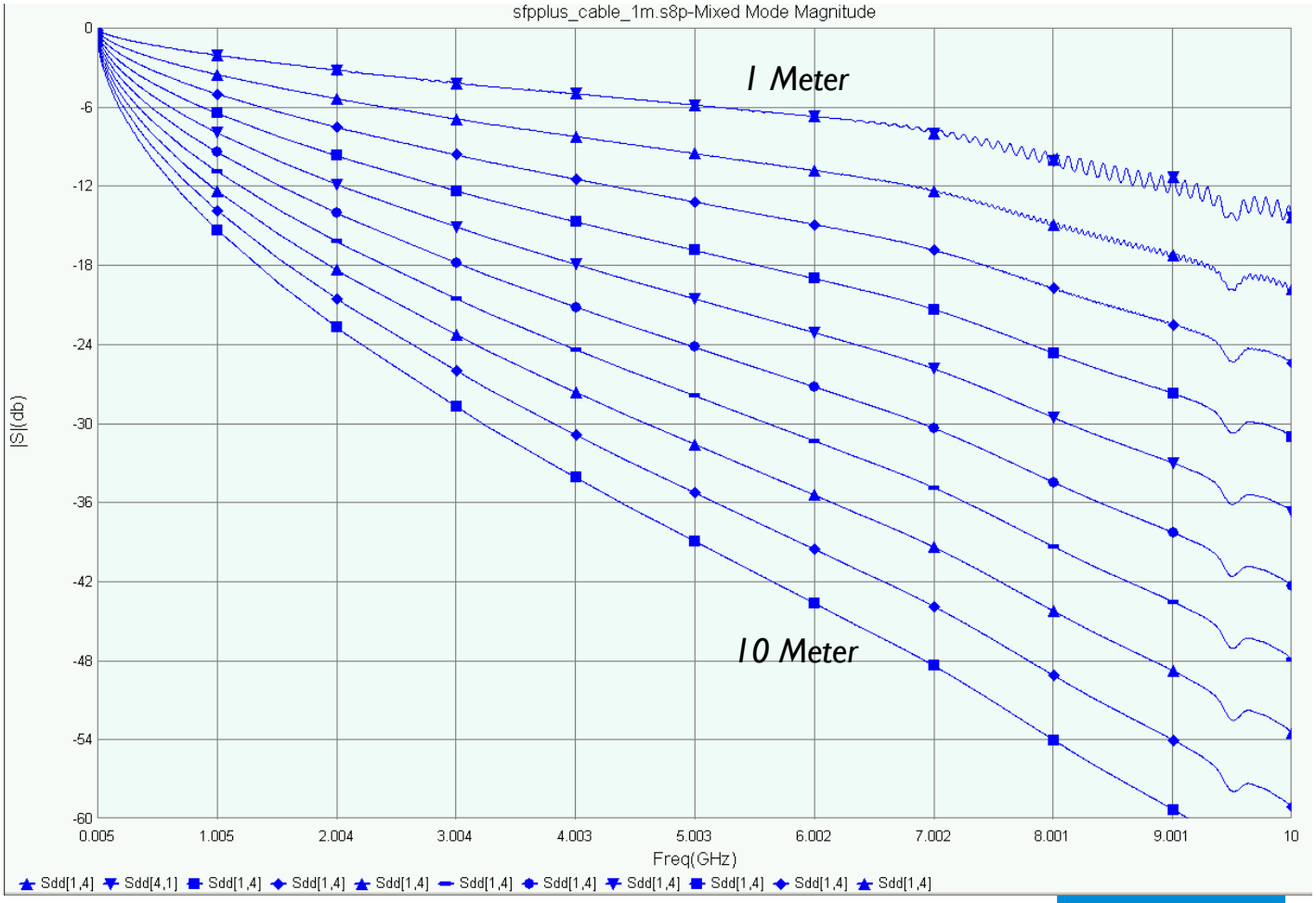
Simulation of Cable Assembly with Various Lengths of Synthesized Cable

Various lengths of synthetic cable models are placed into an end-to-end channel simulation.



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Summary

- Problems with S-parameters may be resolved by:
  - Embracing the errors (passivity, causality, artifacts)
    - Perform a do-over with higher accuracy methods
    - Accept the errors and limit error propagation
- Problems with Frequency to Time Domain conversion
  - Evaluate S-Parameter sampling
    - If original S-Parameters are undersampled for your design, there is no way to "fix" them.
    - Start with step size that is consistent with channel length times 4.
  - Eliminate S-Parameter cascades
    - Concatenate and resample in the frequency domain prior to time domain conversion.
    - Evaluate upper frequency limit of FD-to-TD conversion
- Use measurement-fitted T-line models to simply the modeling/simulation process
- Use macro models for accurate verification of your favorite time domain simulation method.

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