

13-TU1, Tuesday Jan 28th, 2nd Speaker 9:20 am to 9:55

Fixture S-parameter model from 2x Fixture Physical Test Structures

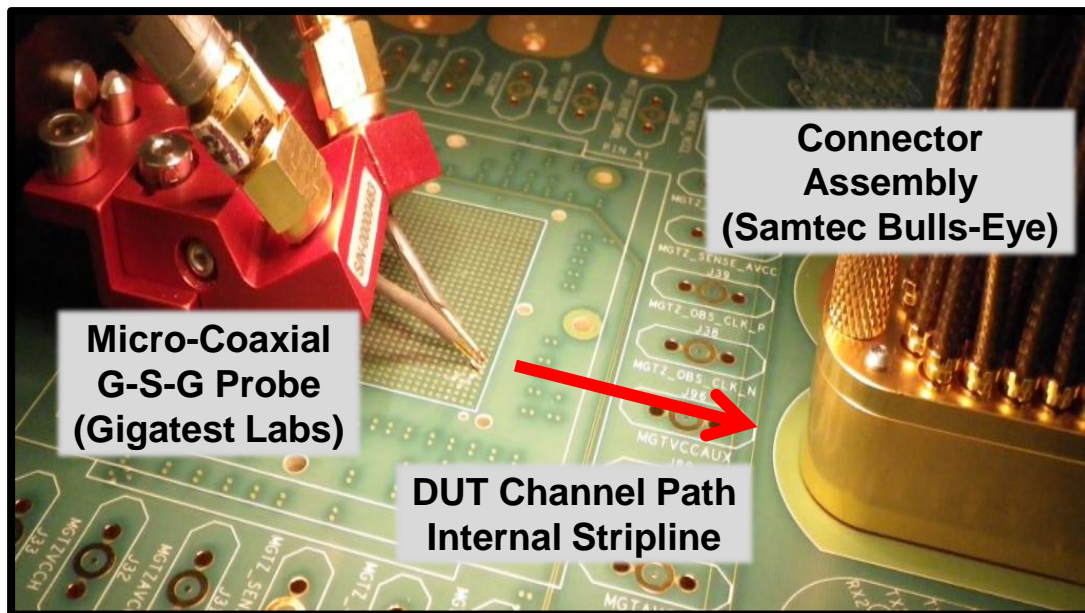
Mike Resso



January 28-31, 2014 | Santa Clara Convention Center | Santa Clara, CA

Fixture Models for De-Embedding

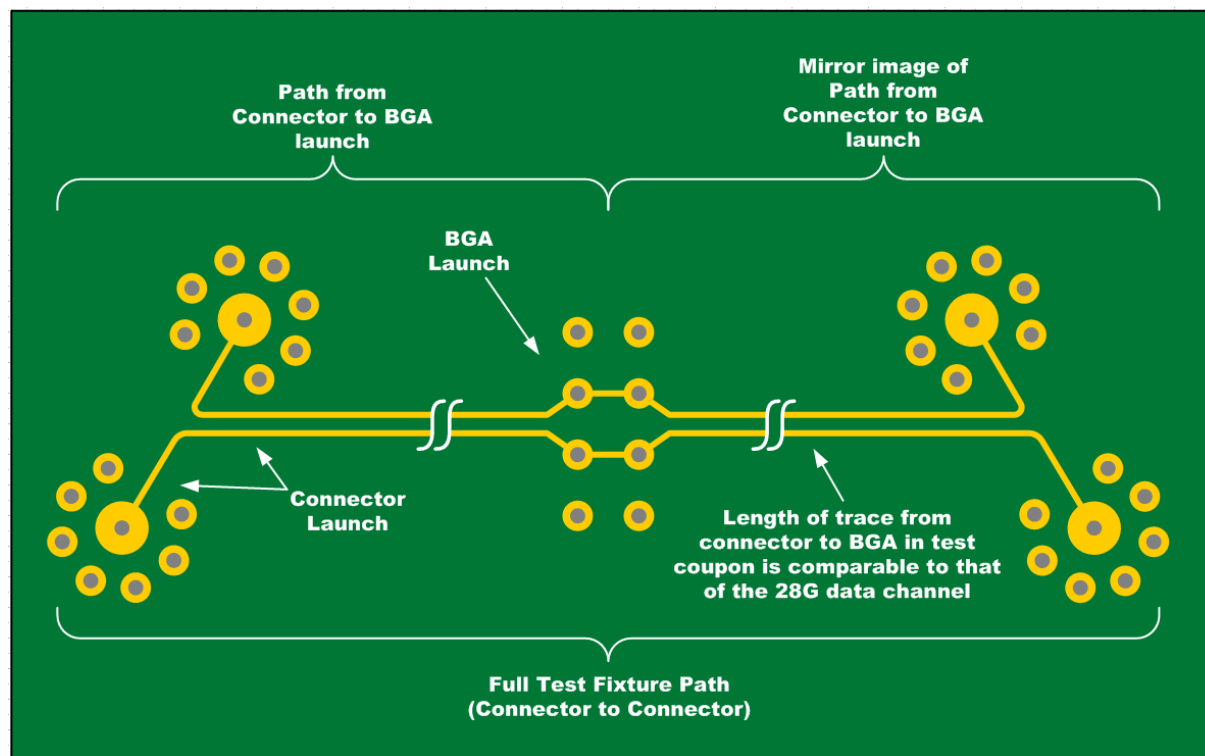
High Density Fixture with Multiple High Speed Connections



Channel Model De-Embedding Options

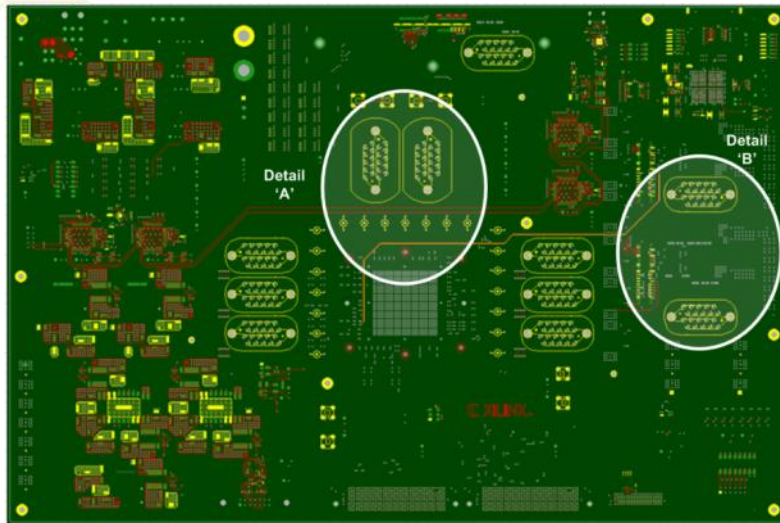
- 1) Direct Probe Measurement
- 2) Test Coupon Structure with AFR
- 3) Hybrid Multi-Path Simulation with Minimal Test Structures

Test Fixture

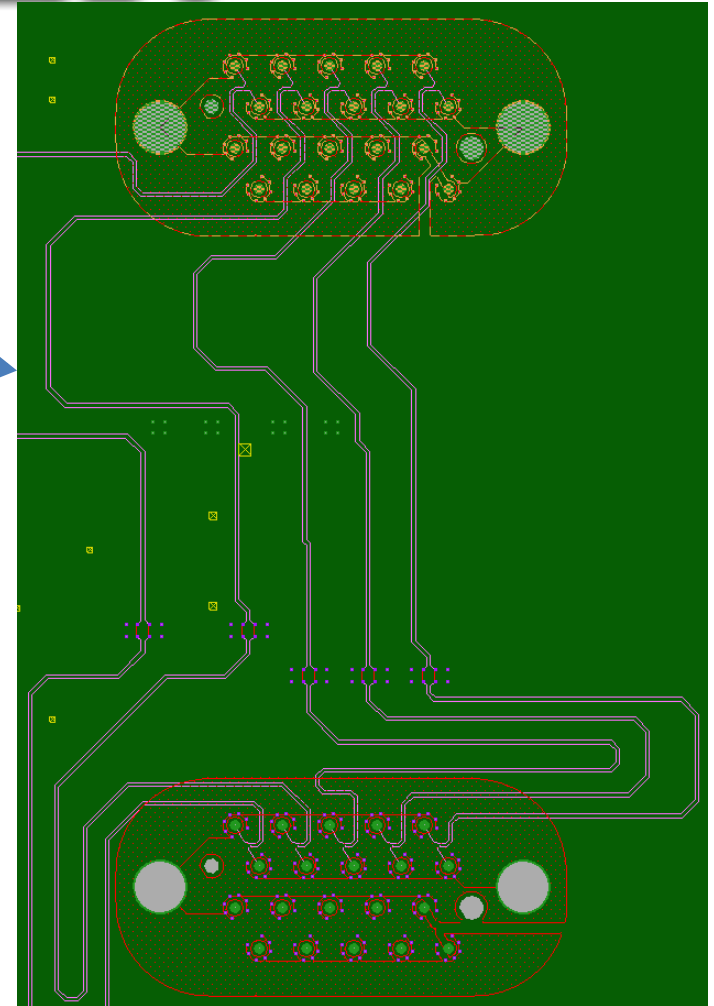


- Routed on same layers as channel fixture traces
- Identical launch structures to channel fixtures

Test Fixture Layout



Detail 'B'



- Routed between Bullseye connectors.

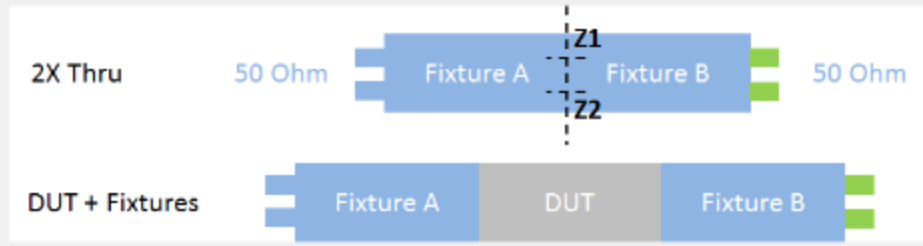
2X THRU AFR Dialog Box

Automatic Fixture Removal (AFR) - Differential

Description: AFR extracts fixture S-parameters from 2X Thrus and performs de-embedding on the DUT+Fixtures measurement to characterize only the DUT.

Advanced settings

Concept



Select 2X Thru file: C:\Users\mresso\Desktop\DesignCon 2014\2293m

☒ Save extracted fixture files for future use

Save fixture files to: C:\Users\mresso\Desktop\DesignCon 2014

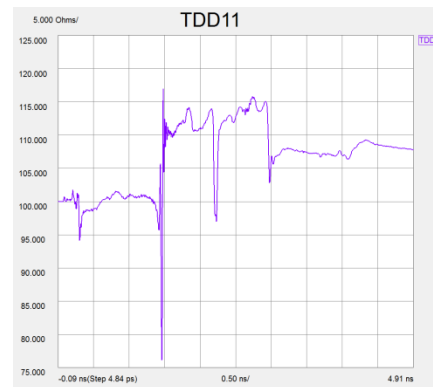
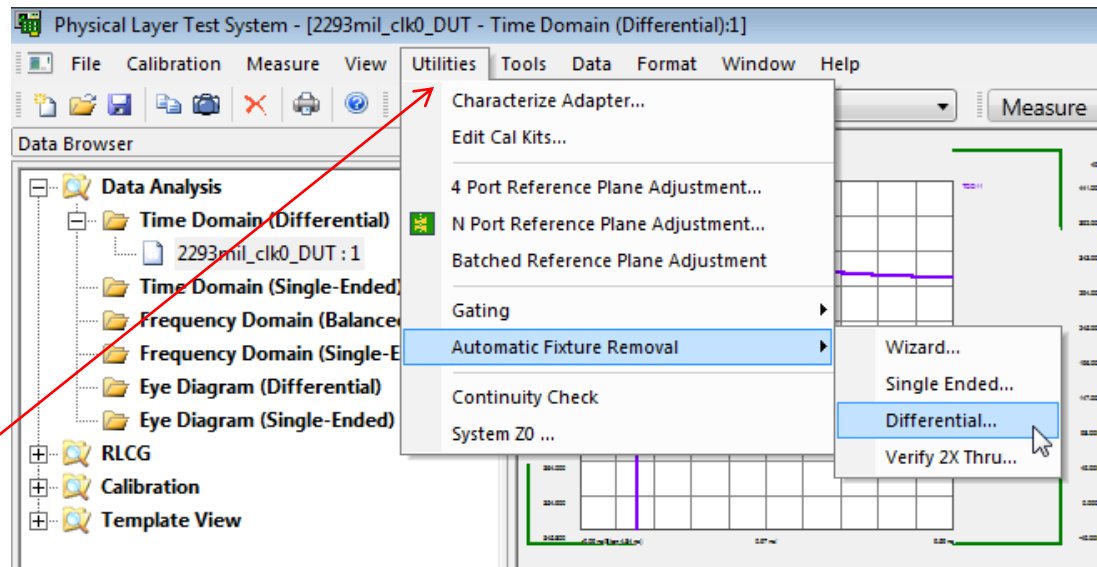
Base file name: Mike

Note: Suffix '1' and '2' will be appended to the base file name for the two fixtures

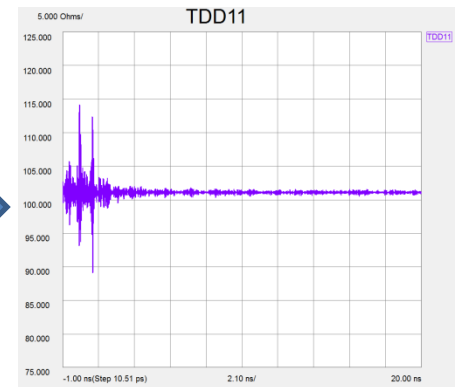
Apply Undo Exit Help Set as Default

AFR Step-by-Step

- Load 2X THRU file
- View data in Differential Time Domain
- Open AFR dialog box
- Use 2X THRU as both DUT and 2x THRU
- Result will be near zero
- Save fixture files
- You now have model of the test fixture



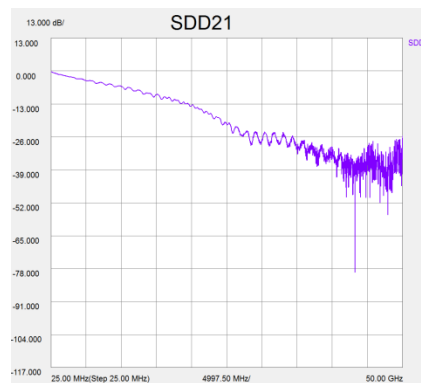
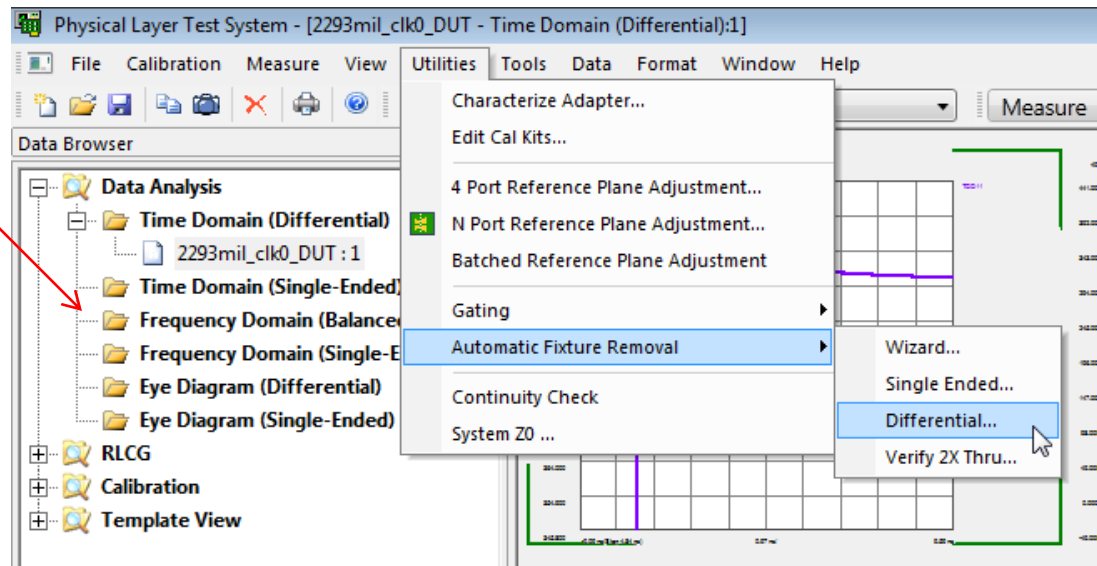
Before AFR



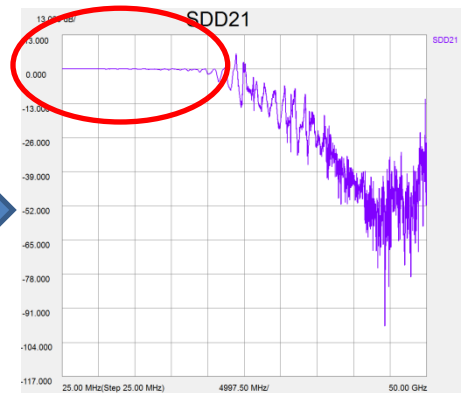
After AFR

AFR Step-by-Step

- Change into balanced frequency domain
- Double-check that SDD21 has “gone to zero” in the frequency range of interest
- Apply and Undo AFR in various domains for practice



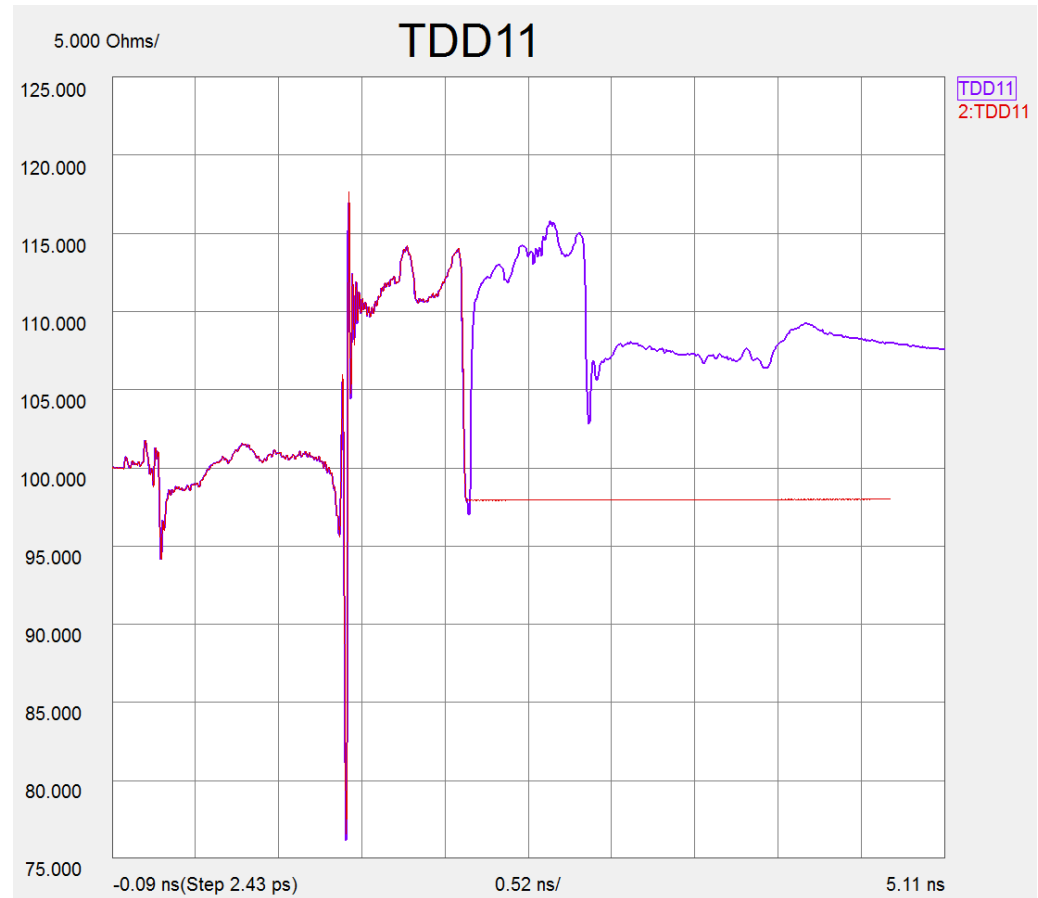
Before AFR



After AFR

AFR Step-by-Step

- Overlay fixture model onto the original 2x THRU file
- Open extracted test fixture model file
- Use “data sharing” to view both waveforms onto one plot
- Notice perfect matching waveforms



Next Speaker

- **28 Gb/s SERDES Channel Overview – Romi Mayder and Jack Carrel (20min)**
- **Fixture S-parameter model from 2x Fixture Physical Test Structures – Mike Resso (35 min)**
- **Fixture S-parameter model from Simulated Measurement Based Model – Heidi Barnes (35 min)**
- **Waveform Measurements at the DUT using S-parameter model de-embedding. Rob Sleight (1 hour)**
- **Lessons Learned – Jack Carrel (15 min)**

Back-Up Slides

- **DesignCon 2011 Presentation Excerpts**
- **Co-developed with Dr. Eric Bogatin**
- **2X THRU details**
- **Resources**



A Simple, Yet Powerful Method to Characterize Differential Interconnects

Mike Resso, Agilent Technologies

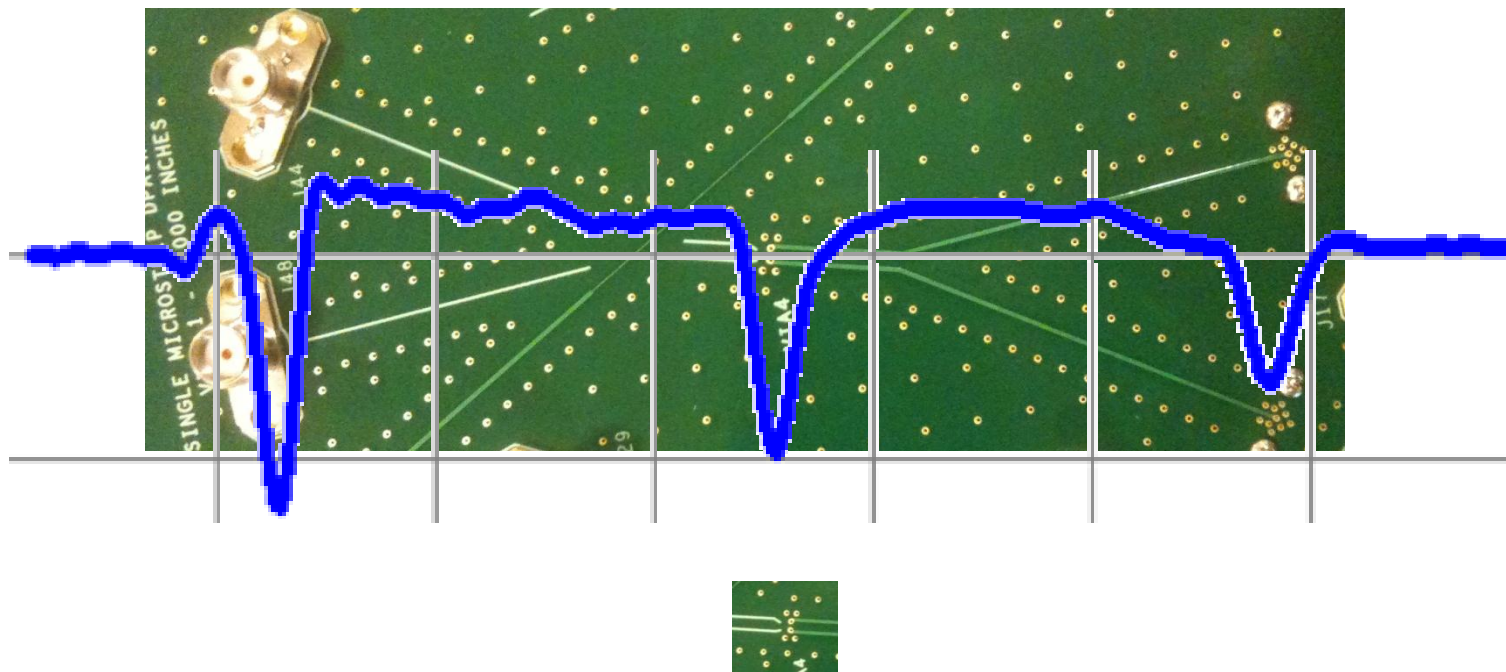
Overview

- Measurements in perspective
- The automatic fixture removal (AFR) technique for symmetric fixtures
- Looking under the hood
- Examples and accuracy estimates
- Break
- Revealing the secrets to practical applications

The screenshot shows the ArcView 3.2a software interface. The main window displays a 3D visualization of a watershed model. The map shows a network of roads and rivers, with a color-coded surface representing elevation or flow. A 'Layers' panel on the left lists various data layers. A 'Properties' dialog box is open, showing the 'Display' tab with a 'Color' map. A 'Data Table' dialog box is also open, displaying a table of data for the selected layer.

The Problem: Directly Measuring a Behavioral Model of a Specific Structure

- What I want to measure is embedded in the middle of a bunch of interconnect I don't care about



*I just want the via structure, or the connector, or the cable,
or the interface, or the uniform trace,...*

The Solution: De-embedding

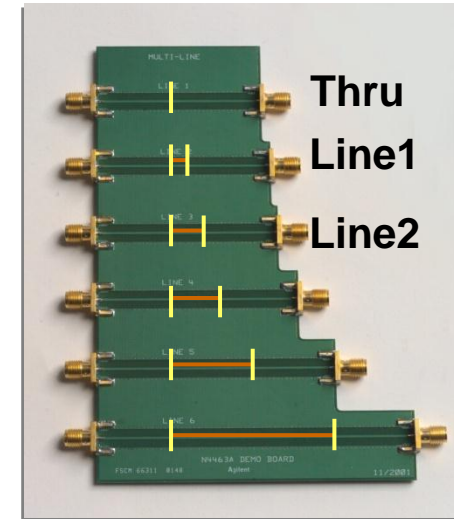
- Traditional Calibration

- ✓ SOLT
- ✓ TRL (thru, reflect, line)
- ✓ LRM (line, reflect, match)



- De-embedding using

- ✓ Measured test fixtures
- ✓ Calculated test fixtures by 3D full wave field solver
- ✓ Calculated test fixtures by approximation (port extension)

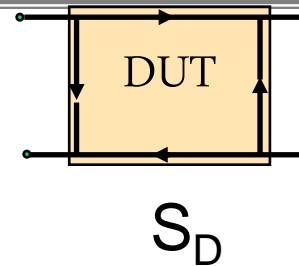


- The new way: really simple, automatic fixture removal (AFR)

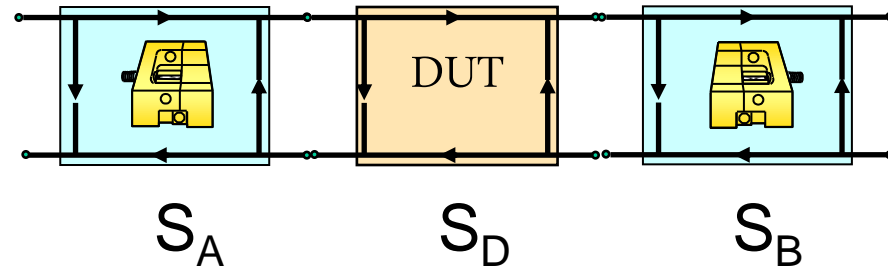
- ✓ Must have a symmetric, 2x thru of the fixture only

De-Embedding “Automagically”

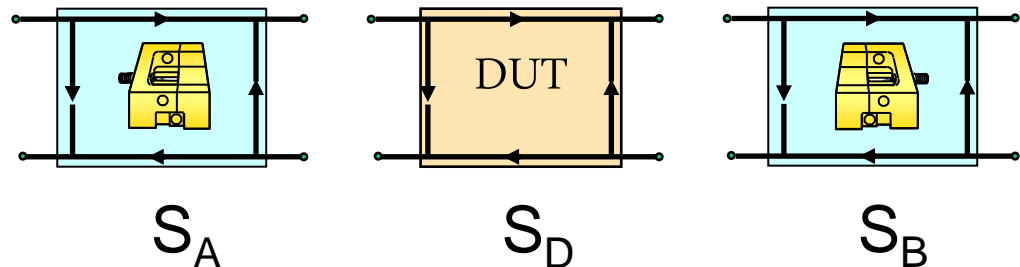
What we want: DUT performance



What we measure:
composite measurement
of DUT and fixtures

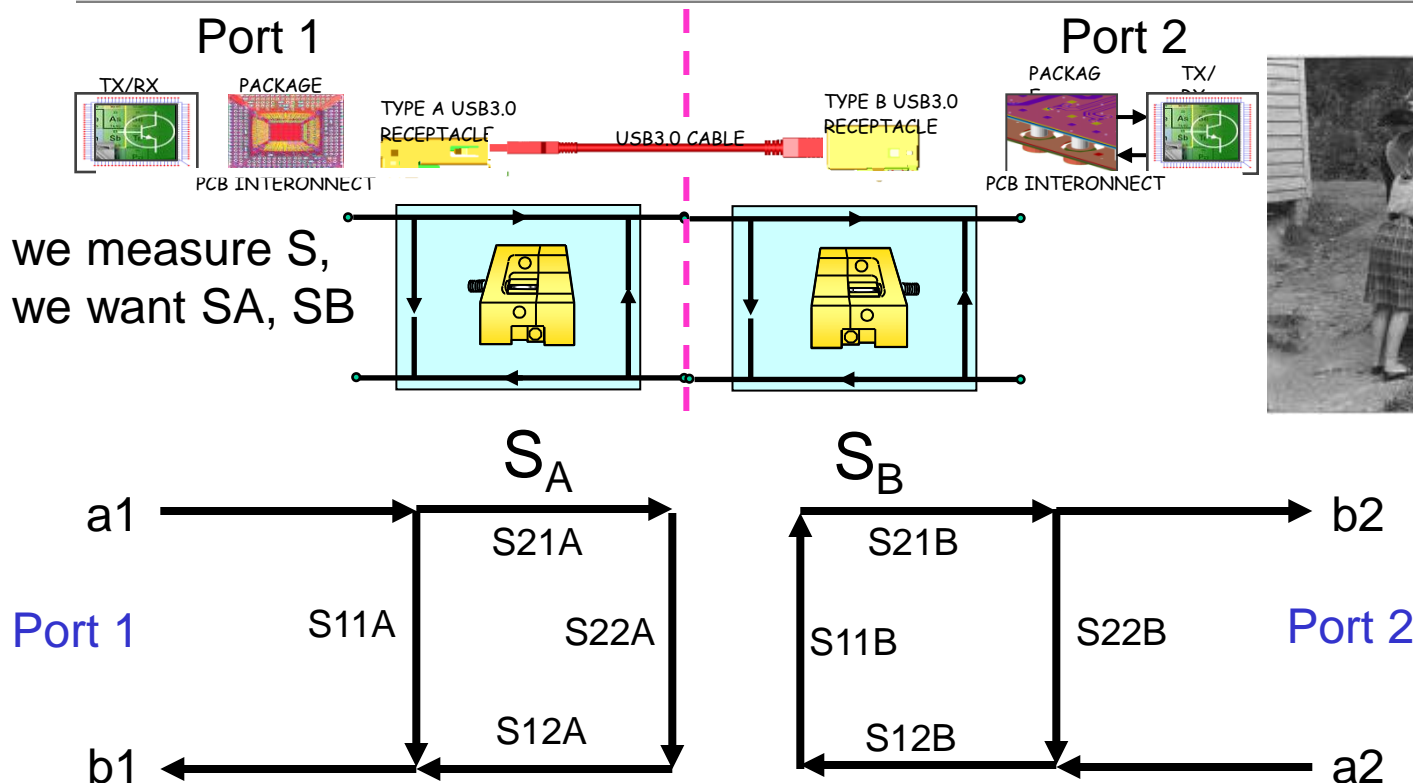


With the separate fixtures' S-Parameters, we can de-embed the DUT alone from the composite measurements



The challenge: getting the S_A and S_B de-embed files

The Automatic Fixture Removal (AFR) Process for a Mirror-Image Symmetrical Fixture (Looking Under the Hood)



Apply:

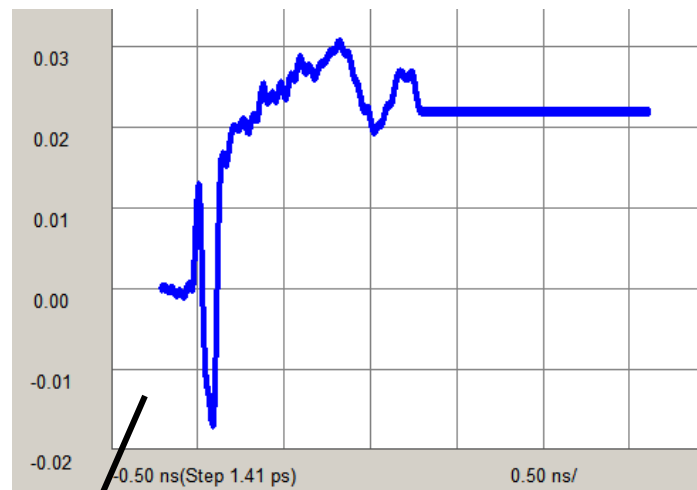
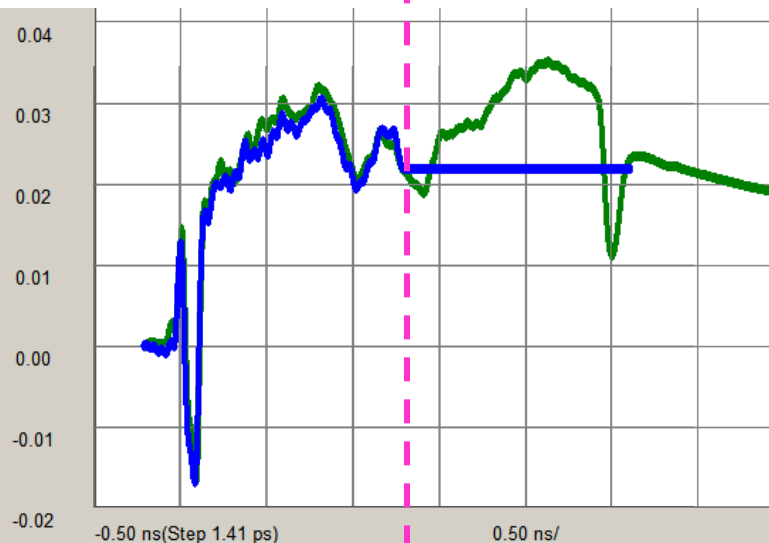
- Symmetry in the fixture: $S_{11A} = S_{22B}$, $S_{22A} = S_{11B}$, $S_{21A} = S_{12A} = S_{21B} = S_{12B}$
- Network Theory
- Calculate S-parameter file for each mirror image half of the fixture.



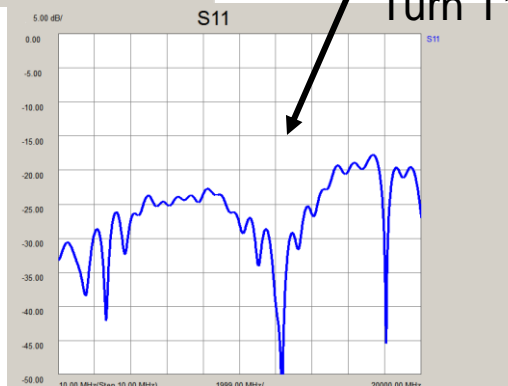
A Key Step in the Complete Process: Use Time Domain Gating to Get S11A, S22B



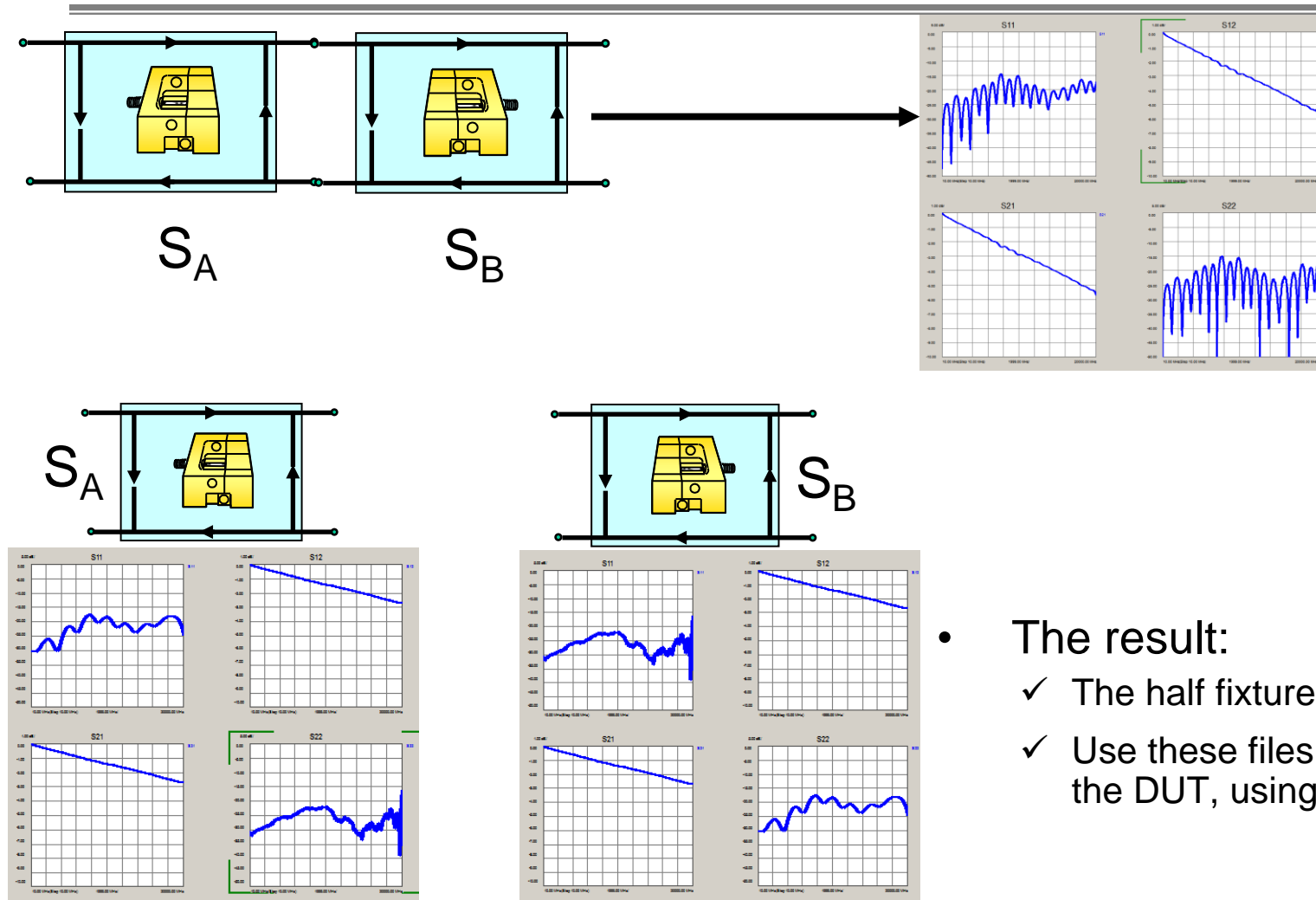
Use time domain gating to get T11A from T11



Turn T11A into S11A



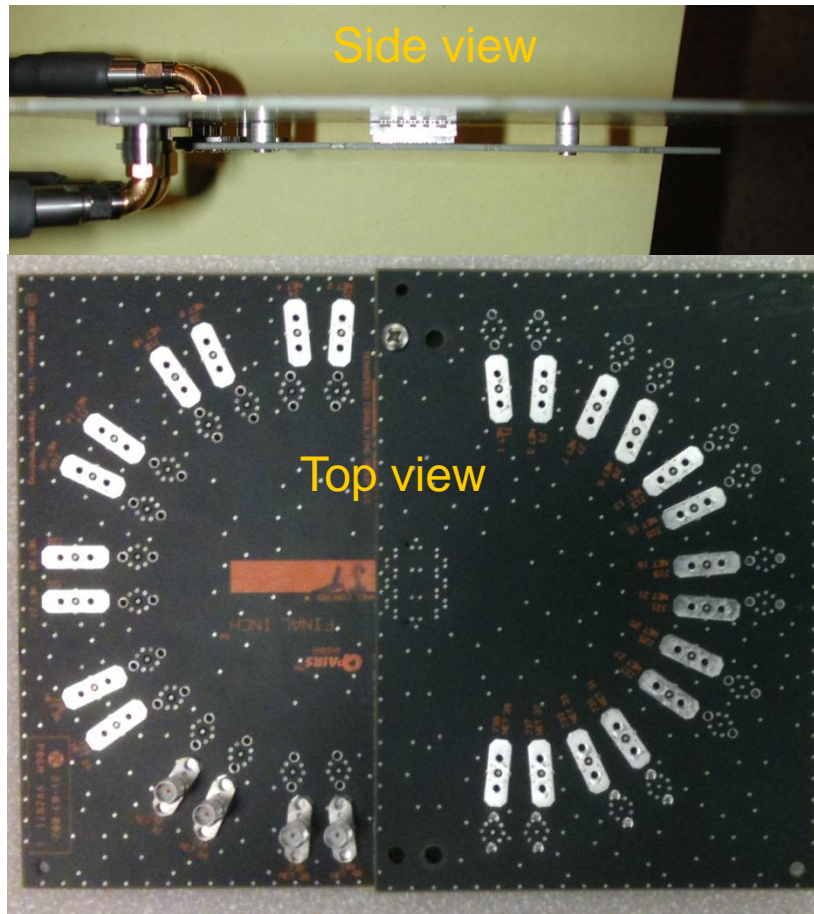
Final Step: Calculating Just the Half-Fixture S-Parameter Files



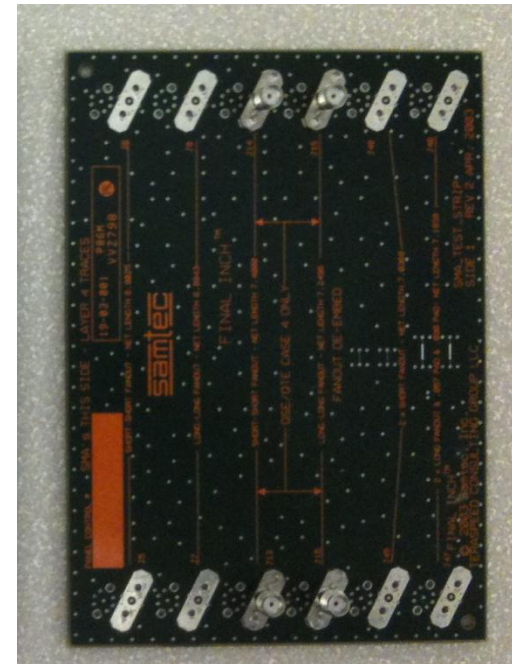
The Complete Process of Extracting The DUT from the DUT + Fixture

- Step 1: Start with
 - ✓ DUT + fixture
 - ✓ 2x thru ref fixture
- Step 2: Apply AFR to 2x thru ref fixture to get de-embed files
- Step 3: De-embed DUT only from DUT + fixture
- Step 4: Analyze the de-embedded DUT

An Example: 4-port measurement of a Samtec Board to Board Connector

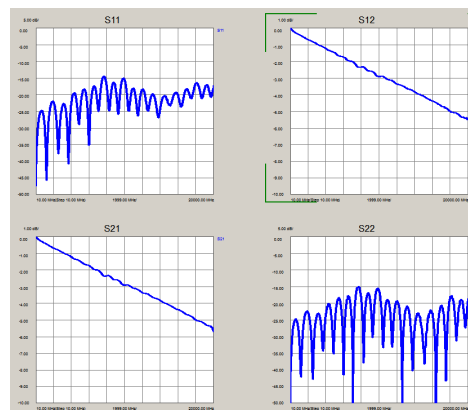
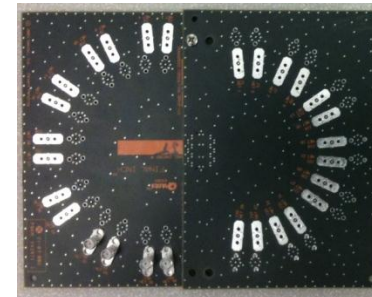
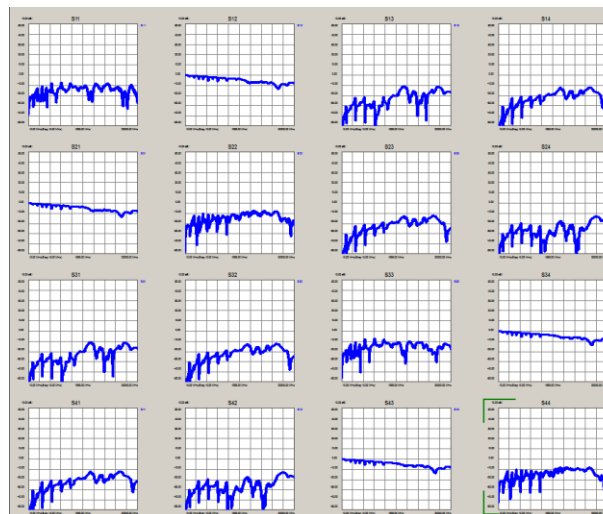


2x thru ref fixture



Samtec Connector

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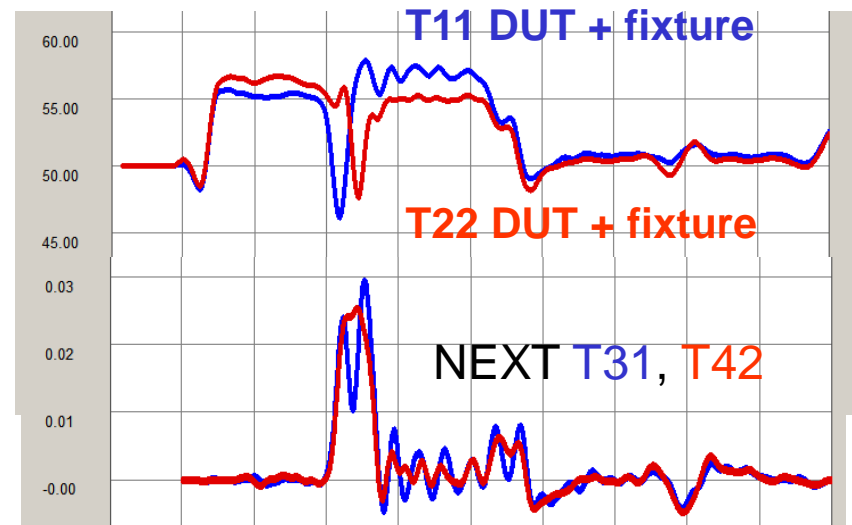
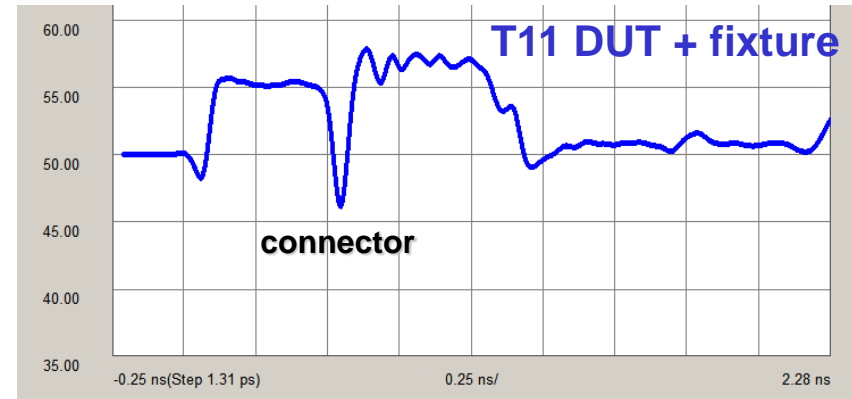
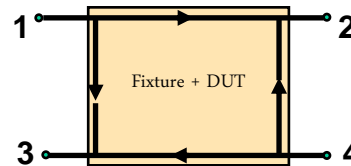
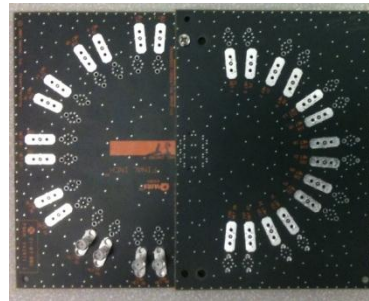


Samtec Connector

Always look at your data

"You can observe a lot by looking" -- Yogi Berra

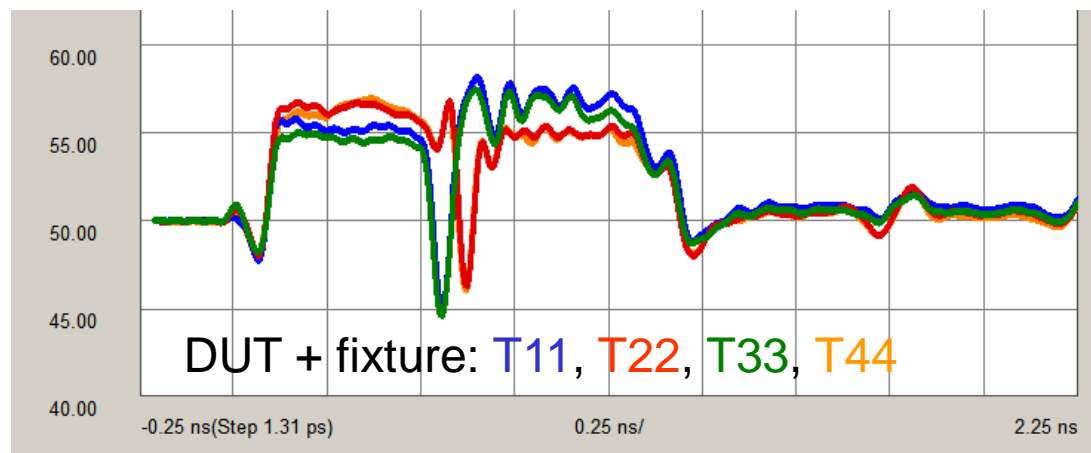
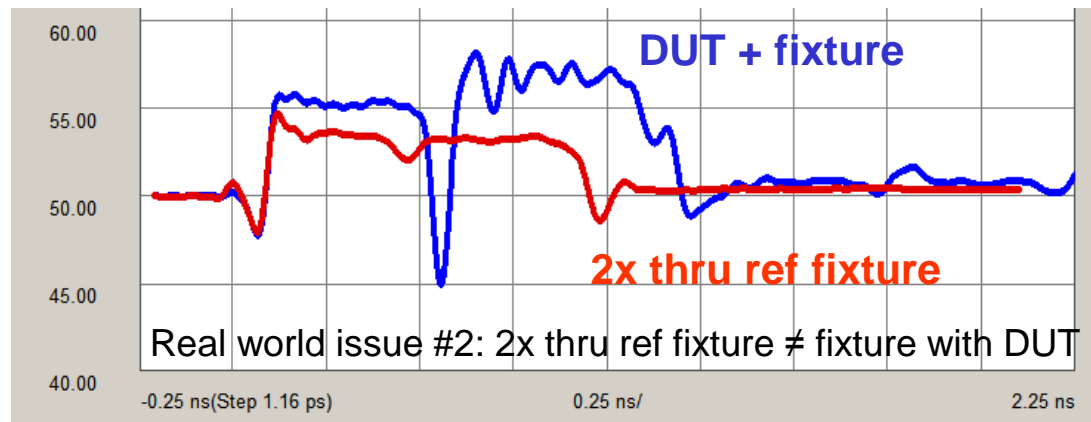
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Real world issue #1: not all the fixtures are identical or symmetric

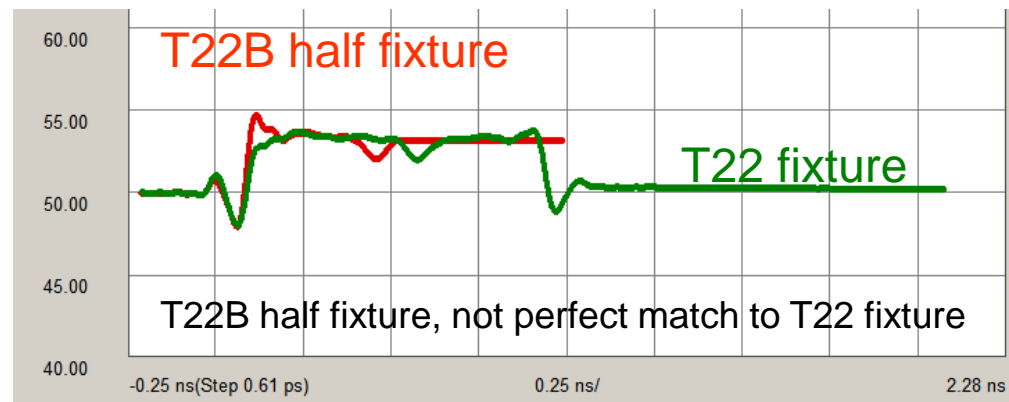
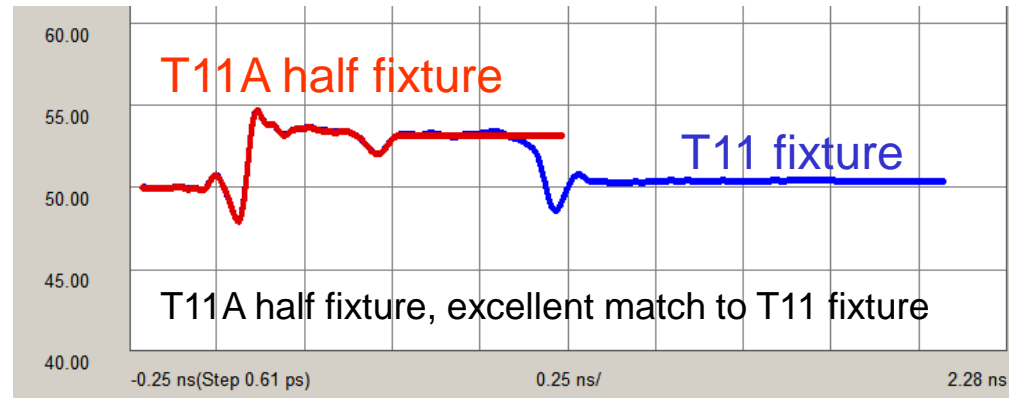
Samtec Connector

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Samtec Connector

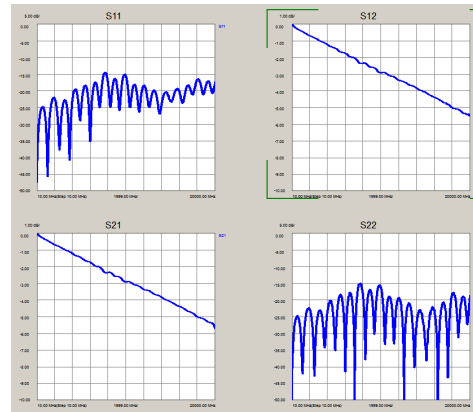
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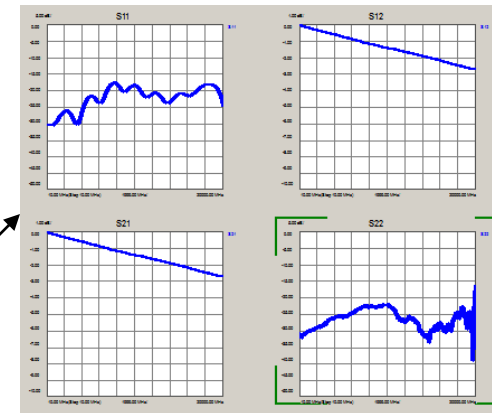
Real world issue #3: 2x thru ref fixture not perfectly symmetrical

Samtec Connector

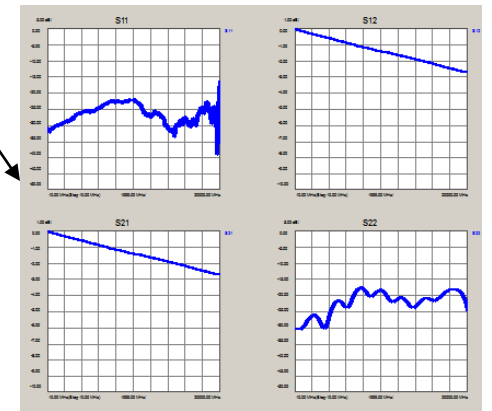
- Step 1: Start with
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- Step 2: Apply AFR to 2x thru ref fixture to get de-embed files
- Step 3: De-embed DUT only from DUT + fixture
- Step 4: Analyze the de-embedded DUT



De-embed file A

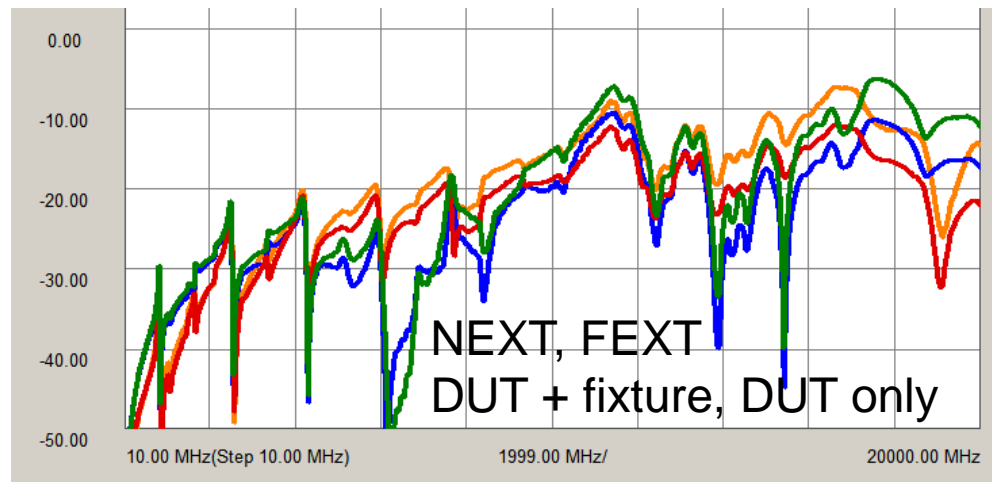
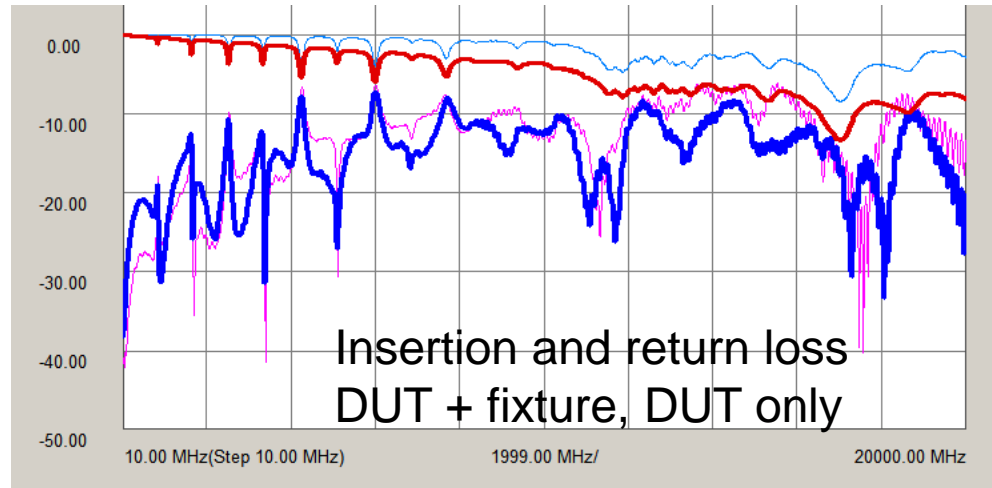


De-embed file B



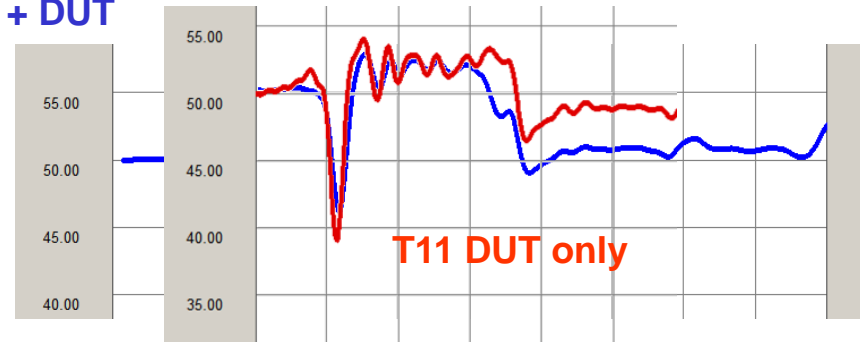
Samtec Connector

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- Step 3: De-embed DUT only from DUT + fixture
- Step 4: Analyze of the de-embedded DUT



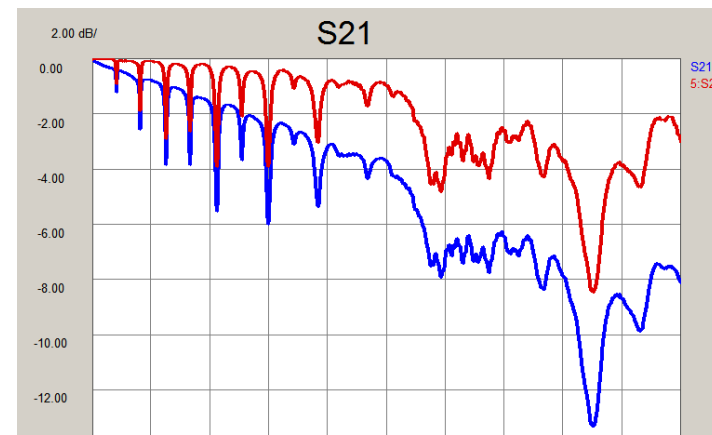
Samtec Connector

T11 fixture + DUT



At this rise time ~ 50 psec, connector impedance is lower than as measured in the fixture

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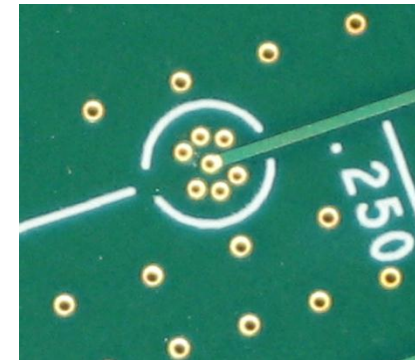
*Most of the attenuation is due to the fixture
Resonance dips probably due to coupling to other open lines*

How Well Does The AFR Method Really Work?

- Plan

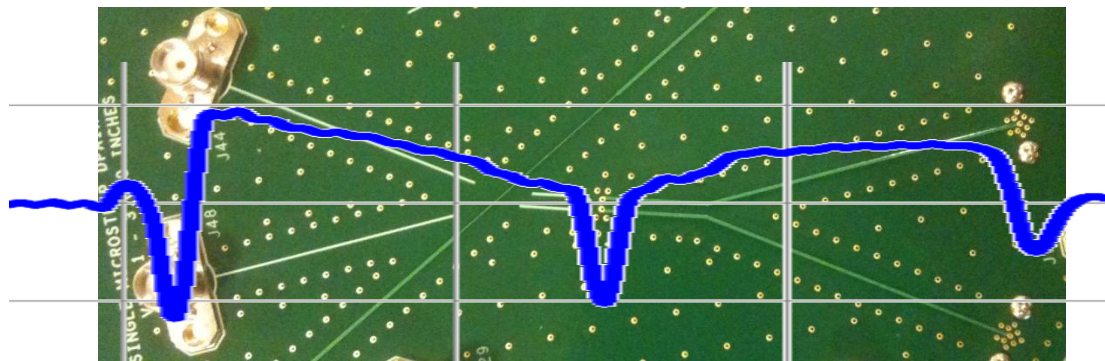
- ✓ Model a real physical system with an equivalent circuit model to create a known response
- ✓ Use a single via with transmission line feeds and typical launches
- ✓ Create S-parameters for a simulated DUT and a simulated fixture
- ✓ Change features in fixture and compare de-embedded DUT with actual DUT
- ✓ Explore the sensitivity of the fixture on the de-embedded DUT

A real Via



Courtesy of Wild River Technologies

Measured TDR response

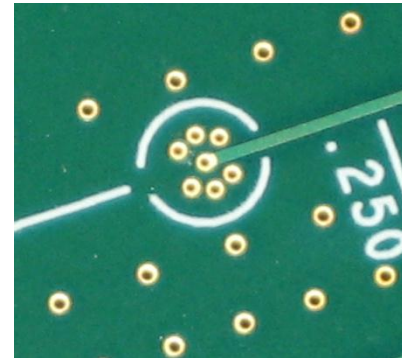


What circuit elements should we include in the model for this DUT + fixture?

Building Calibration Examples Using Synthesized S-Parameter Data

Using Agilent ADS to synthesize precision S-parameter files to test the accuracy of the AFR Method

(this way we know what the answer is supposed to be)

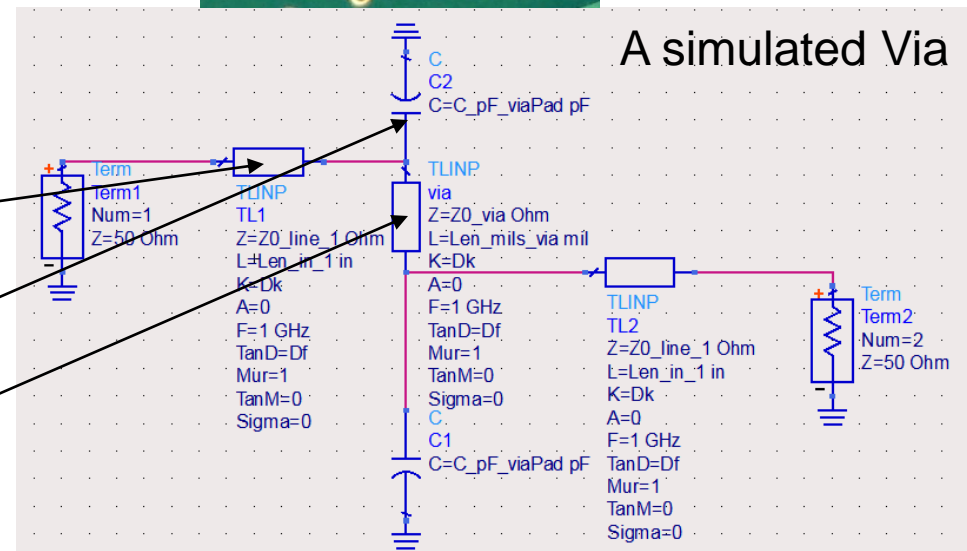


Courtesy of Wild River Technologies

A real Via

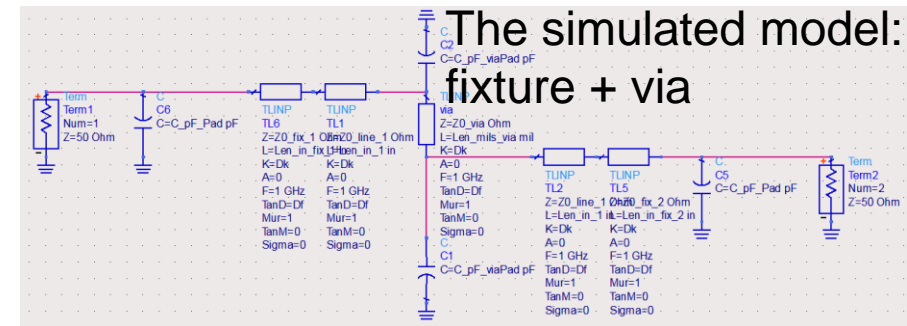
- A Simple Model of a Thru Via in ADS

- ✓ 0.25 inch long, 50 Ohm line feed on top and bottom
- ✓ 0.25 pF capture pad on the top, bottom surface
- ✓ 64 mil long uniform 60 Ohm transmission line



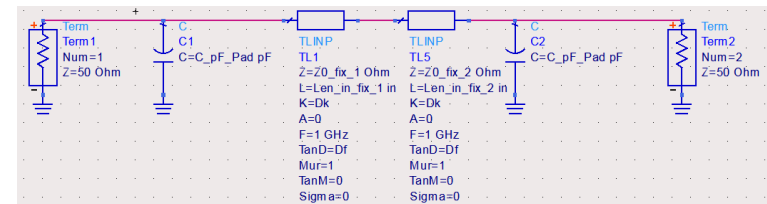
A simulated Via

Synthesize Precision S-Parameters for a Simulated Via Inside a Fixture



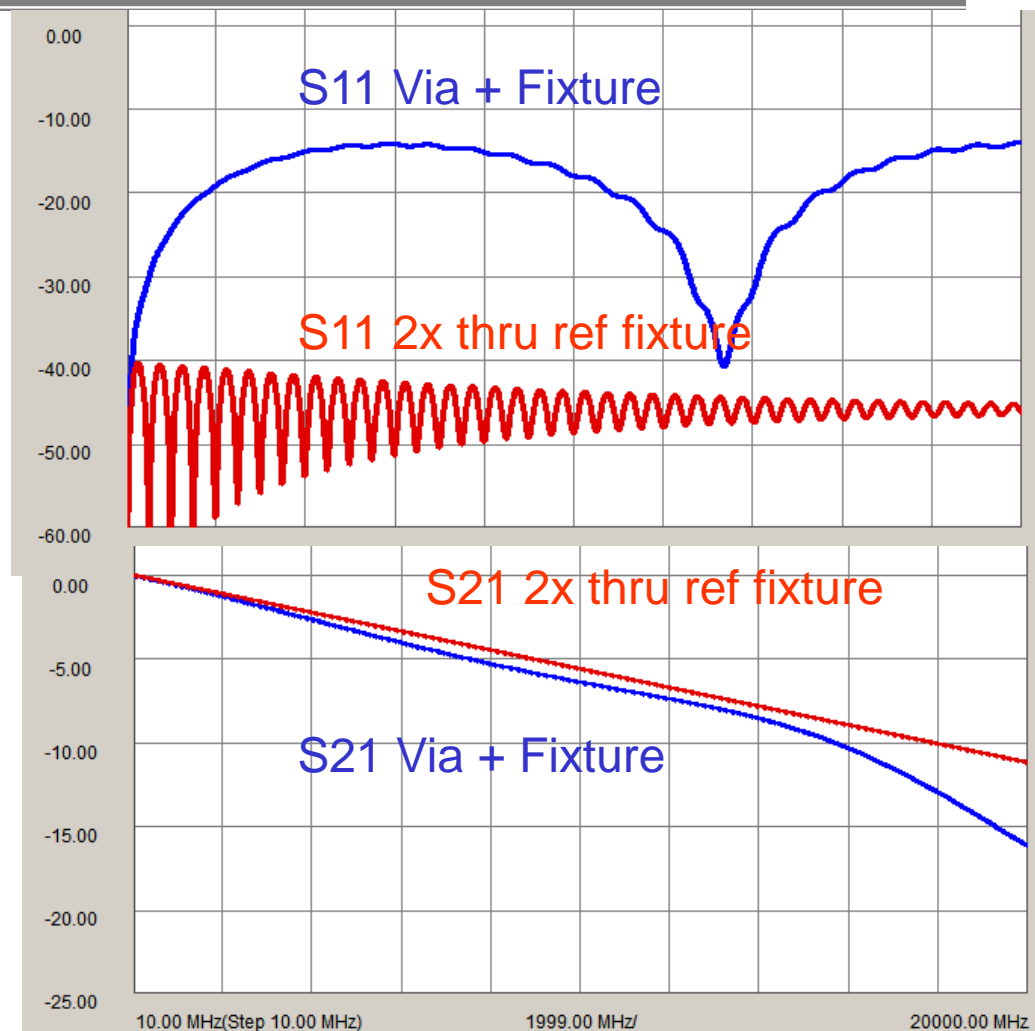
- Fixture on either side is:
 - ✓ 3 inch uniform, lossy transmission line, with launches
 - ✓ 2x thru ref fixture same as the DUT launch
- 2x thru ref fixture only
- Apply AFR to three cases:
 - ✓ Case 1: fixture is uniform lossy transmission line
 - ✓ Case 2: fixture is non uniform, lossy line
 - ✓ Case 3: fixture is not perfectly mirror image symmetrical, non uniform, lossy line
 - ✓ Case 4: fixture is perfectly mirror image symmetrical, but 2x ref thru is not

The simulated model:
2x thru ref fixture



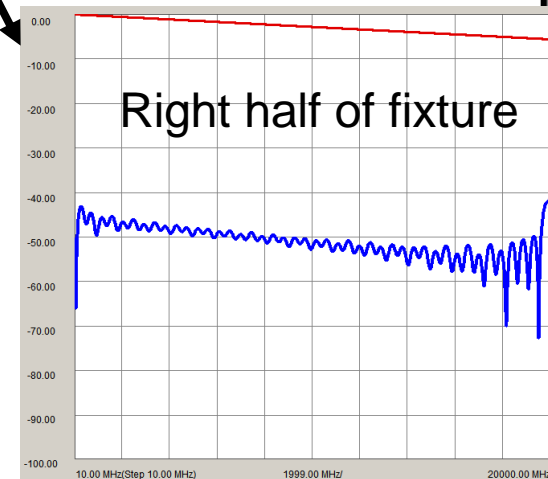
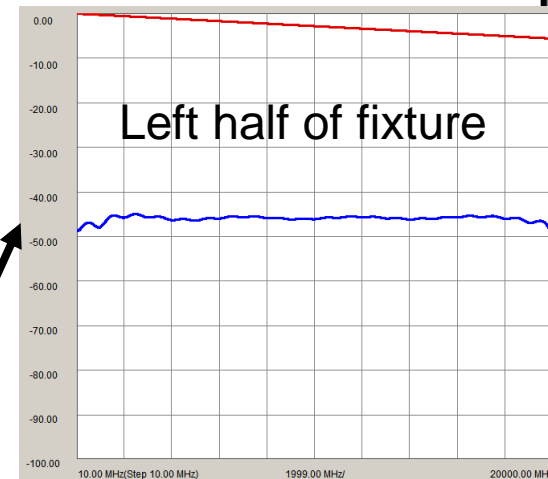
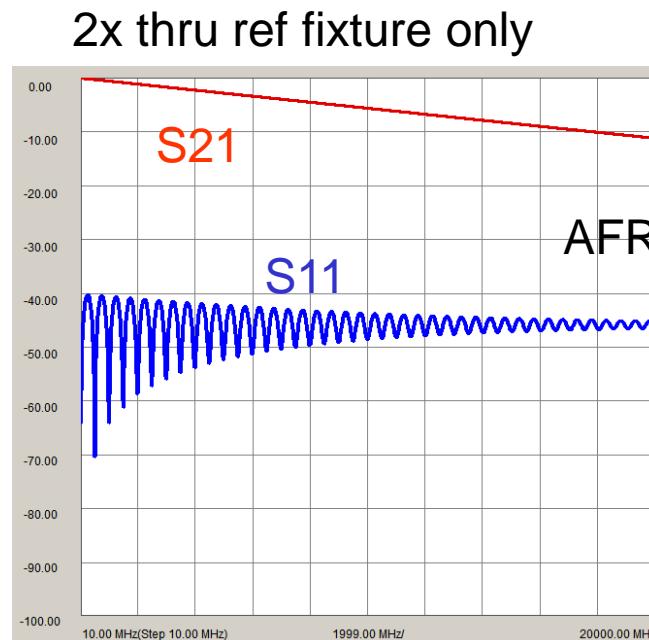
Case 1: Fixture is Uniform, 50 Ohm, Lossy Symmetric Transmission Line

- Step 1: Start with
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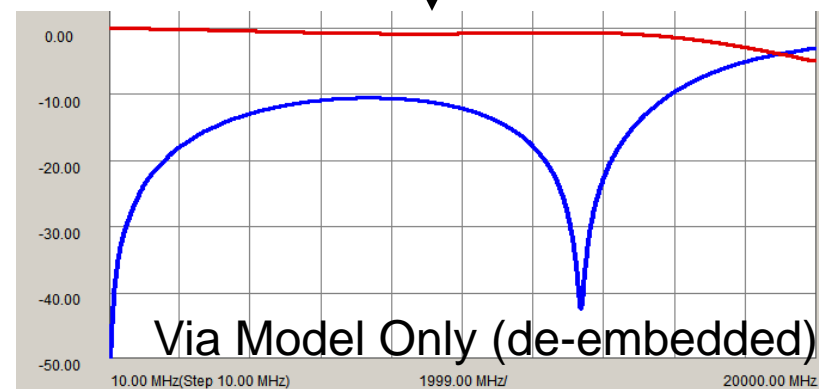
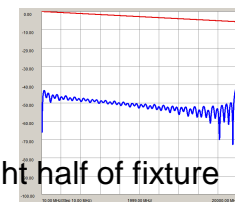
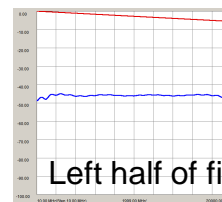
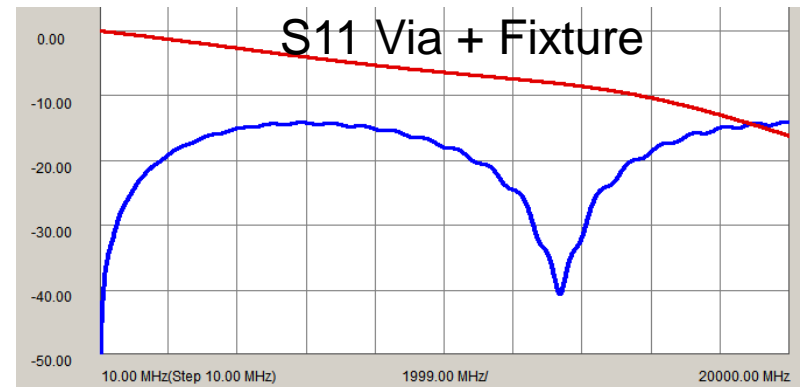
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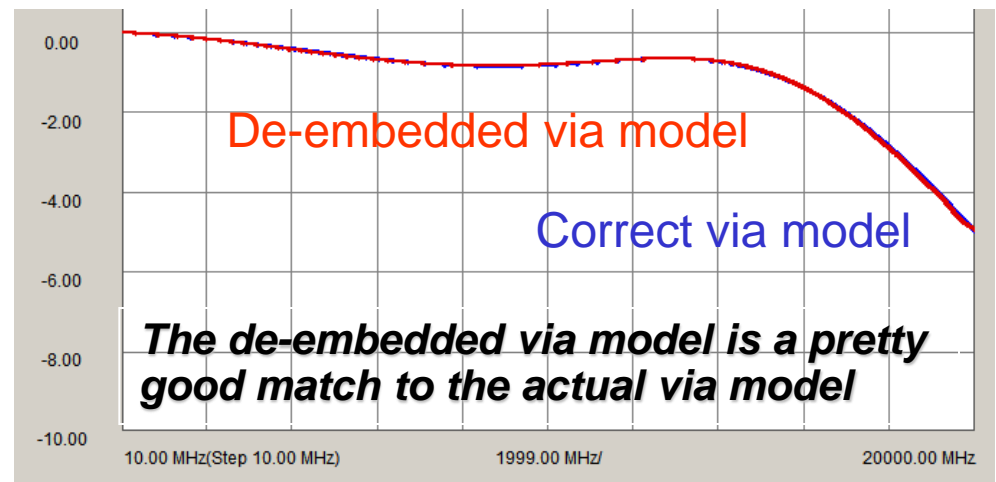
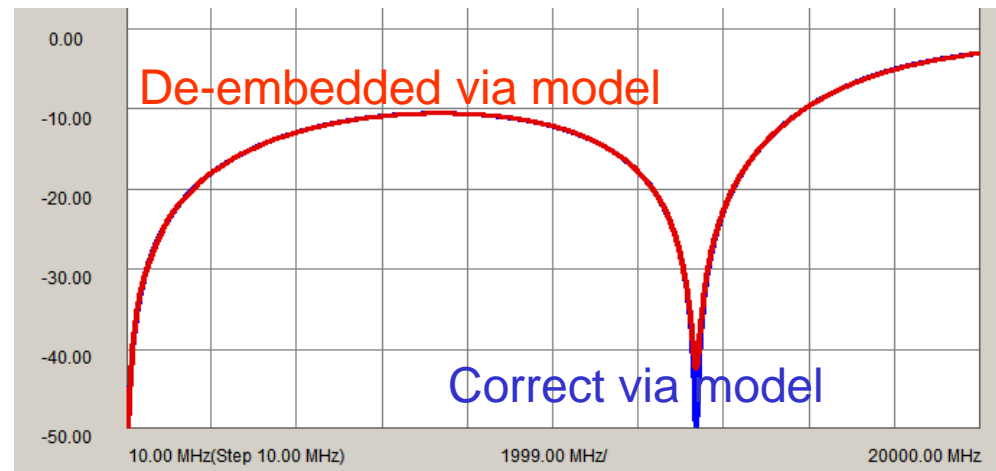
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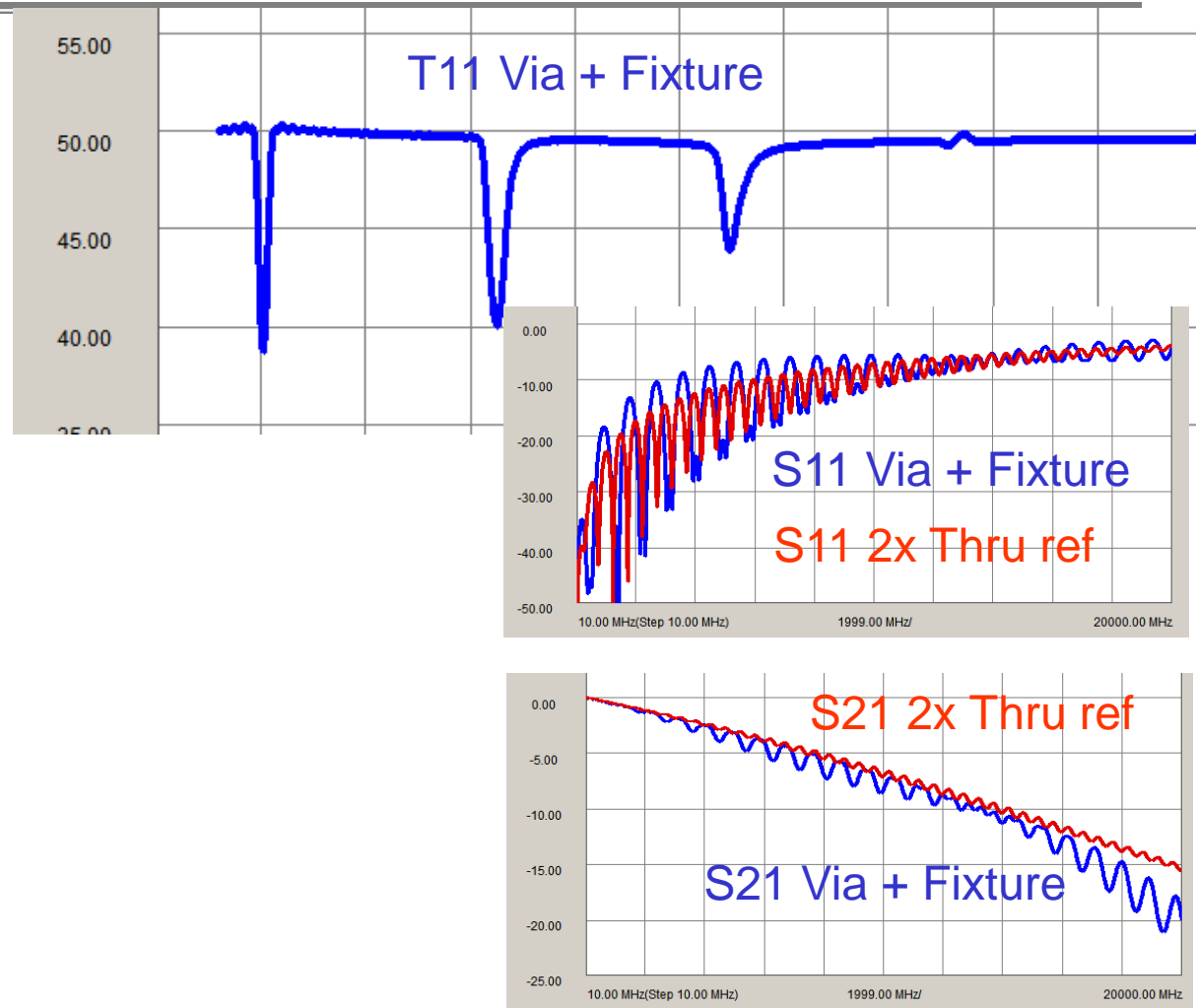
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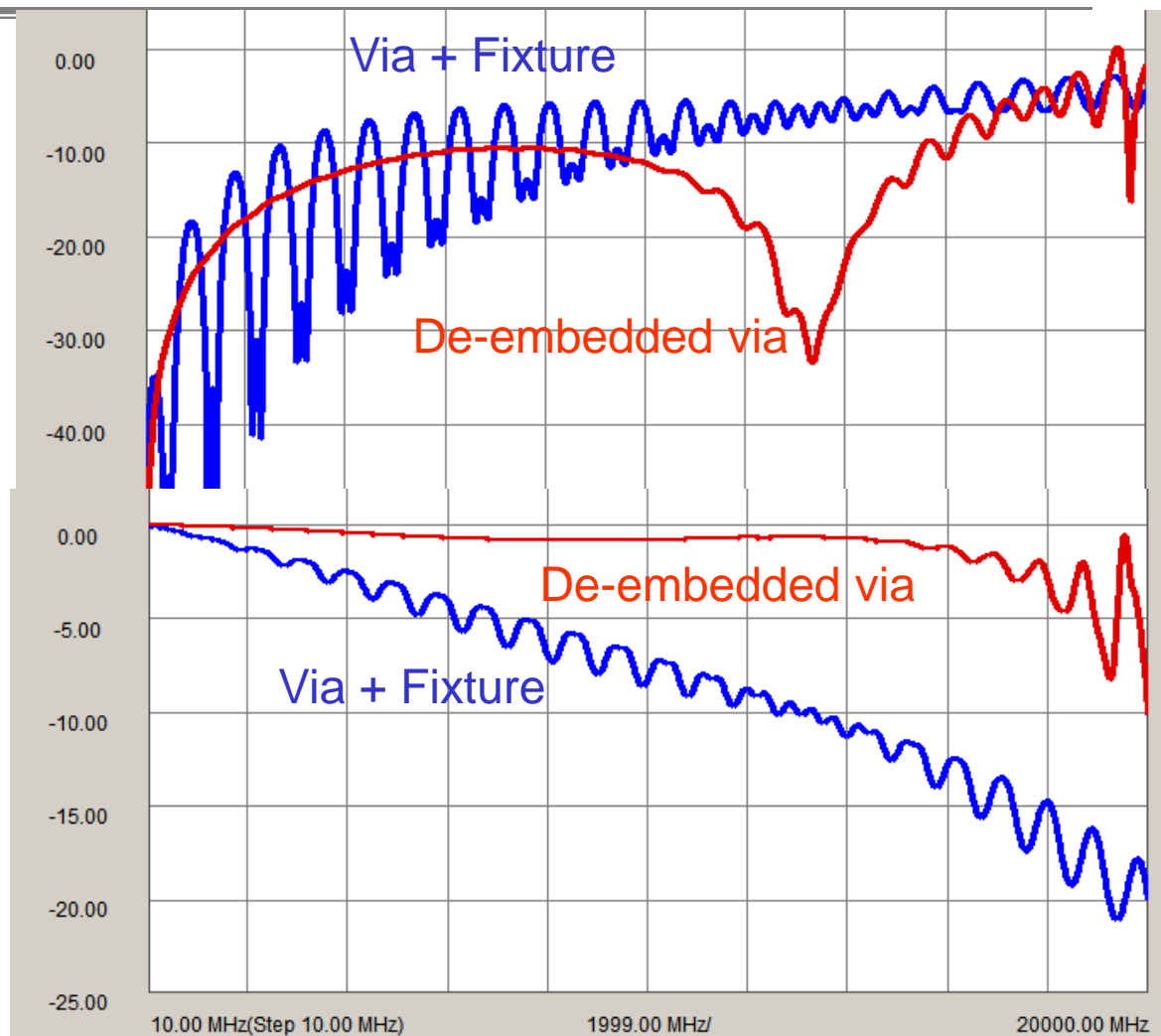
Case 2: Fixture is non-uniform, 50 Ohm, Lossy Symmetric Transmission Line

- Step 1: Start with
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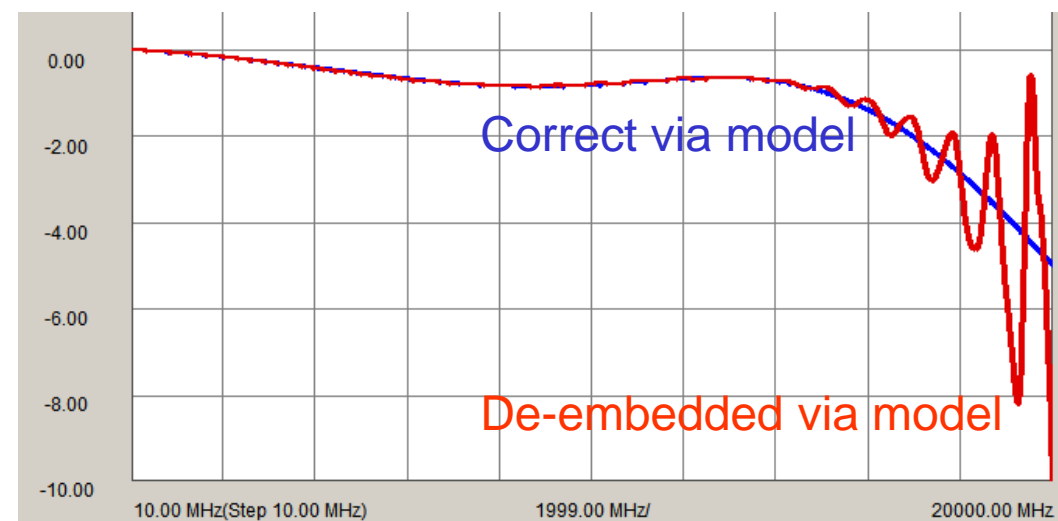
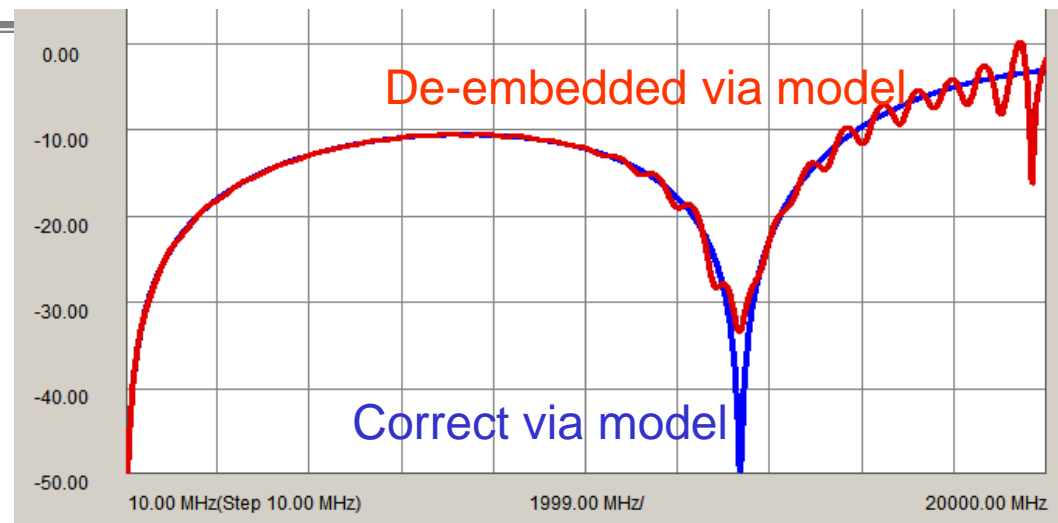
Case 2: Fixture is non-uniform, 50 Ohm, Lossy Symmetric Transmission Line

- Step 1: Start with
 - ✓ DUT + fixture
 - ✓ 2x thru ref fixture
- Step 2: Apply AFR to 2x thru ref fixture to get de-embed files
- Step 3: De-embed DUT only from DUT + fixture
- Step 4: Analyze the de-embedded DUT



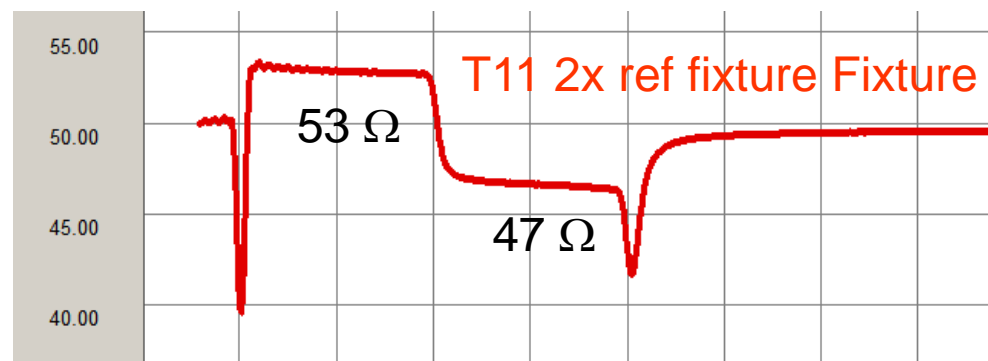
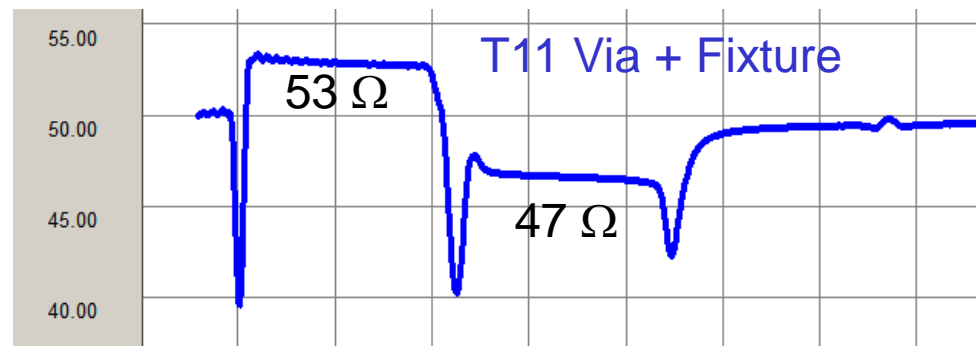
Case 2: Fixture is non-uniform, 50 Ohm, Lossy Symmetric Transmission Line

- Step 1: Start with
 - ✓ DUT + fixture
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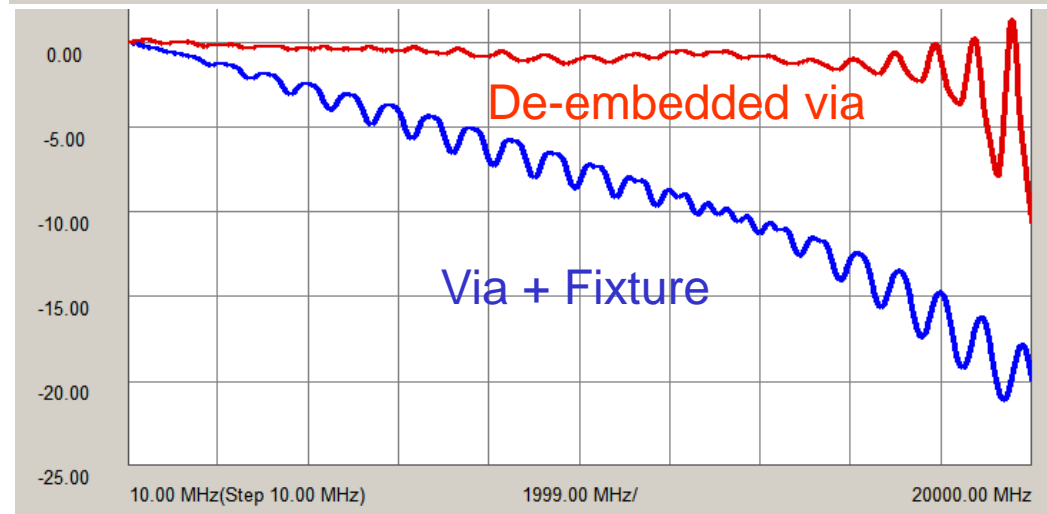
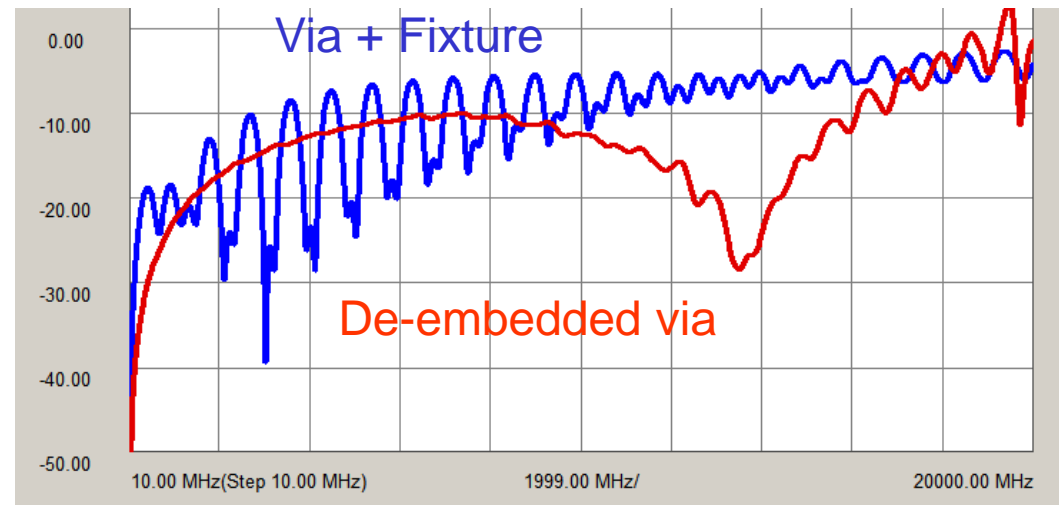
Case 3: Fixture is Non-uniform, Asymmetric Lossy Transmission Line

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- Step 2: Apply AFR to 2x thru ref fixture to get de-embed files
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- Step 4: Analyze the de-embedded DUT



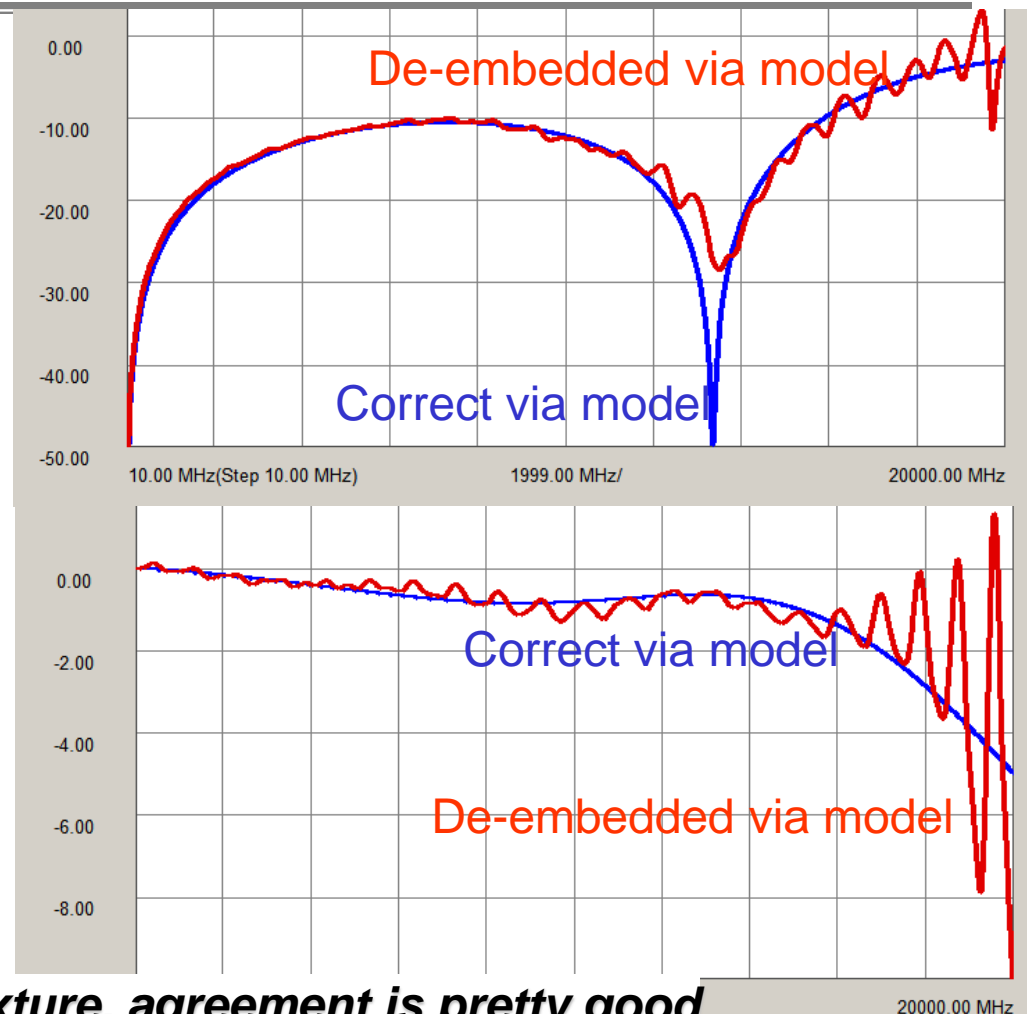
Case 3: Fixture is Non-uniform, Asymmetric Lossy Transmission Line

- Step 1: Start with
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- Step 2: Apply AFR to 2x thru ref fixture to get de-embed files
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Case 3: Fixture is Non-uniform, Asymmetric Lossy Transmission Line

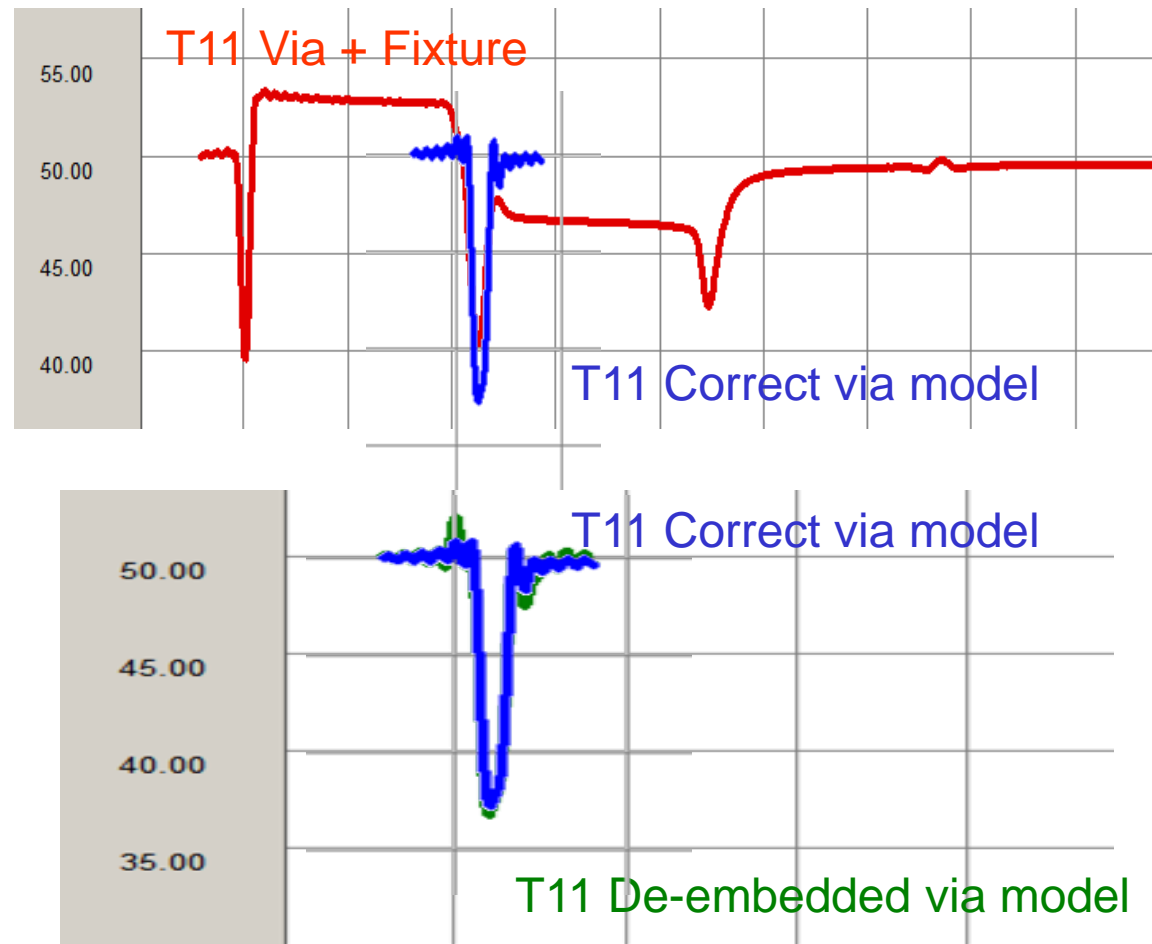
- Step 1: Start with
 - ✓ DUT + fixture
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Even with asymmetric fixture, agreement is pretty good

Case 3: Fixture is Non-uniform, Asymmetric Lossy Transmission Line

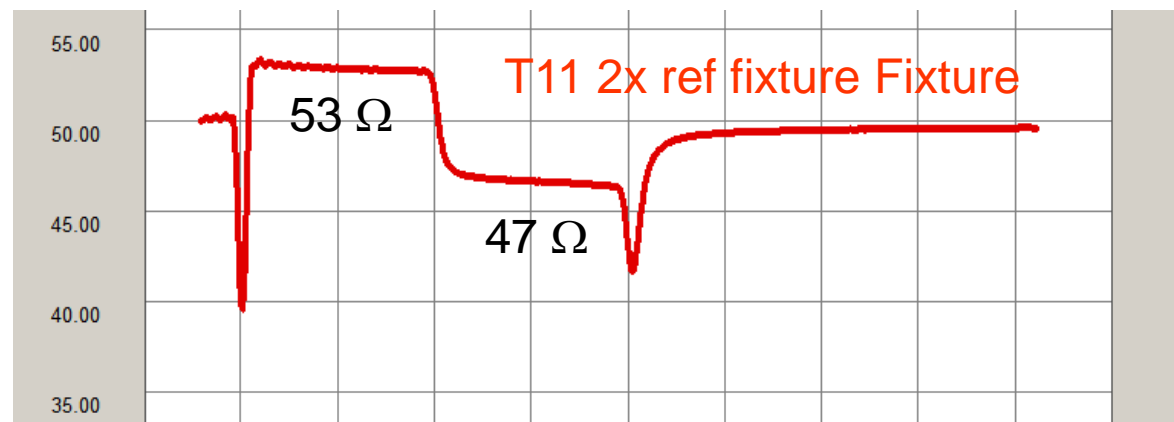
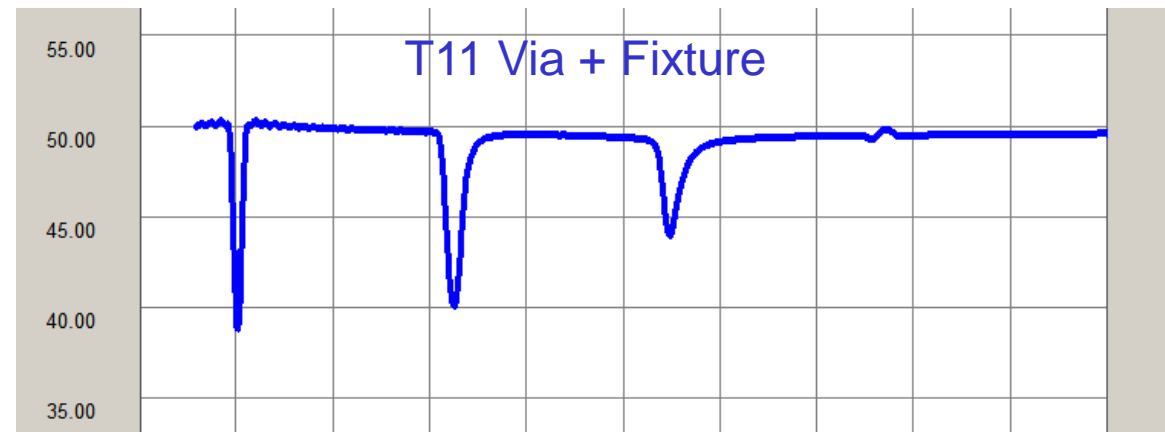
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Even with asymmetric fixture, agreement is pretty good

Case 4: 2x ref thru is Asymmetric Lossy Transmission Line, fixture is symmetric

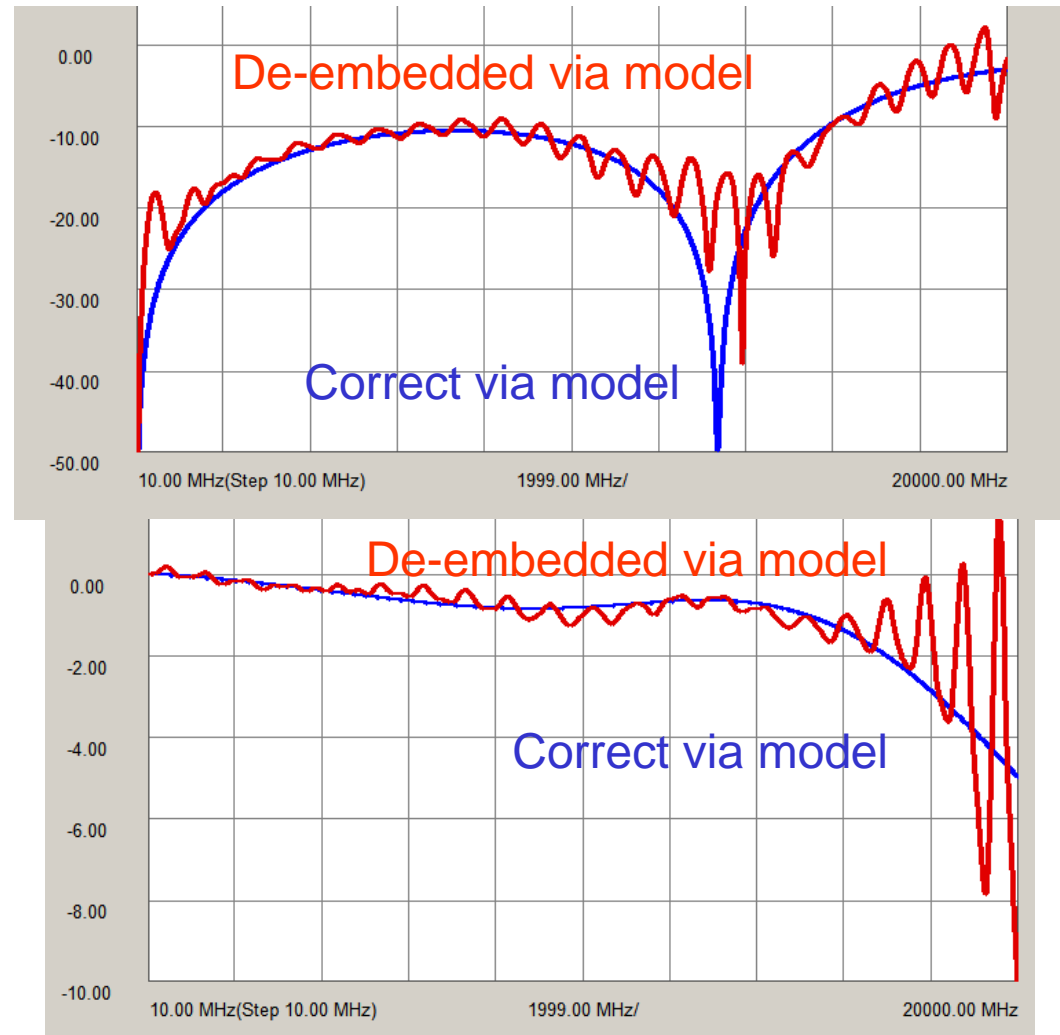
- Step 1: Start with
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- Step 2: Apply AFR to 2x thru ref fixture to get de-embed files
- Step 3: De-embed DUT only from DUT + fixture
- Step 4: Analyze the de-embedded DUT



Note: 2x thru ref fixture is different from the DUT + fixture

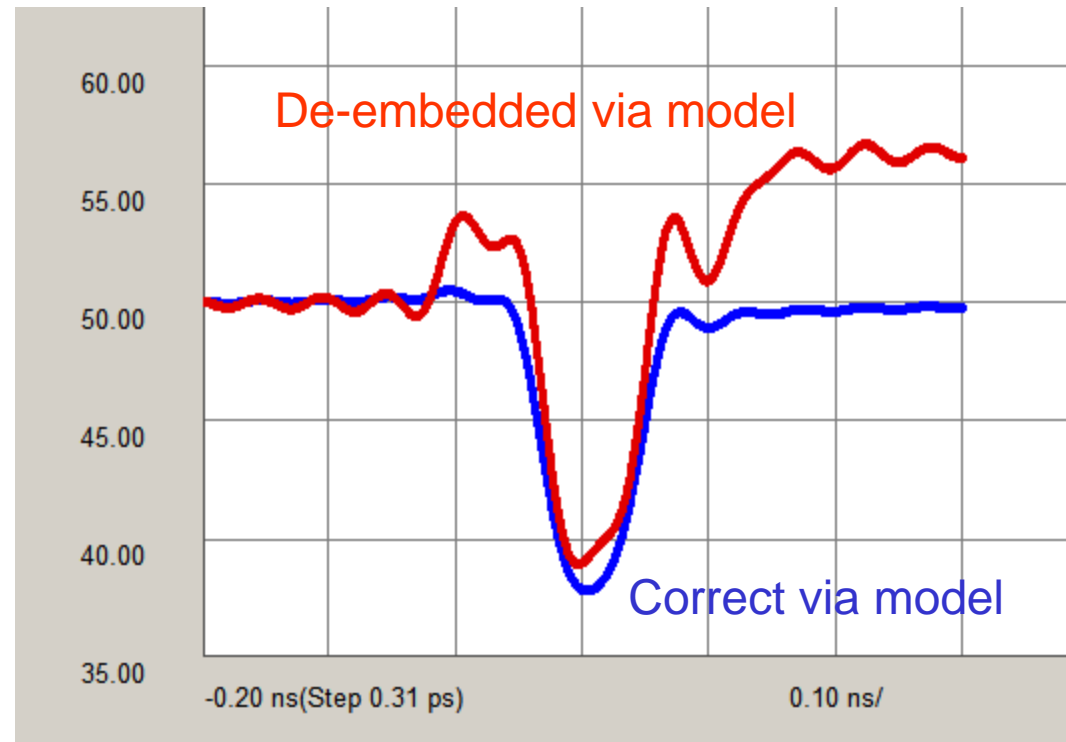
Case 4: 2x ref thru is Asymmetric Lossy Transmission Line, fixture is symmetric

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Case 4: 2x ref thru is Asymmetric Lossy Transmission Line, fixture is symmetric

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Observations About ANY De-embed Process

- ***ANY*** de-embedding technique relies on:
 - ✓ the reference structures being identical to the fixture structures
 - ✓ The fixture feeds on both ends of the DUT being identical
- The accuracy of ***ANY*** de-embed process is only as good as the quality of the fixture and references
- The Automatic Fixture Removal (AFR) process is simple to implement
 - ✓ Can be applied to single ended interconnects
 - ✓ Can be applied to differential interconnects

Application Tricks Methods

- Always design in a 2x thru ref fixture to be identical to the actual fixture to the DUT
- Always split the reference plane in a uniform transmission line region
 - ✓ Otherwise, the fringe fields are specific to the probe and intrinsic to the DUT
- Always design the fixture as transparent as possible
 - ✓ Short length, low loss
 - ✓ Uniform transmission lines matched to 50 Ohms
 - ✓ Short via stubs
 - ✓ Signal vias surrounded by return vias
 - ✓ Optimize barrel diameter, clearance holes to make 50 Ohm via
 - ✓ Minimum coupling between the lines
- What if the fixtures on the two ends are not the same?
 - ✓ Build two different 2x thru fixtures- both symmetric
 - ✓ Extract S-parameter files for each half fixture
 - ✓ Use a different de-embed files on each end
 - ✓ (need a picture!)
- Always compare T11, T22 of assembly, T11, T22 of fixture

After the Break:

- Revealing the secrets to practical measurements
 - ✓ Uniform transmission line and loss per length
 - ✓ Via or circuit board feature
 - ✓ Connector models
 - ✓ Cable properties