Hands-On Tutorial for Fixture Removal of 28 Gb/s TX Measurements

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

- 28 Gb/s SERDES Channel Overview – Romi Mayder (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 Sleigh (1 hour)

- Lessons Learned – Jack Carrel (15 min)
28 Gb/s SERDES Channel Overview

Jack Carrel
Romi Mayder

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Introduction

- SerDes links running at 28Gb/s
- Understanding performance at device pin is important
- Need to characterize the transmitter at device pin
- Measurement is dependent on Channel Fixture
  - PCB Channel
  - Connectors
  - Cables
- Channel Fixture de-embedding required to observe launch waveform
28nm FPGA with GTZ XCVR 7H580T

Heterogeneous VH580T

VH580T GTZ TX
Eye Diagram: 28.05Gb/s

VH580T GTZ
RX Eye Scan: 28.05Gb/s:
Thru 12.5dB Trace
28G Fixture Channel

Xilinx Virtex-7 FPGA
28G Tx Package-PCB Transition
Package Substrate
PCB Traces
SMA SMA
PCB-Connector Transition
Samtec® BullsEye™ Test Connector
Physical Description PCB Stackup

- 22 Layers
- HS signal layers: Panasonic Megtron6
- Other layers: ISOLA 370HR - FR4
- For Megtron6 and 370HR interleaved in lower layers for mechanical stability
- For economic reasons other layers are standard FR4 (ISOLA 370HR)
Physical Description Pin/Via Breakout

- Highspeed Signal Pin pad (Backdrilled)
- Standard Signal Pin pad (not Backdrilled)
- Ground Via (Not Backdrilled)

Vias
- 10 mil Drill
- 20 mil pad
- 28 mil anti-pad

Backdrill – 8 mils of target layer +/- 3mils
Physical Description  PCB Layout
Channel/Physical - PCB

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<th>Trace Width (mil)</th>
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Detail ‘A’
Fixture De-Embed Challenge
Next Speaker

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- Lessons Learned – Jack Carrel (15 min)
Fixture S-parameter model from 2x Fixture Physical Test Structures

Mike Resso
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

- 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

2X Thru

50 Ohm

Fixture A

Z1

Fixure B

50 Ohm

DUT + Fixtures

Fixture A

DUT

Fixture B

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
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
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
28 Gb/s SERDES Channel Overview – Romi Mayder and Jack Carrel (20min)

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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 Roles of Interconnect Measurements (S-Parameters)

- Emulate system performance with a behavioral model
- Characterize a component
- Verify a component to a spec
- Validate simulation/model to hardware
- Extract materials properties
- Debug a problem
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 text fixtures
  - Calculated test fixtures by 3D full wave field solver
  - Calculated text 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)

We measure $S$, we want $S_A, S_B$

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 result:
  - The half fixture S-parameters
  - Use these files to de-embed the DUT, using PLTS or ADS
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
Samtec Connector

- 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
Samtec Connector
Always look at your data
“You can observe a lot by looking” -- Yogi Berra

- Step 1: Start with
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  - 2x thru ref fixture
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- Step 4: Analyze the de-embedded DUT

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

- 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

Real world issue #2: 2x thru ref fixture ≠ fixture with DUT
Samtec Connector

- 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

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

- 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

De-embed file A

De-embed file B
Samtec Connector

- 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 of the de-embedded DUT

![Graphs showing insertion and return loss](Slide-Picture)

- NEXT, FEXT
- DUT + fixture, DUT only
- Insertion and return loss
- DUT + fixture, DUT only
Samtec Connector

- 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

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

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

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)

• 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
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
Case 1: Fixture is 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
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- **Step 1:** Start with
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- Step 4: Analyze the de-embedded DUT

The de-embedded via model is a pretty good match to the actual via model.
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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- 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
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  - 2x thru ref fixture
- 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
  - 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
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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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- Step 4: Analyze the de-embedded DUT

Even with asymmetric fixture, agreement is pretty good
Case 3: Fixture is Non-uniform, Asymmetric Lossy 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

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
  - 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

Note: 2x thru ref fixture is different from the DUT + fixture
Case 4: 2x ref thru is Asymmetric Lossy Transmission Line, fixture is symmetric

- 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

De-embedded via model
Correct via model
Case 4: 2x ref thru is Asymmetric Lossy Transmission Line, fixture is symmetric

- **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
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
28 Gb/s SERDES Channel Overview

Heidi Barnes

Agilent Technologies
Hybrid Fixture 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

Method #3 - Hybrid Channel Model De-Embedding Solution

Direct Measurement of the Cable/Connector Assembly and PCB Transition + Measurement Based PCB Path Model for Variable Path Lengths
Hybrid Fixture Cable Assembly

Direct Measurement of the Cable/Connector Assembly and PCB Transition using 2x Through Path Automatic Fixture Removal (AFR)

Samtec Bulls-Eye Coaxial PCB Connector

2x Test Fixture Through Path
PCB Layer 5
AFR Reference Plane

Port 1
Port 2
Port 3
Port 4

Bulls-Eye PCB Loopback Footprint

S21
S11
y-axis: -2 dB/div
x-axis: 3 GHz/div

TDR
y-axis: 5 ohms/div
x-axis: 0.2 nS/div

0.00 30 GHz
Hybrid Fixture Channel Simulation

Measurement Based Transmission Line Model Creation
Tune PCB DK and Loss Characteristics to Match Measurements

Test Fixture Structures

- a) 2x Through Path
- b) 2x Through Path + 2 inches

Measurement Based Model

Coaxial Cable Model

PCB Multi-Layer T-Line Model

Extract Material Properties
Megtron, Layer 5
Stripline Width = 4.1 mils
DK Height Above = 4.1 mils
DK Height Below = 6 mils
DK = 3.7
Loss Tangent = 0.0132
Copper Conductivity = 3e7
Copper Thickness = 0.5 mils
“Hybrid Channel Model De-Embedding easily corrects for path length variation enabling best case routing for each high speed connection. Costly length matching to the longest path is avoided.”

Example Path Loss Distribution

Min. Fixture Path 2.043 inches
Max. Fixture Path 3.712 inches

Shortest Path vs. Longest Path

Ideal De-Embed for all Paths
Shortest Path
Longest Path
Open ADS

• Check the task bar – it should be running...
  – If not open ADS and select recently opened workspace
    DesignCon_13TU1_Fixture_DeEmbed_Model_hlb130124_wrk

• Make sure the –readme schematic is open
  – double click on the –readme schematic in the Folder View

• Use the Push and Pop Icons to step through the –readme schematic:
-readme Examples

Push into and Pop out of the schematic symbols

Simulated Measurement Based Model Creation:

Example 1: 2x Thru (set up the model)

Time Domain Sweep

Example 2: 2x Thru + 2inches (refine the model)

Time Domain Sweep

Example 3: 1x Thru (use a half of the 2x model)

Frequency Domain Sweep

Select the Subcircuit Icon
Then use **Push and Pop** to go
To the subcircuit example
And return to the top level

-readme
Schematic ToolBar

Undo and Redo Changes

Pop back up to the –readme schematic

Simulate and see results
28 Gb/s SERDES Channel Overview – Romi Mayder and Jack Carrel (20min)

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Robert Sleigh
Channel Model
De-Embedding Options

1) Direct Probe Measurement
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De-embedding: Partial vs. Full

**Partial De-embedding:**
- Removes insertion loss
- Does NOT remove reflections (assumes an ideal source, receiver)
- Easier to implement

**Full De-embedding:**
- Removes insertion loss and reflections between circuit elements
- More accurate (but less forgiving if models/delays are not correct)
Validate S-parameter Models

Description of Procedure

Procedure:

1. **Measure the “Reference Signal”** directly (no probe or channel)

   ![Diagram showing measurement setup]

   **28G TX Source** → **DCA (Scope)**

2. **Embed**: Using “Reference Signal”, embed the channel model, predict the degraded signal.

   **28G TX Source** → **DCA (Scope)** → **Embed: Meas. PCB Channel**

3. **Actual**: Insert the actual channel (probe launch), directly measure degraded signal. Compare to “Embed”.

   **28G TX Source** → **GigaTest uProbe** → **PCB Channel** → **BullsEye Connector** → **DCA (Scope)** → **De-Embedding: None**

4. **De-embed**: Remove channel effects from actual, compare waveform/jitter results to “Reference Signal” (3 models).

   **28G TX Source** → **GigaTest uProbe** → **PCB Channel** → **BullsEye Connector** → **DCA (Scope)** → **De-Embedding: Meas. PCB Channel**

   **De-Embedding: Test Coupon AFR**

   **De-Embedding: Hybrid Channel**

* Note - All four tests were run with both 28G TX Sources.
But first…have the end in mind!

Using the channel model, simulate what we should expect at the output of the fixture.

Input: “Ideal” 28 Gb/s (simulated signal)

Output: Degraded 28 Gb/s signal (simulated signal)

Embed fixture model

☑️ We have an open eye diagram!
☑️ Edge Speed: ~ 16 ps
☑️ Eye Amplitude: ~ 21% lower
☑️ ISI (p-p): 2.8ps (PRBS7); 3.1 ps (PRBS15)

=> All seem reasonable…proceed to making measurements.
Demo# 1 – Have the end in mind...

What will an “ideal” signal look like at the output of my channel?
Recall Instrument Setup: FlexDCA_Simulate_Signal_After_Channel.setx

Operators (separate tabs)

Available input signals/waveforms for functions/operators (valid/configured signals)

Outputs (probes)

1. Drag/Drop operator
   Click to setup channel.
   3. Drag/Drop probe (to select color, or click output to setup function. E.g. F2)

2. Drag/Drop input
   Click to setup input signal.

Analyze:
1. Waveform – look reasonable?
2. Measure rise time.
3. Look for an open eye diagram.
4. Measure ISI (Jitter Mode).
Validate S-Parameter Model #1 (Probe) using 28G PG
Step #1-3: Eye/Scope Results at output of channel/fixture (DUT)
[Ref Signal: Pattern Generator (PG)]

1. Measure reference
   - Blue – Reference signal
   - Pink – Simulated fixture (using s4p file)
   - Green – Actual signal via fixture

2. Simulated
   - Measured PCB Channel S-Parameter Model
   - 28G Generator
   - GigaTest uProbe
   - PCB Channel
   - BullsEye Connector
   - DCA (Scope)
   - De-Embedding: None

3. Actual
   - Actual PCB Channel (DUT)
   - Measured PCB Channel
   - 28G Generator
   - DCA (Scope)
   - De-Embedding: None

Results: excellent correlation between simulated and actual waveforms => Model #1 looking good…
Validate S-Parameter Model #1 (Probe) using 28G PG

Step #4: De-embed and compare waveform results

[Ref Signal: 28G Pattern Generator (PG)]

Summary => Model #1 (Probe) looks good so far.
Validate S-Parameter Model #1 (Probe) using 28G PG

Step #4: De-embed and compare Jitter Results

[Ref Signal: Pattern Generator (PG)]

1. Measure reference

28G Pattern Generator  →  86100D Scope

3. Actual signal through channel

28G Pattern Generator  →  Fixture  →  Xilinx  →  86100D Scope

4. De-embed channel, compare to Reference

28G Pattern Generator  →  Xilinx  →  Fixture  →  86100D Scope

ISI: 5.44 ps p-p

ISI: 9.01 ps p-p

ISI: 5.40 ps p-p

Good Correlation => further validates Model #1
Validate S-Parameter Model #1 (Probe) using 28G Xilinx TX:
Step #1-3: Eye/Scope Results at output of channel/fixture (DUT)

[Ref Signal: Xilinx 28G GTZ]

1. Measure reference
   - Blue – Reference signal
   - Pink – Simulated fixture (using s4p file)
   - Green – Actual signal via fixture

2. Simulated
   - Measured PCB Channel
   - Simulated S-Parameter Model

3. Actual
   - Actual PCB Channel (DUT)

Results: good correlation between simulated and actual waveforms => validates model
Validate S-Parameter Model #1 (Probe) using 28G Xilinx TX
Step#4: De-embed and compare waveform results
[Ref Signal: Xilinx 28G GTX]

Offsetting the waveforms shows the de-embedded signal (PINK) restores much of the structure found in the original waveform (Dark BLUE).

- Amplitude restored (slightly high)
- Edge speed restored
- Waveshape restored

Summary => Model #1 looks good so far.
How well does the “Probe” model compare to the 28G Reference?

Recall Instrument Setup: 2_FlexDCA.Validate.Probe.Model-Xilinx_TX_Ref

Analyze:
1. Waveform: compare F3 de-embed waveform to F1 reference.
2. Measure rise time.
3. Check out Eye/Mask results.
4. Measure ISI (Jitter Mode).
Validate S-Parameter Model #1 (Probe) using 28G Xilinx TX: Step #4: De-embed and compare Jitter Results

[Ref Signal: Xilinx 28G GTZ]

1. Measure reference
   - 28G Pattern Generator
   - 86100D Scope

2. Actual signal through channel
   - 28G Pattern Generator
   - Fixture Xilinx
   - 86100D Scope

3. De-embed channel, compare to Reference
   - 28G Pattern Generator
   - Xilinx Fixture
   - 86100D Scope

ISI: 4.88 ps p-p
ISI: 8.80 ps p-p
ISI: 4.88 ps p-p

Good Correlation => further validates model
Validate S-Parameter Model #2 (AFR) using 28G Xilinx TX
Step #4: De-embed and compare waveform results
[Ref Signal: Xilinx 28G GTX]

Summary => Reference signal, Model #1 (Probe) and Model #2 (AFR) correlate well.
Validate S-Parameter Model #3 (Hybrid) using 28G Xilinx TX
Step #4: De-embed and compare waveform results

[Ref Signal: Xilinx 28G GTX]

| Xilinx 28G GTZ Transmitter | PCB Channel | BullsEye Connector | GigaTest uProbe | PCB Channel | BullsEye Connector | GigaTest uProbe | PCB Channel | BullsEye Connector | GigaTest uProbe | PCB Channel | BullsEye Connector | GigaTest uProbe | PCB Channel | BullsEye Connector | GigaTest uProbe | PCB Channel | BullsEye Connector | GigaTest uProbe | PCB Channel | BullsEye Connector | GigaTest uProbe | PCB Channel | BullsEye Connector |
|---------------------------|-------------|-------------------|----------------|-------------|-------------------|----------------|-------------|-------------------|----------------|-------------|-------------------|----------------|-------------|-------------------|----------------|-------------|-------------------|----------------|-------------|-------------------|----------------|-------------|-------------------|----------------|-------------|

Dark Blue – Reference Signal
Green – Actual signal via fixture
Pink – De-embed using Direct Probe s4p file
Orange – De-embed using AFR s4p file
Light Blue – De-embed using Hybrid s4p file

Summary => Reference signal and all three models correlate well.
28G Device Measurement

Use each S-parameter model to de-embed Channel Fixture

**Input**
(waveform measured directly at the output of the fixture)

1. S-parameter model from:
   Direct probe measurement

2. S-parameter model from:
   Test fixture structure measurement (AFR)

3. S-parameter model from:
   Hybrid simulation (ADS)

**De-embedded Output**
(simulated signal at the balls of the IC)

Note 1 – the “Align” function simply removes filter delay and aligns waveforms making it easier to compare waveforms.
Demo# 3 – Compare de-embed results

Predict waveform at the balls of the device using all 3 models.
Recall Instrument Setup: 4_FlexDCA_Validate_Probe_Model-Xilinx_TX_Ref

Analyze:
2. Measure rise time.
3. Check out Eye/Mask results.
4. Measure ISI (Jitter Mode).

F3 – “Probe” model
F3 – “AFR” model
F3 – “Hybrid” model

5A, 5B (D5A) Measured at output of test fixture.
28G Device Measurement
Use each S-parameter model to de-embed Channel Fixture

- Raw Waveform – measured at the connectorized output of the fixture
- S-parameter model used: Direct probe measurement
- S-parameter model used: Test Fixture Structure (AFR)
- S-parameter model used: Hybrid (ADS)

De-embedding a channel fixture provides:
- increased eye amplitude
- faster rise times
- lower jitter
- More accurate representation of the signal at the balls of the device.
- Increased margins.
After removing the fixture effects through the use of de-embedding techniques, the 25.78 Gb/s signal at the balls of the device had the following (minimum) improvements in signal quality:

- Rise Time: 2.6 ps faster
- Eye Amplitude: 226 mV higher
- Deterministic Jitter (DJ): 440 fs lower.
Demo #4 – Why is there ringing in my de-embedded waveform?

Too much “noise” on your de-embedded eye diagram? 
Recall Instrument Setup: 5_FlexDCA_Ringing_Example.setx
28 Gb/s SERDES Channel Overview – Romi Mayder and Jack Carrel (20 min)

Fixture S-parameter model from 2x Fixture Physical Test Structures – Mike Resso (40 min)

Fixture S-parameter model from Simulated Measurement Based Model – Heidi Barnes (40 min)

Waveform Measurements at the DUT using S-parameter model de-embedding. Rob Sleigh (1 hour)

Lessons Learned – Jack Carrel (15 min)
Lessons Learned

Jack Carrel

XILINX ALL PROGRAMMABLE.
Lessons Learned for 28Gbps - Loss

1. Well designed broad band via transitions are achievable and are very repeatable.
2. PCB T-Line Loss is easily managed by modern pre- and post- emphasis techniques.
Lessons Learned for Fixture De-Embed

1. PCB T-Line loss dominates in a well designed fixture, but this is easy to De-Embed.
2. Measured Test Coupons enable building blocks for simulating all path lengths.

The cable loopback provides the Fixture Input.

The 2x Through Path provides the Fixture Input and Fixture Output.
Hybrid Fixture De-Embed

The Fixture Input can be De-Embedded from the 1x Fixture Path to get Fixture Output

\[
(S_{\text{Fixture Input}})^{-1} \times (S_{\text{Fixture Input and Output}}) = (S_{\text{Fixture Output}})
\]

Cascading S-Parameters for each Fixture Path

Adjustable Path Length
Simulated T-Line Loss
Conclusion

• Test Fixture is simple to build and measure

• Partial de-embedding
  – Substantially less effort than full de-embed
  – Results are sufficient in most cases

• Hybrid de-embed allows test fixture to be used for many channel lengths

• Results of de-embed are comparable to actual

• This methodology is useful because:
  – Economical use of time and resources
  – Does not require elaborate measurement equipment and set up
  – Results are adequate without expensive effort and resources