DesignCon® 2014

13-TU1, Tuesday Jan 28th, 4th Speaker 10:45 am to 11:45

28 Gb/s SERDES Channel Overview

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UBM Tech

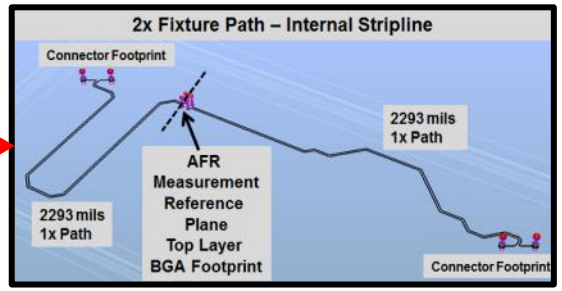
Channel Fixture Models for 28Gbps SERDES

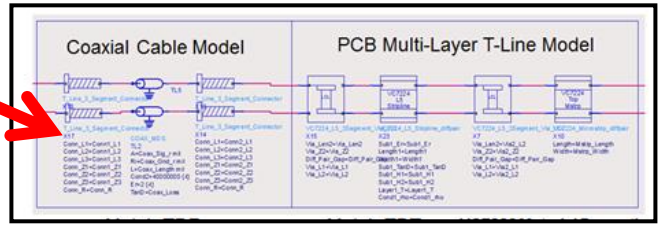
Channel Model De-Embedding Options

1) **Direct Probe** Measurement

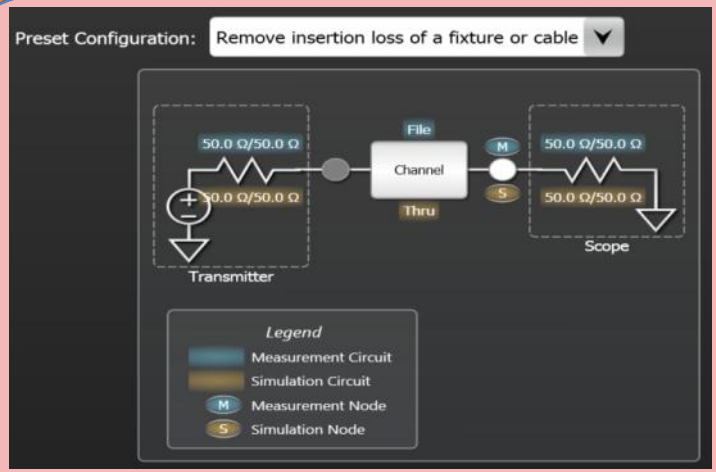
2) **Test Coupon** Structure with AFR

3) **Hybrid** Multi-Path Simulation with Minimal Test Structures





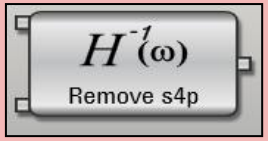
De-embedding: Partial vs. Full

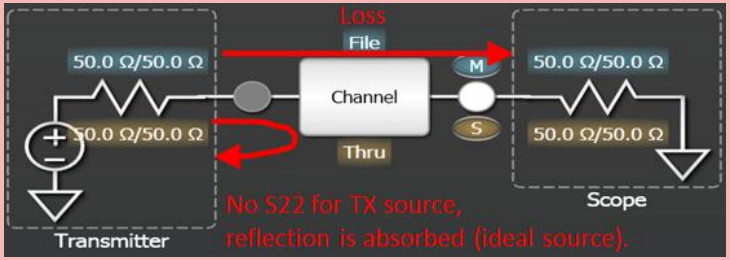


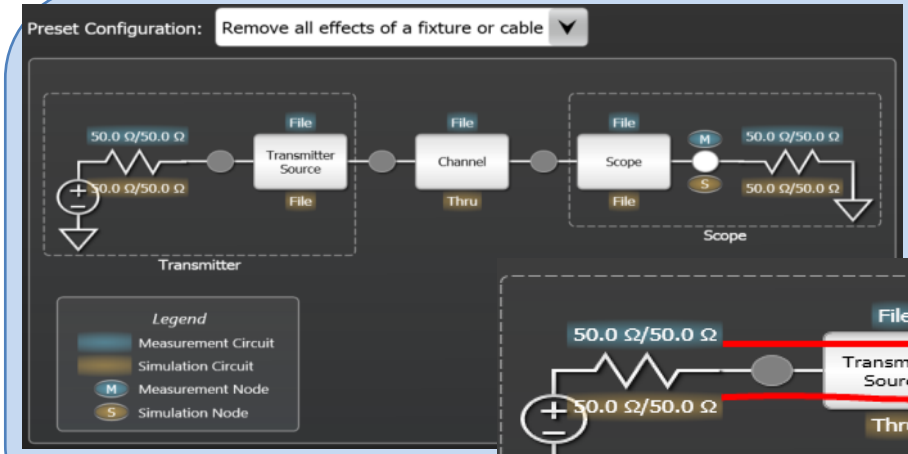
Partial De-embedding:

- Removes insertion loss
- Does NOT remove reflections (assumes an ideal source, receiver)
- Easier to implement

This paper's focus.

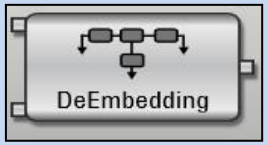


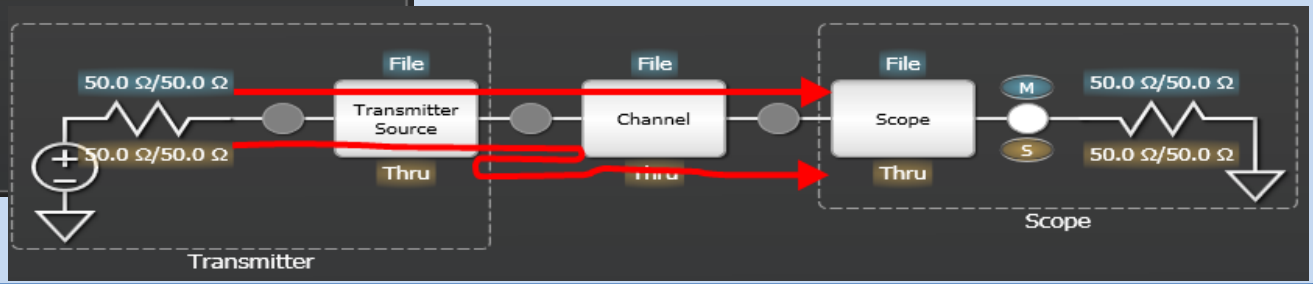




Full De-embedding:

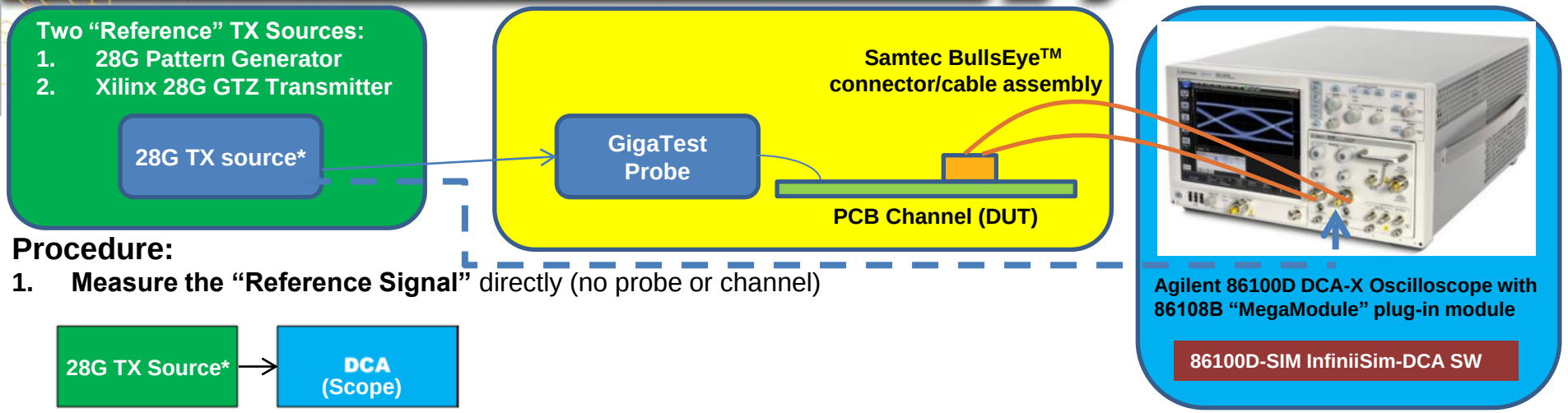
- Removes insertion loss and reflections between circuit elements
- More accurate (but less forgiving if models/delays are not correct)





Validate S-parameter Models

Description of Procedure



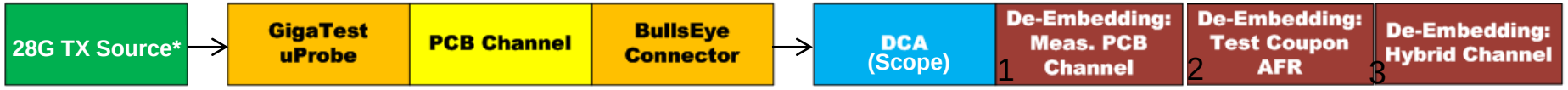
Procedure:

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

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

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

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

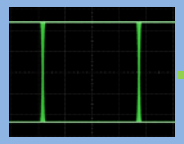


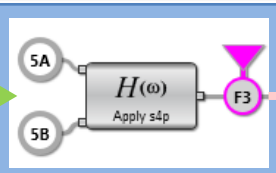
* Note - All four tests were run with both 28G TX Sources.

But first…have the end in mind!

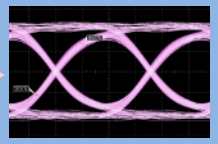
Using the channel model, simulate what we should expect at the output of the fixture.

Input : "Ideal" 28 Gb/s (simulated signal)

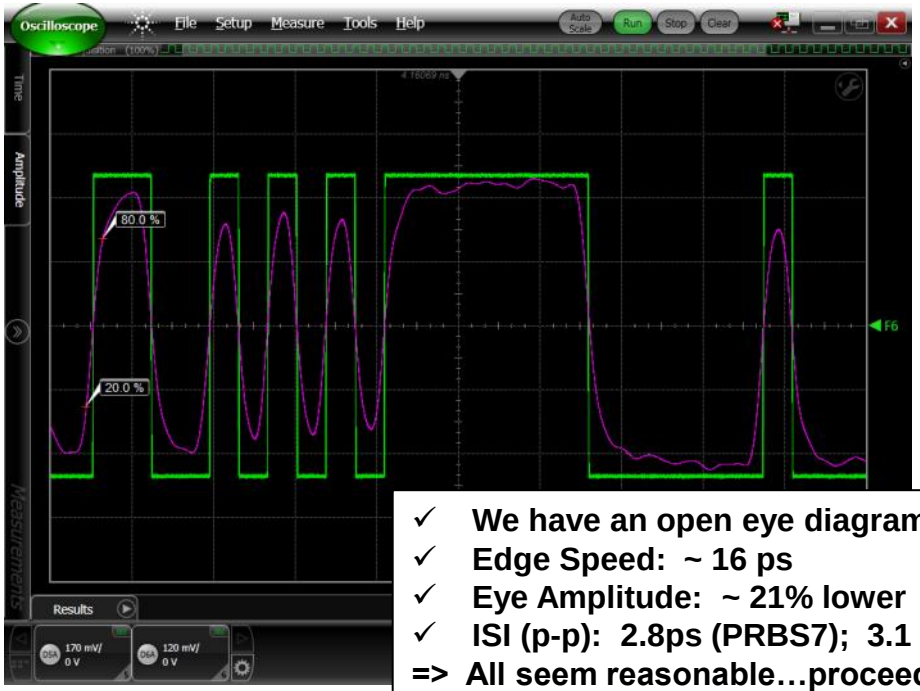




Embed fixture model



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



- ✓ **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.

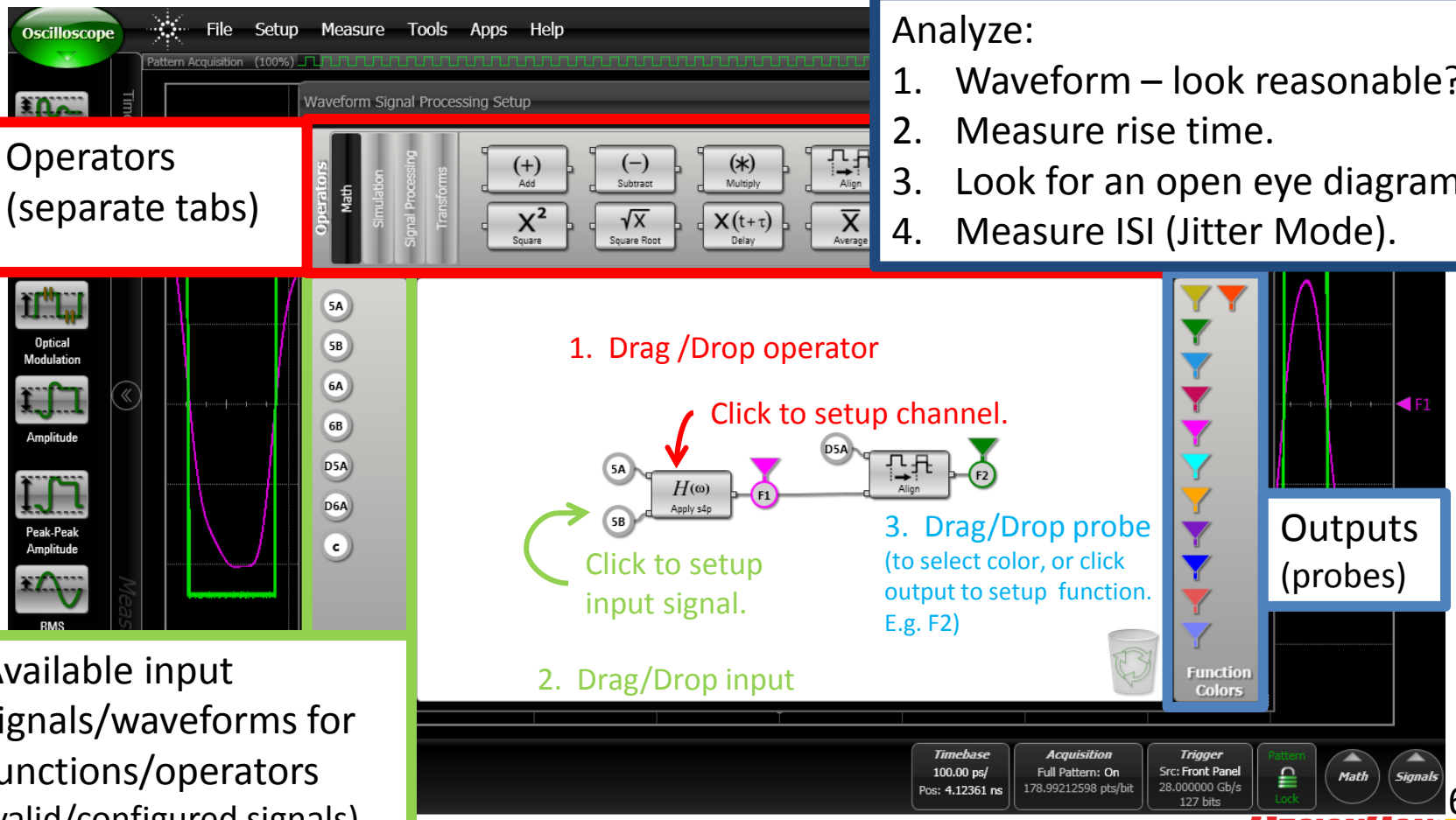
Measurement		Current
Amplitude	F3	743.95 mV
Amplitude	F6	801.38 mV
Rise Time	F3	20.2 ps
Rise Time	F6	400 fs

Measurement		Current
Eye Ampl	F3	632 mV
Eye Ampl	F6	800 mV
Rise Time	F3	16.0 ps
Rise Time	F6	400 fs

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)

Analyze:

1. Waveform – look reasonable?
2. Measure rise time.
3. Look for an open eye diagram.
4. Measure ISI (Jitter Mode).

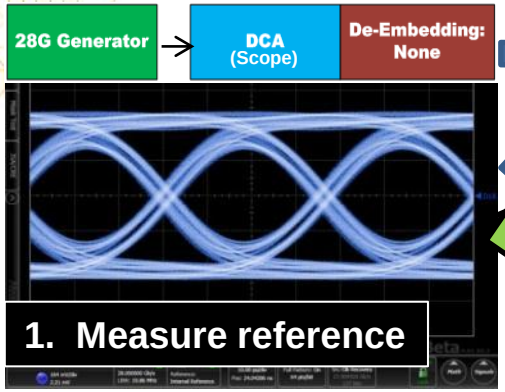
Outputs (probes)

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

Validate S-Parameter Model #1 (Probe) using 28G PG

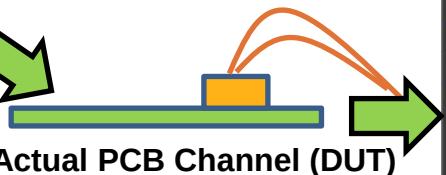
Step #1-3: Eye/Scope Results at output of channel/fixture (DUT)

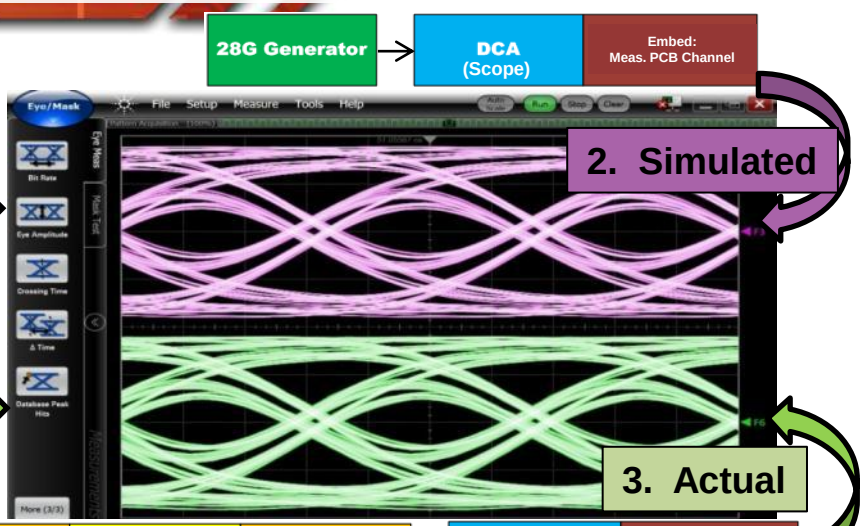
[Ref Signal: Pattern Generator (PG)]



Embed Channel Model

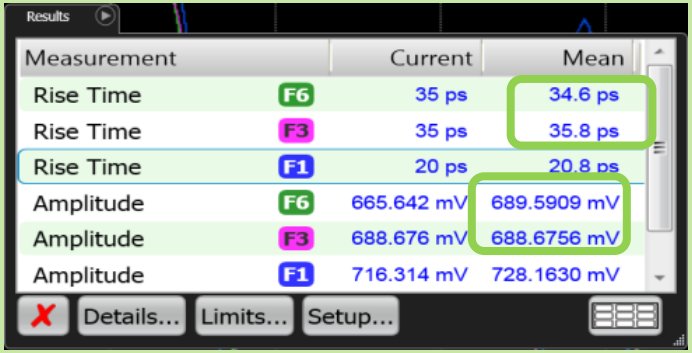
Measured PCB Channel S-Parameter Model

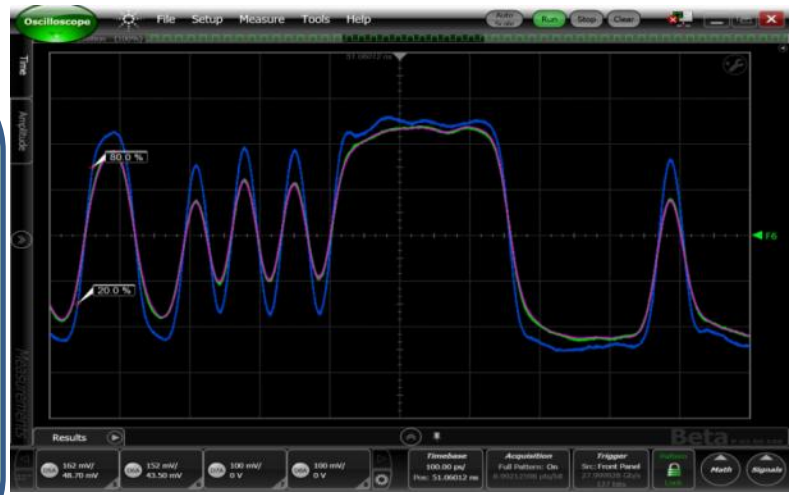




Blue – Reference signal
Pink – Simulated fixture
(using s4p file)
Green – Actual signal via fixture

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)]

- ✓ **Amplitude restored**
- ✓ **Edge speed restored**
- ✓ **Waveshape restored**

Blue – Reference Signal
Green – Actual signal via fixture
Pink – De-Embedded signal

Summary => Model #1 (Probe) looks good so far.

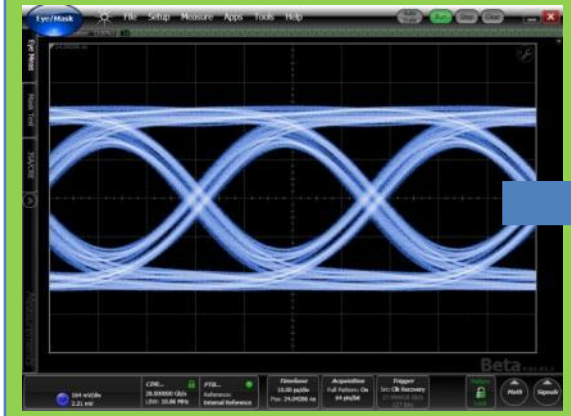
Validate S-Parameter Model #1 (Probe) using 28G PG

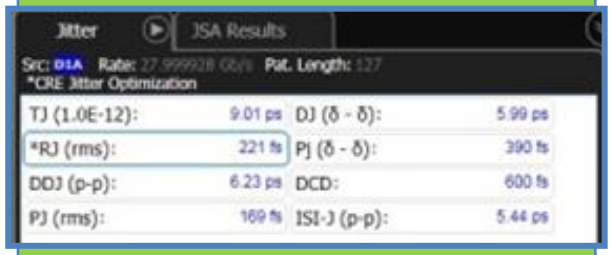
Step #4: De-embed and compare Jitter Results

[Ref Signal: Pattern Generator (PG)]

1. Measure reference

28G Pattern Generator → 86100D Scope

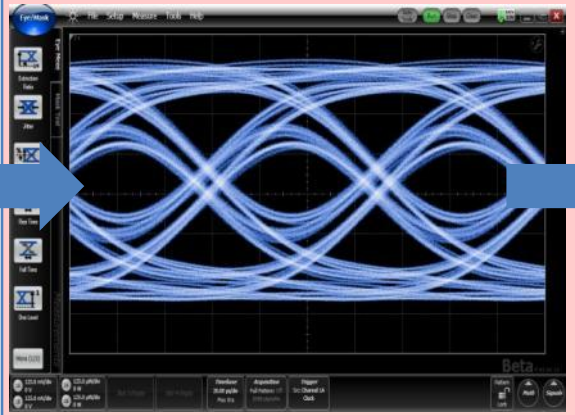




ISI: 5.44 ps p-p

3. **Actual** signal through channel

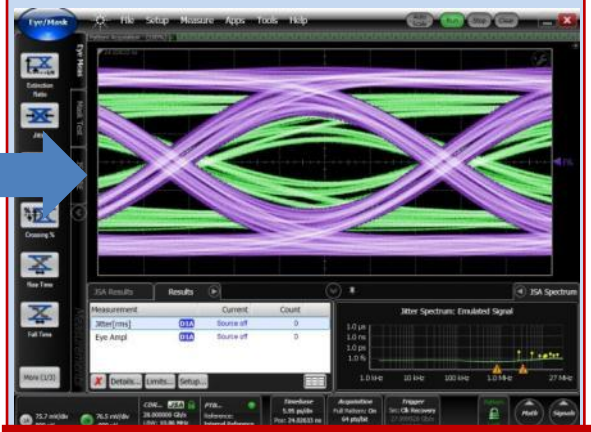
28G Pattern Generator → Fixture Xilinx → 86100D Scope



ISI: 9.01 ps p-p

4. De-embed channel, compare to Reference

28G Pattern Generator → Xilinx Fixture → 86100D Scope (De-Embed)



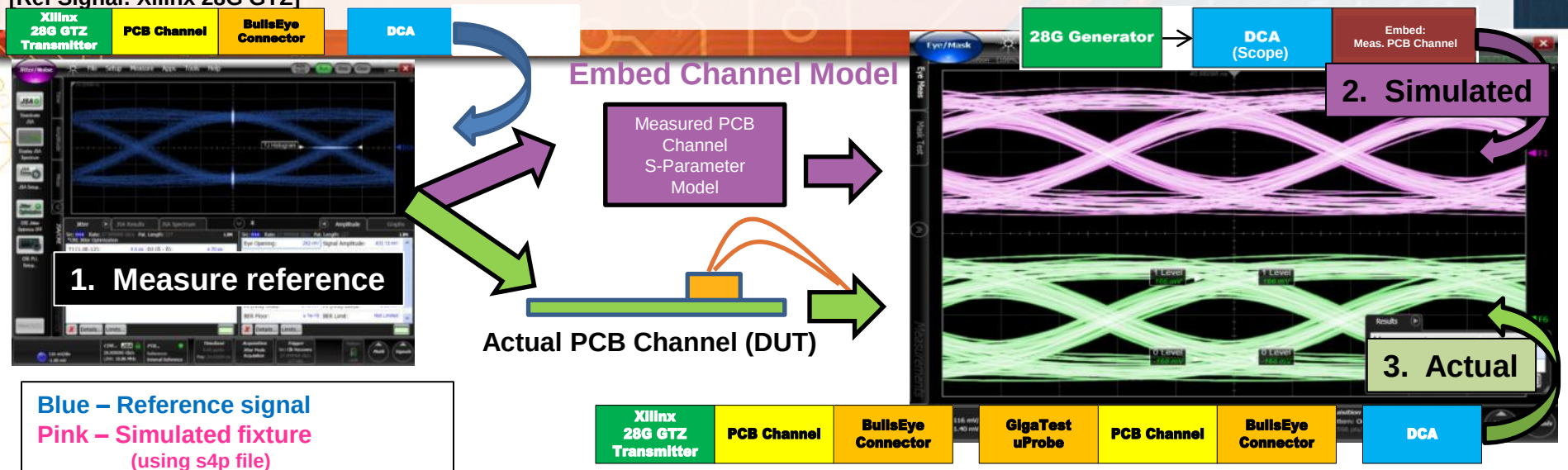
ISI: 5.40 ps p-p

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]



Blue – Reference signal
Pink – Simulated fixture
(using s4p file)
Green – Actual signal via fixture

Results: good correlation between simulated and actual waveforms => validates model

Results

Measurement		Current	Mean
Rise Time	F6	26 ps	25.44 ps
Rise Time	F1	25 ps	23.91 ps
Rise Time	D5A	16 ps	15.32 ps
Amplitude	F6	407.215 mV	404.6743 mV
Amplitude	F1	379.580 mV	373.2868 mV
Amplitude	D5A	429.330 mV	430.1302 mV

Details... Limits... Setup...

Validate S-Parameter Model #1 (Probe) using 28G Xilinx TX

Step#4: De-embed and compare waveform results

[Ref Signal: Xilinx 28G GTX]

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

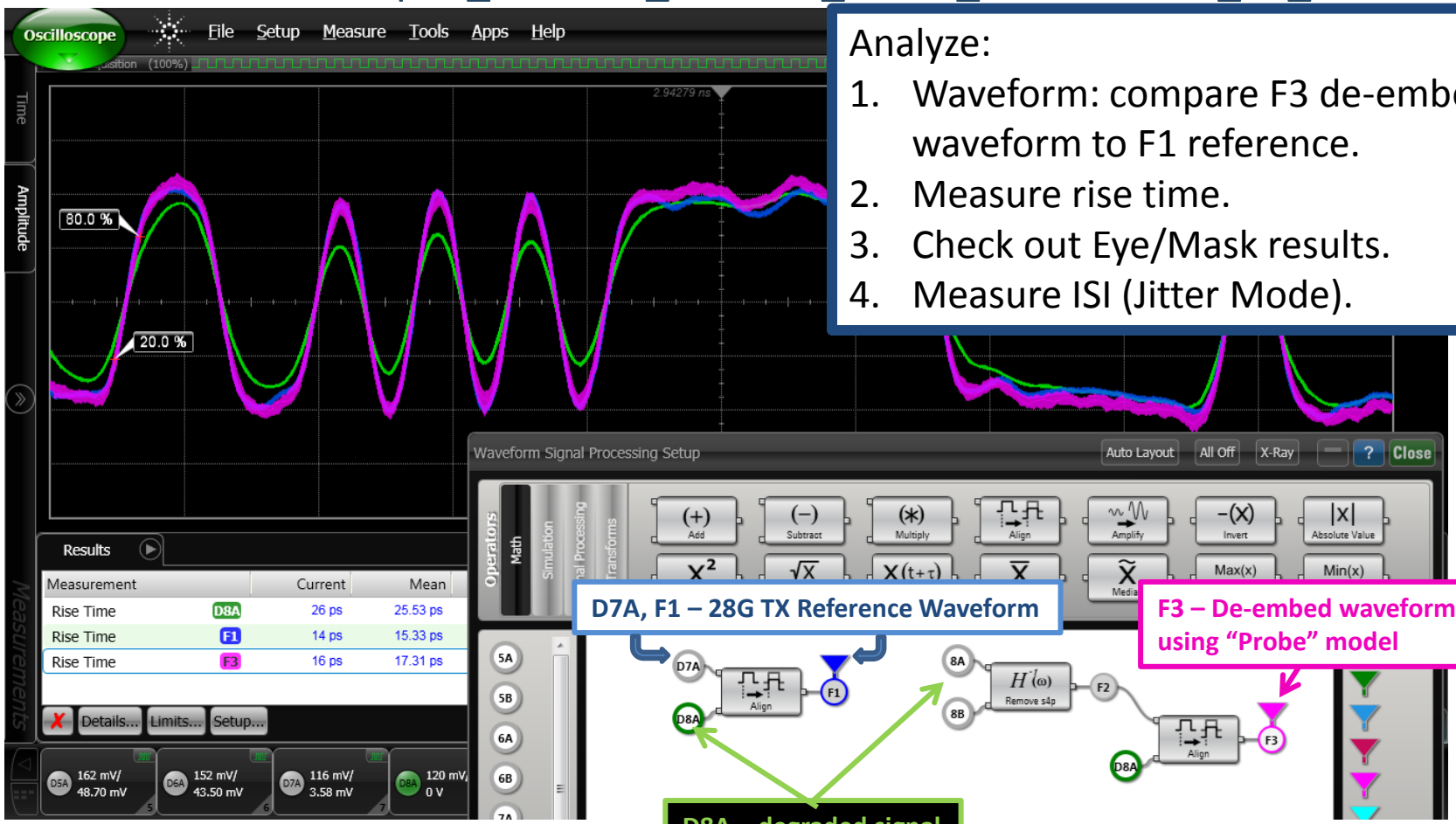
Blue – Reference Signal
Green – Actual signal via fixture
Pink – De-Embedded signal

Summary => Model #1 looks good so far.

Demo# 2 – Validate “Probe” Model

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).

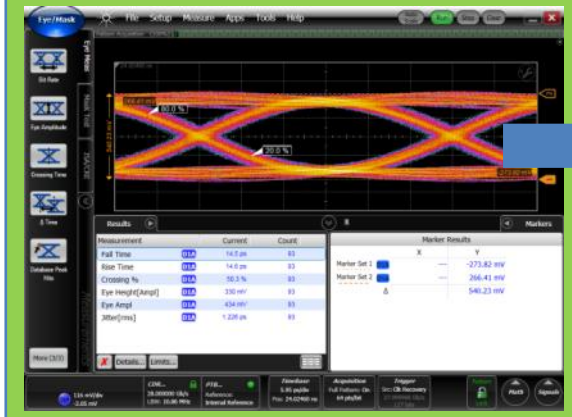
Validate S-Parameter Model #1 (Probe) using 28G Xilinx TX:

Step #4: De-embed and compare Jitter Results

[Ref Signal: Xilinx 28G GTZ]

1. Measure reference

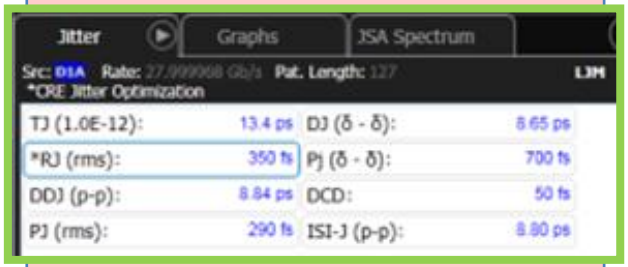
28G Pattern Generator → 86100D Scope



ISI: 4.88 ps p-p

3. **Actual** signal through channel

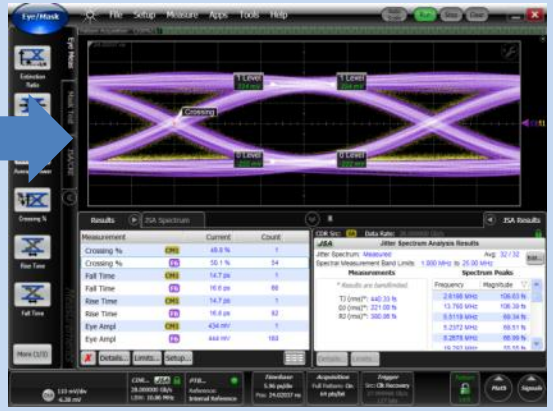
28G Pattern Generator → Fixture Xilinx → 86100D Scope

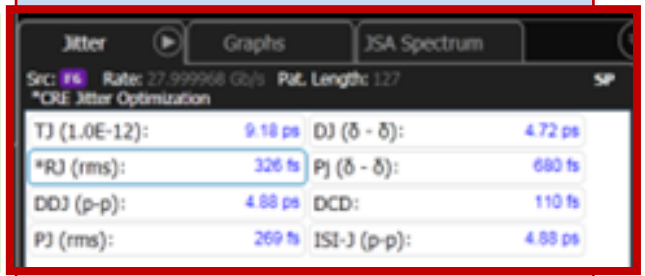


ISI: 8.80 ps p-p

4. De-embed channel, compare to Reference

28G Pattern Generator → Xilinx Fixture → 86100D Scope (De-Embed)





ISI: 4.88 ps p-p

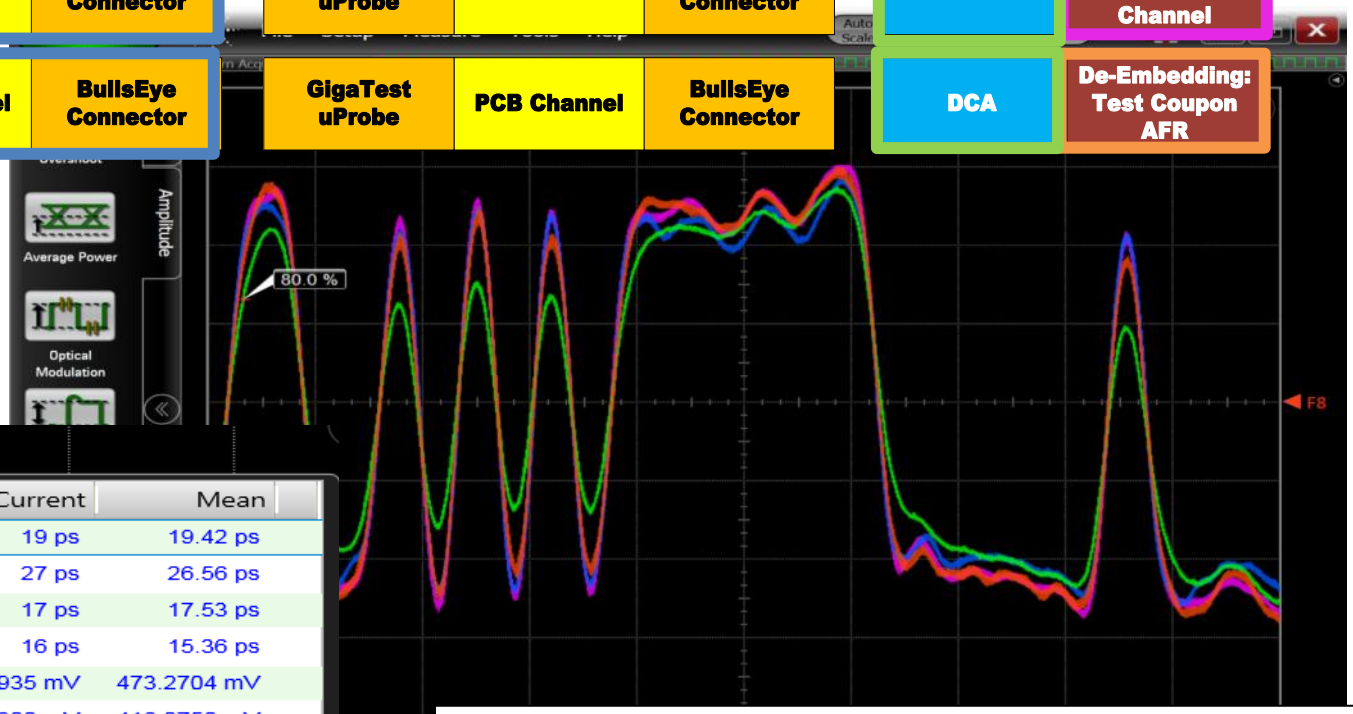
Good Correlation => further validates model

Validate S-Parameter Model #2 (AFR) using 28G Xilinx TX

Step #4: De-embed and compare waveform results

[Ref Signal: Xilinx 28G GTX]

Xilinx 28G GTZ Transmitter	PCB Channel	BullsEye Connector	GigaTest uProbe	PCB Channel	BullsEye Connector	DCA	De-Embedding: Meas. PCB Channel
Xilinx 28G GTZ Transmitter	PCB Channel	BullsEye Connector	GigaTest uProbe	PCB Channel	BullsEye Connector	DCA	De-Embedding: Test Coupon AFR



Results

Measurement		Current	Mean
Rise Time	F8	19 ps	19.42 ps
Rise Time	F6	27 ps	26.56 ps
Rise Time	F7	17 ps	17.53 ps
Rise Time	F1	16 ps	15.36 ps
Amplitude	F8	472.935 mV	473.2704 mV
Amplitude	F6	423.800 mV	416.0750 mV
Amplitude	F7	471.400 mV	472.5946 mV
Amplitude	F1	456.045 mV	430.7192 mV

Details... Limits... Setup...

Blue – Reference Signal
Green – Actual signal via fixture
Pink – De-Embed using Direct Probe s4p file
Orange – De-embed using Test Coupon AFR s4p file

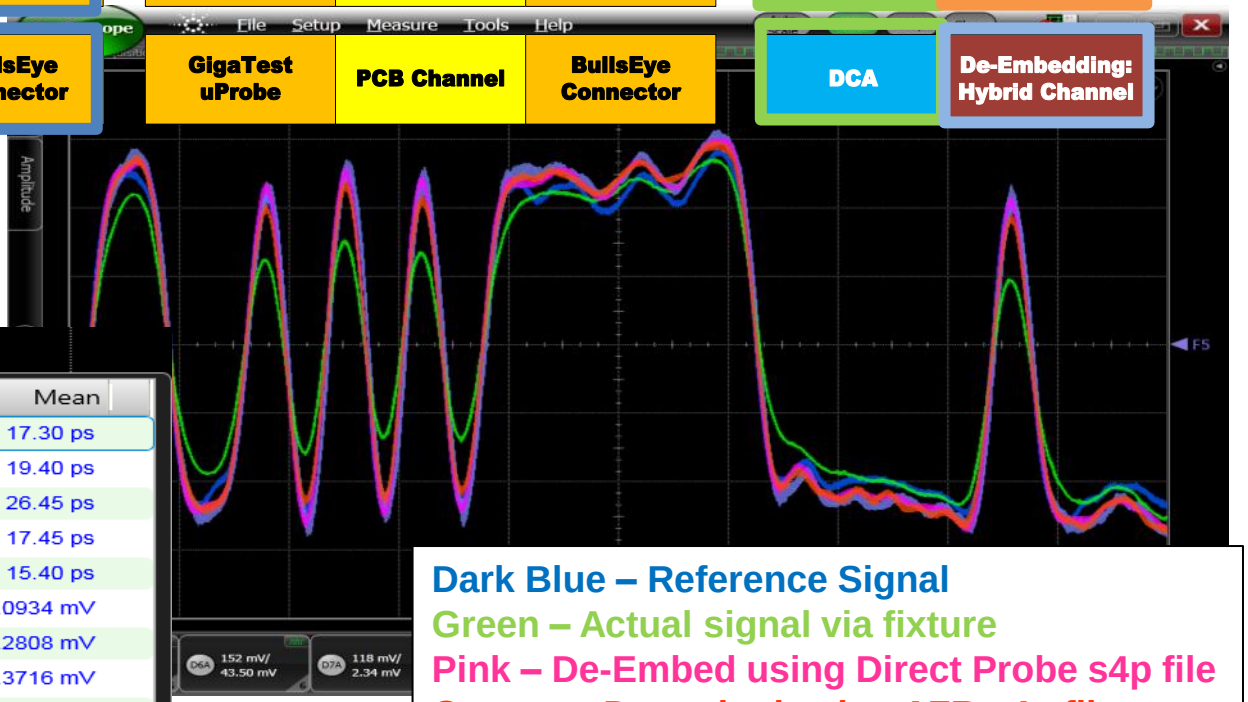
Summary => Reference signal, Model #1 (Probe) and Model #2 (AFR) correlate well.

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	DCA	De-Embedding: Meas. PCB Channel
Xilinx 28G GTZ Transmitter	PCB Channel	BullsEye Connector	GigaTest uProbe	PCB Channel	BullsEye Connector	DCA	De-Embedding: Test Coupon AFR
Xilinx 28G GTZ Transmitter	PCB Channel	BullsEye Connector	GigaTest uProbe	PCB Channel	BullsEye Connector	DCA	De-Embedding: Hybrid Channel



Results

Measurement		Current	Mean
Rise Time	F5	17 ps	17.30 ps
Rise Time	F8	19 ps	19.40 ps
Rise Time	F6	28 ps	26.45 ps
Rise Time	F7	17 ps	17.45 ps
Rise Time	F1	17 ps	15.40 ps
Amplitude	F5	482.150 mV	480.0934 mV
Amplitude	F8	471.400 mV	473.2808 mV
Amplitude	F6	442.225 mV	418.3716 mV
Amplitude	F7	472.935 mV	471.3692 mV
Amplitude	F1	433.015 mV	431.4386 mV

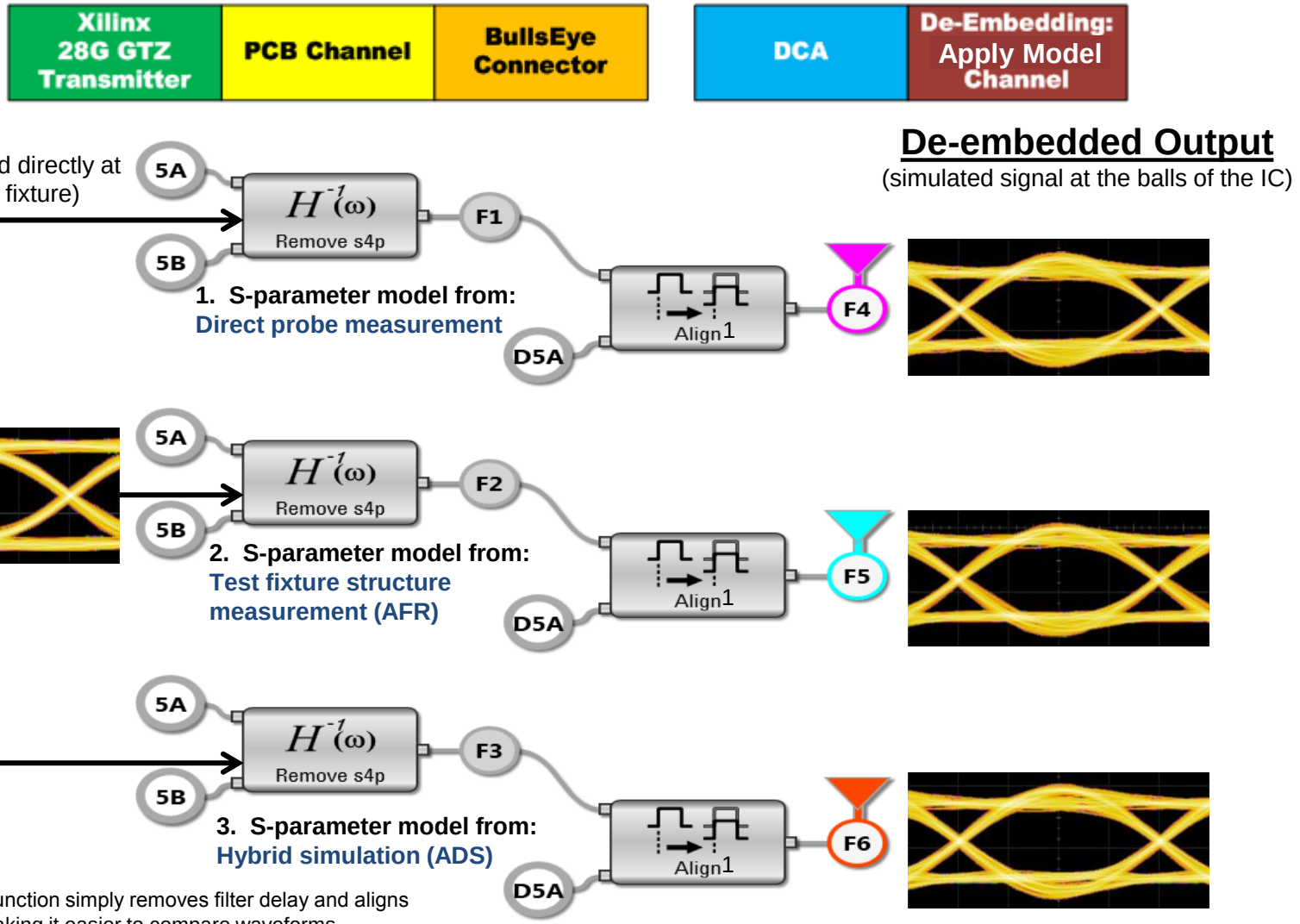
Details... Limits... Setup...

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

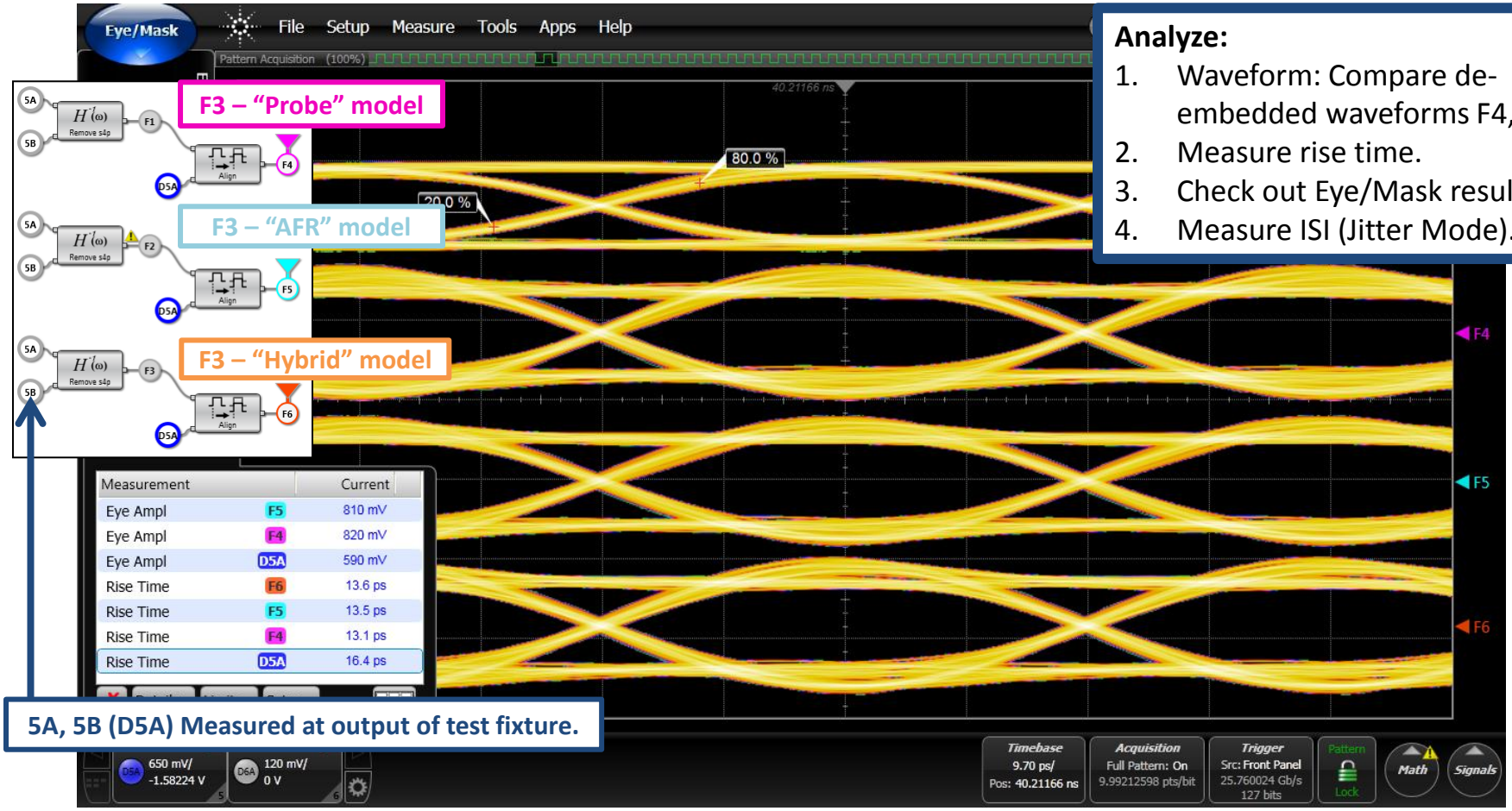


Note 1 – the "Align" function simply removes filter delay and aligns waveforms making it easier to compare waveforms.

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



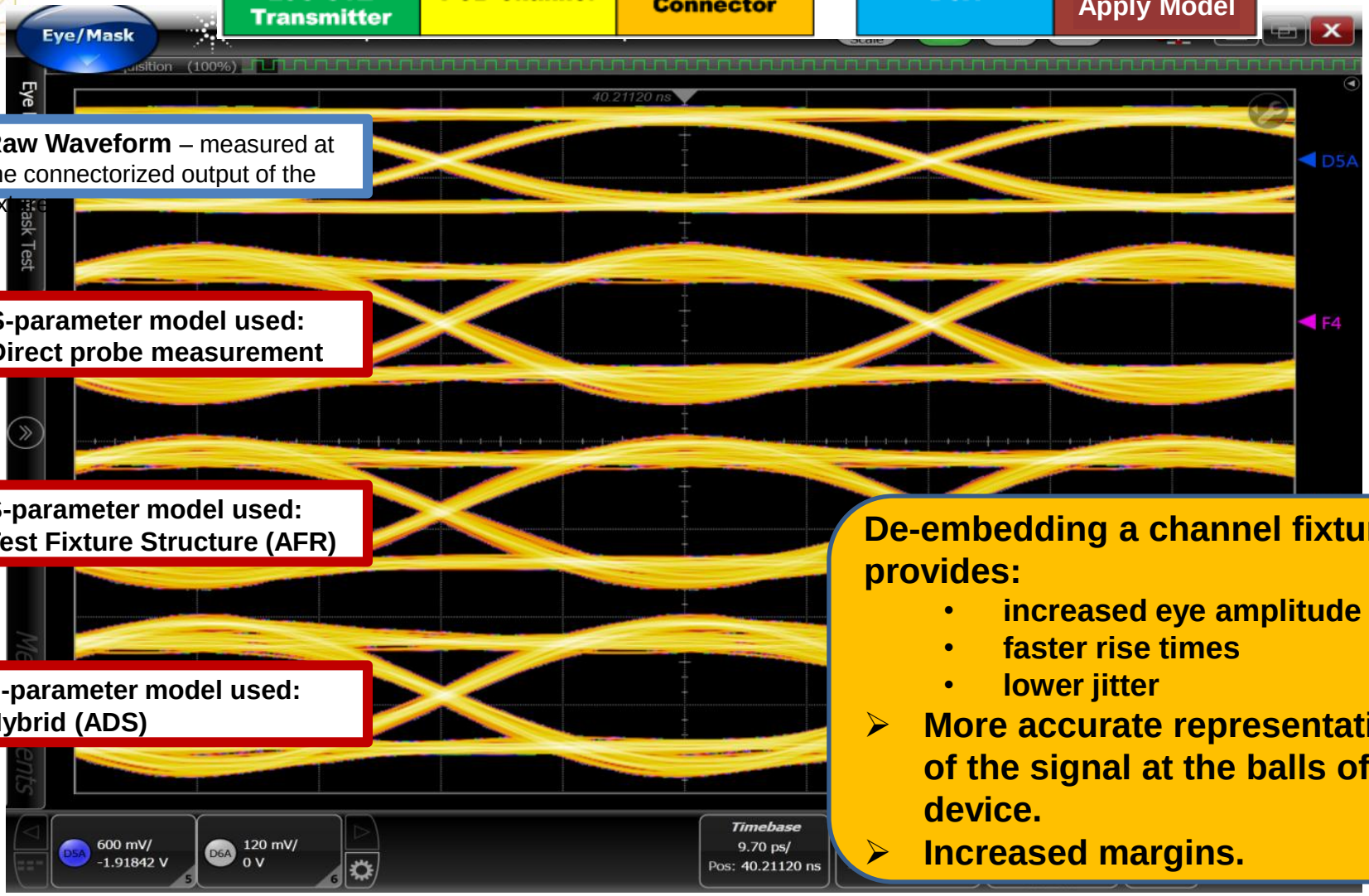
Analyze:

1. Waveform: Compare de-embedded waveforms F4, F5, F6.
2. Measure rise time.
3. Check out Eye/Mask results.
4. Measure ISI (Jitter Mode).

28G Device Measurement

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

Xilinx 28G GTZ Transmitter	PCB Channel	BullsEye Connector	DCA	De-Embedding: Apply Model



Raw Waveform – measured at the connectorized output of the fix

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:

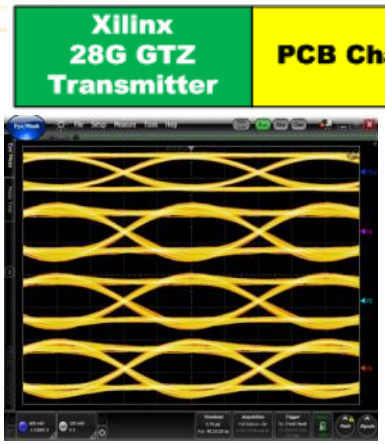
- **increased eye amplitude**
- **faster rise times**
- **lower jitter**

➢ **More accurate representation of the signal at the balls of the device.**

➢ **Increased margins.**

28G Device Measurement

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



		S-Paramater Model Used by De-Embed Function		
FlexDCA Signal Identifier	D5A	F4	F5	F6
Description	Raw Differential Waveform	Direct Probe Measurement	Test Structure (AFR)	Hybrid (ADS)
Rise Time 20-80% (ps)	16.04	12.8	13.32	13.44
Eye Amplitue (mV)	587.5	822.5	813.5	833.0
Deterministic Jitter (δ - δ) (ps)	3.12	2.54	2.66	2.68

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

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 (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)