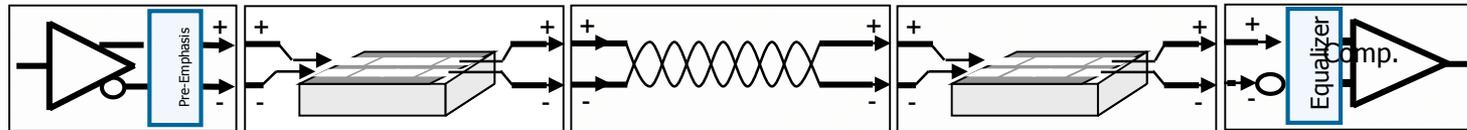


## **Correlation of Measurement and Simulation Results using IBIS-AMI Models on Measurement Instruments**

**Sarah Boen Vo, Tektronix  
Brian Burdick, LSI Corporation**

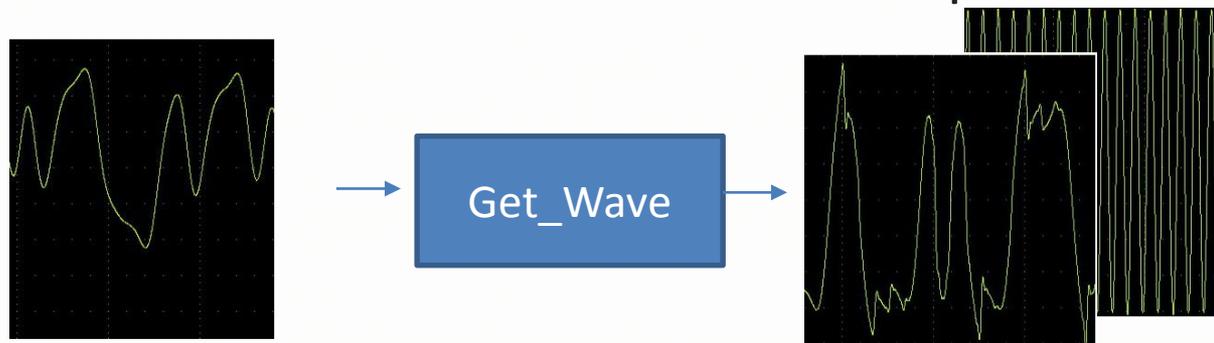
# Introduction

- Correlation between measurement and simulation desired, but has many challenges
  - Simulations are often done before silicon or physical boards are available
    - S-parameters and IBIS-AMI models are often used
  - Measurements on live acquisitions often require post processing before measurements are taken
    - Removal of fixtures and cables
    - Embedding of compliance channels and equalization



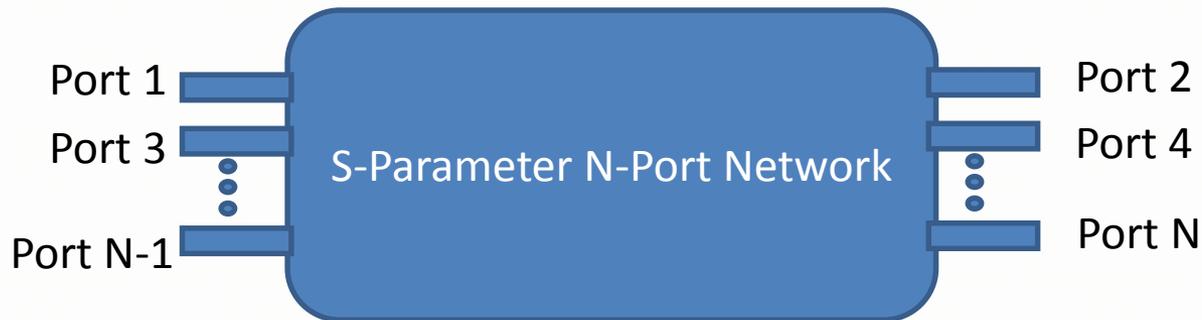
# IBIS-AMI Introduction

- IBIS-AMI is a behavioral model first defined in IBIS 5.0 specification
  - Can be run on several different simulators that support the IBIS-AMI standard
  - Protects IP because the model is compiled for the operating system it is simulated on
  - Works in both the statistical or time domain using an impulse response or a time domain waveform as input to the model



# S-parameter Introduction

- S-parameters describe how high frequency energy propagates through a N-port network as reflected and transmitted energy.
- S-Parameters are complex numbers described with Touchstone SnP files.



# S-Parameter and IBIS-AMI Models in Measurement Equipment

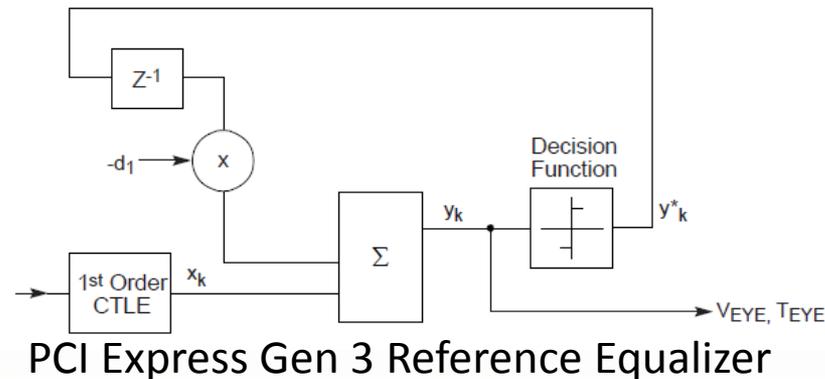
- Similar with simulation environments, S-parameter models can be used in measurement systems to model the behavior of the transmitter, receiver, and transmission line
- IBIS-AMI models can be used to model the complex behavior of the transmitter and the receiver

# S-parameter use in Measurement Systems

- S-parameter models can be used in measurement systems to model the behavior of the transmitter, receiver, and transmission line
  - Frequency spacing and time interval based on the settling time of the system and device bandwidth
  - Extrapolation to DC is handled if the S-parameter does not have a value at DC
  - Cascading of S-parameters are handled by extending time intervals of individual S-parameters to avoid aliasing in the Time Domain

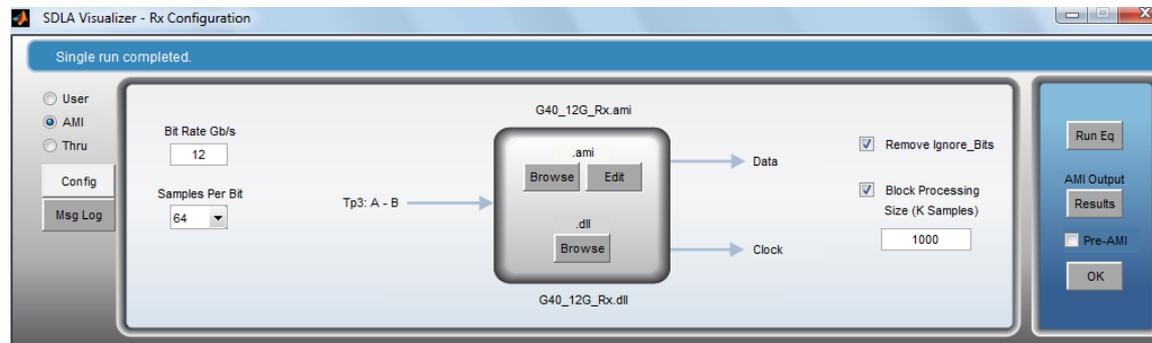
# Introduction to IBIS-AMI Modeling in Measurement Systems

- Measurement environments have relied on custom algorithms for equalization that are based on reference equalizers
  - Correlation with simulation is a challenge
  - Reference models are sufficient for compliance testing, but don't model actual silicon behavior



# Introduction to IBIS-AMI Modeling in Measurement Systems

- IBIS-AMI integration into measurement environments enables silicon specific simulation
- Consideration must be given to model parameters including samples per bit, ignore bits and block size for processing

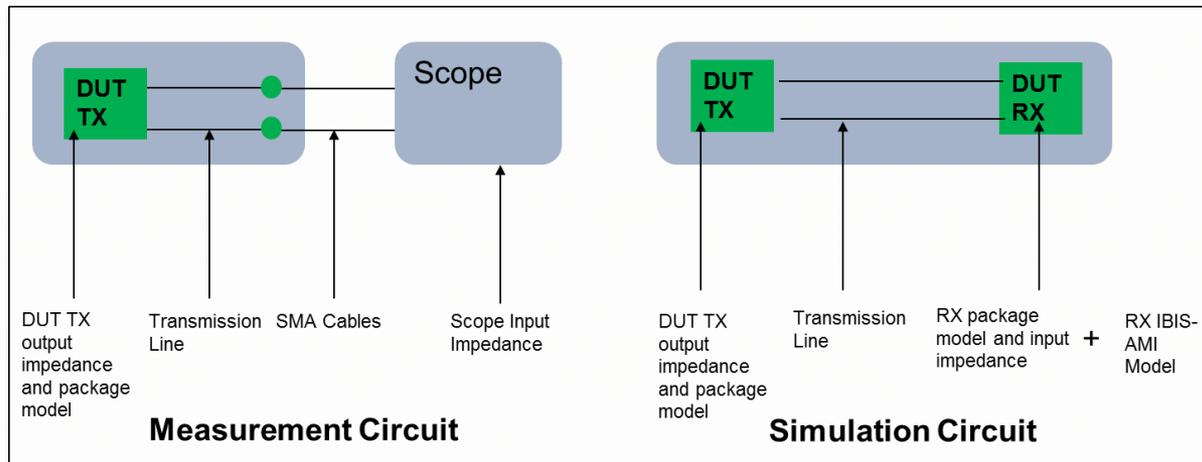


# Correlation Study of Simulation vs. Measurement Systems

- A study was done to determine the level of correlation that can be done between a measurement and simulation environments using S-parameter and IBIS-AMI models
- Further analysis was done to show the differences between using Reference Equalizers and IBIS-AMI models

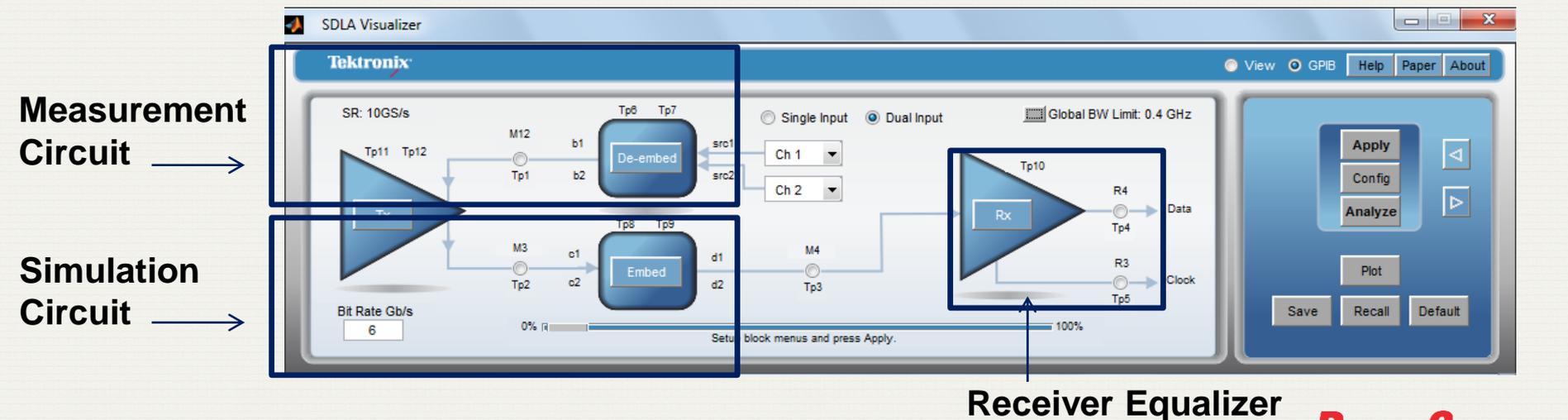
# System Configuration

- Simulation and Measurement Configuration
  - The device is 12Gb/s SAS, 1200mV pk-pk amplitude, generating a PRBS7 pattern
  - Real-time 25Ghz oscilloscope @ 100GS/s sample rate
  - 500K bits measured / simulated



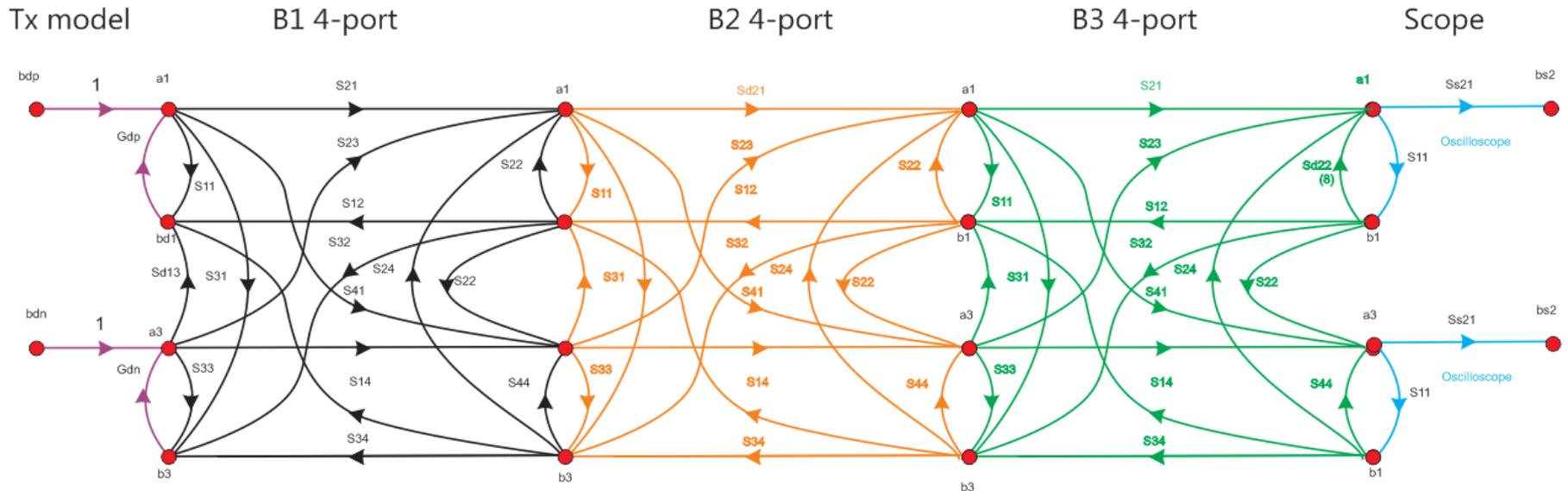
# Measurement System Schematic

- Unlike the simulation environment, the effects of the measurement circuit must be
  - Transmitter output impedance and package model, the breakout channel, SMA cables to the scope, and the input impedance of the scope



Receiver Equalizer

# S-parameter Model Interaction

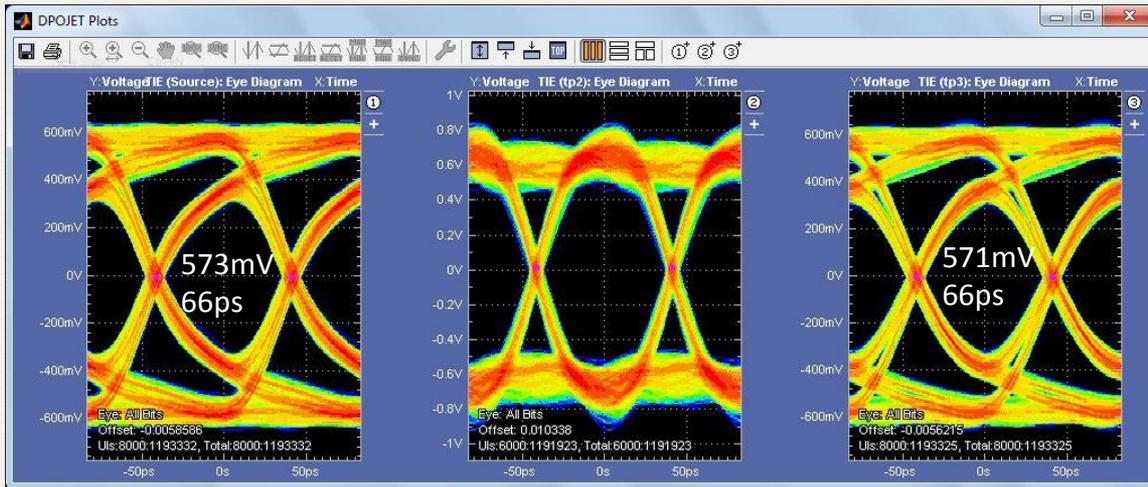


- Crosstalk and reflections and transmission need to be considered
- Parameter change anywhere affects all test points

# De-embed Considerations

- De-embed is an inverse response ... may result in large noise boost at high frequency
- Requires BW limit filter to reduce the noise
- With more loss in DUT... the more boost
  - Resulting in lower bandwidth limit filter to control noise and a slower rise time
- By default, many applications provide an auto function for the bandwidth of the de-embed filter
  - Results should be verified

# De-Embed Verification

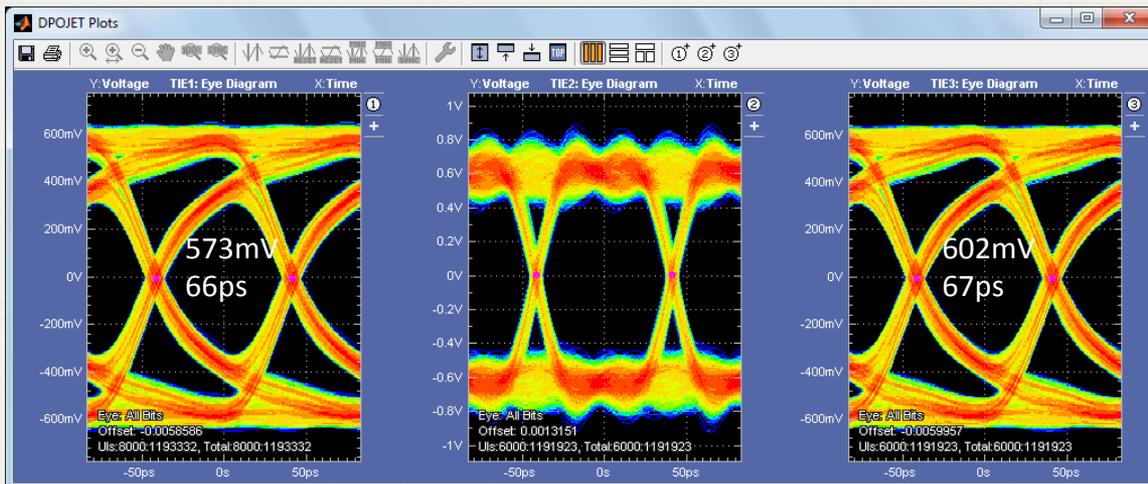


De-embed with  
15Ghz Filter  
based on default  
setting

Acquired Waveform

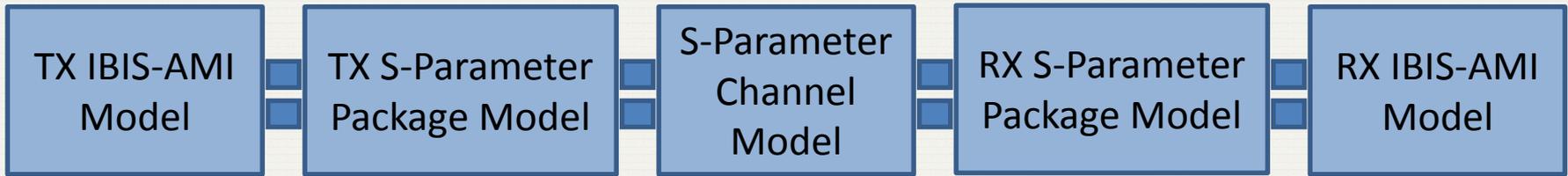
After De-Embedding

After Embedding



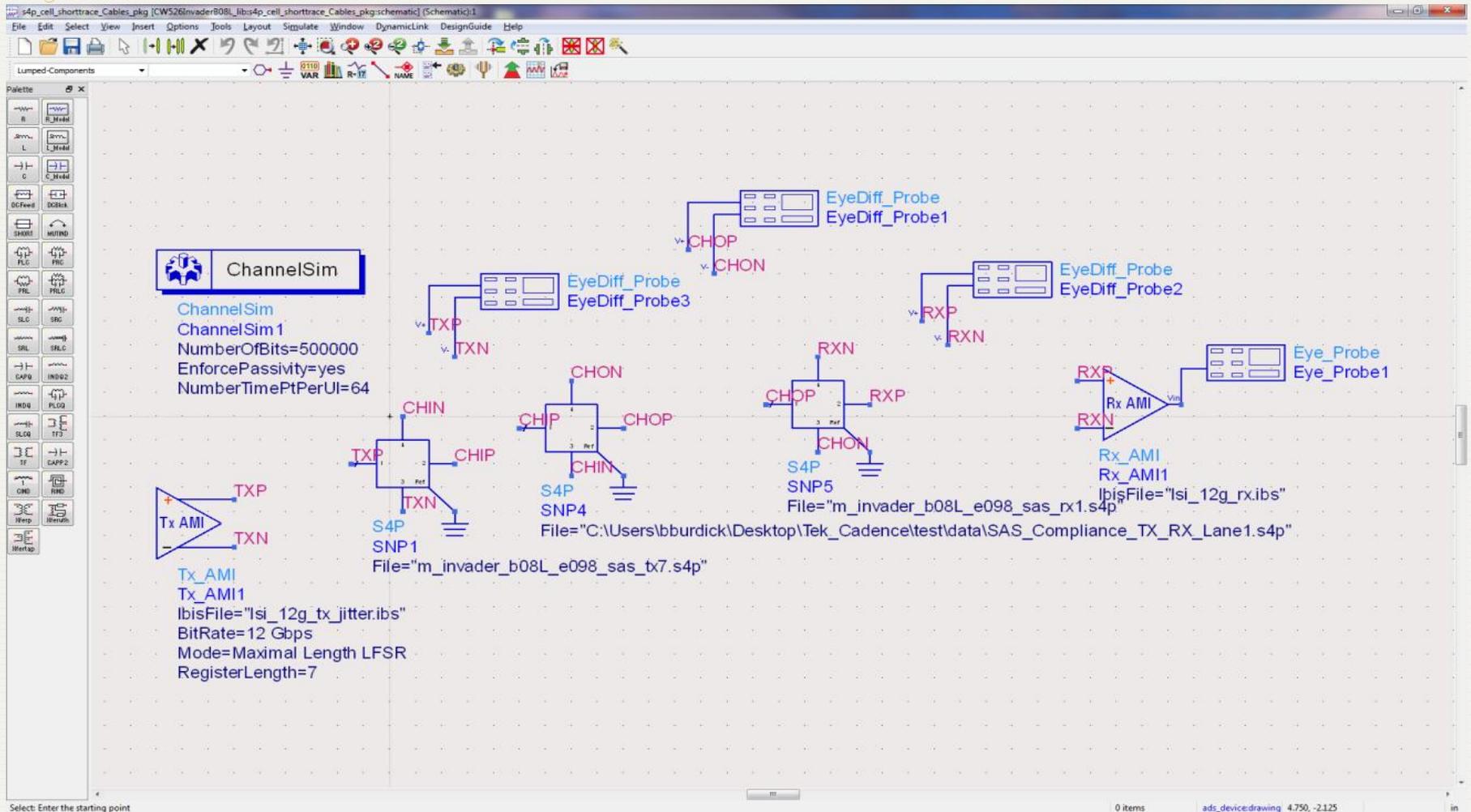
De-embed with  
20Ghz Filter after  
increasing  
bandwidth limit

# Simulation Setup



- SAS3 transmitter and receiver models.
- SAS3 package models.
- Channel model measured with VNA of a SAS3 characterization board.

# Simulation Schematic



Select: Enter the starting point

0 items

ads\_device:drawing 4.750, -2.125

in

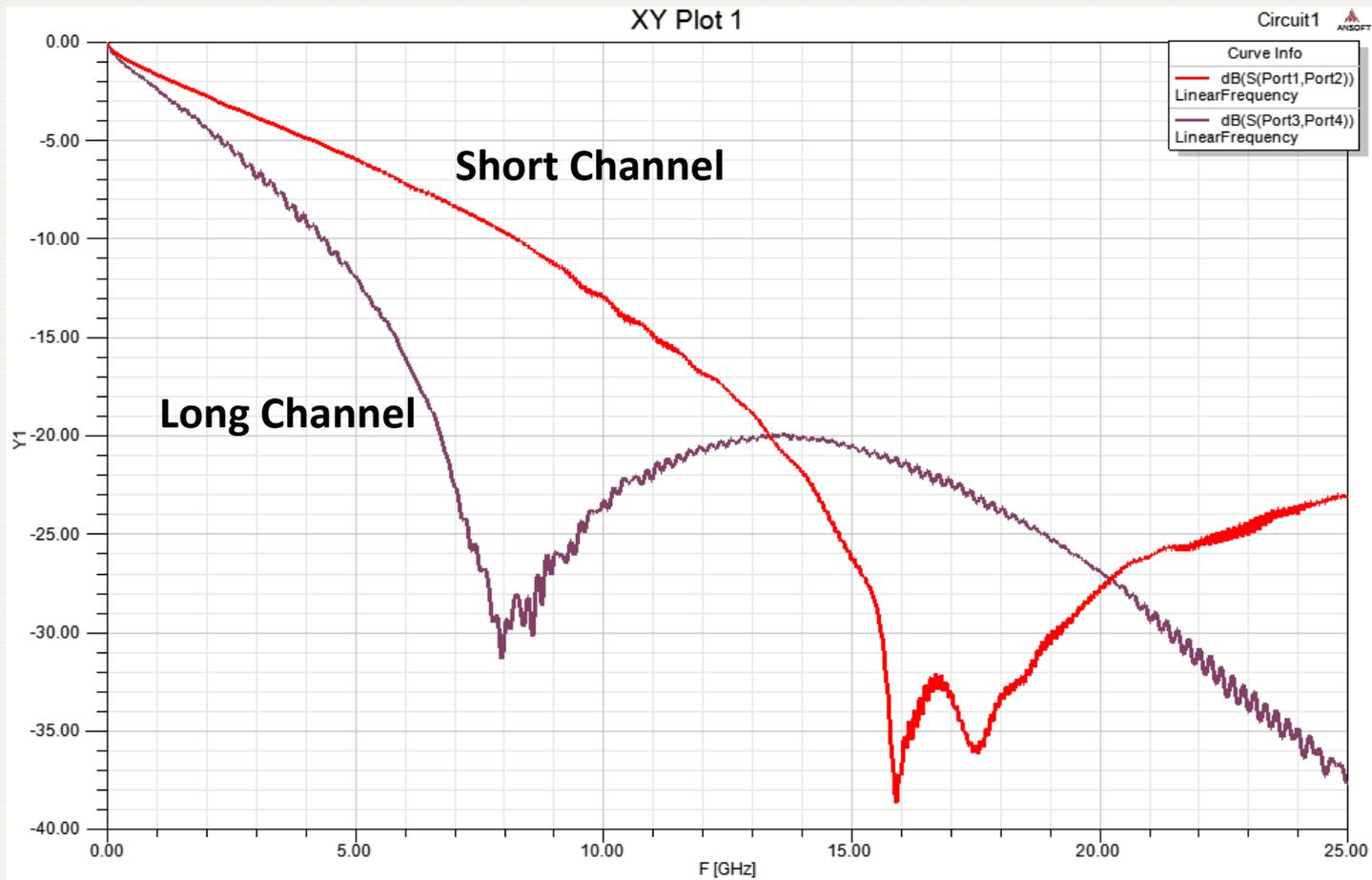
# Correlation Challenges

- Accurate channel model
- Accurate package model
- Silicon that matches simulation models for process.
- Accurate impairments such as noise and jitter in the model

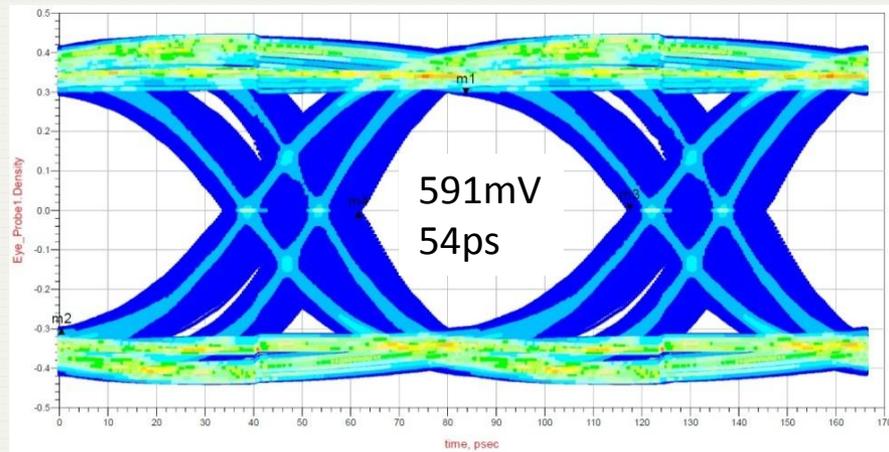
# Test Configurations

- Simulation vs. Measurement correlation was done on three different configurations
  - No transmitter equalization with a short channel
  - Transmitter equalization with a short channel
  - Transmitter equalization with a long channel
- Correlation was also done using the reference 10-tap DFE and IBIS-AMI model

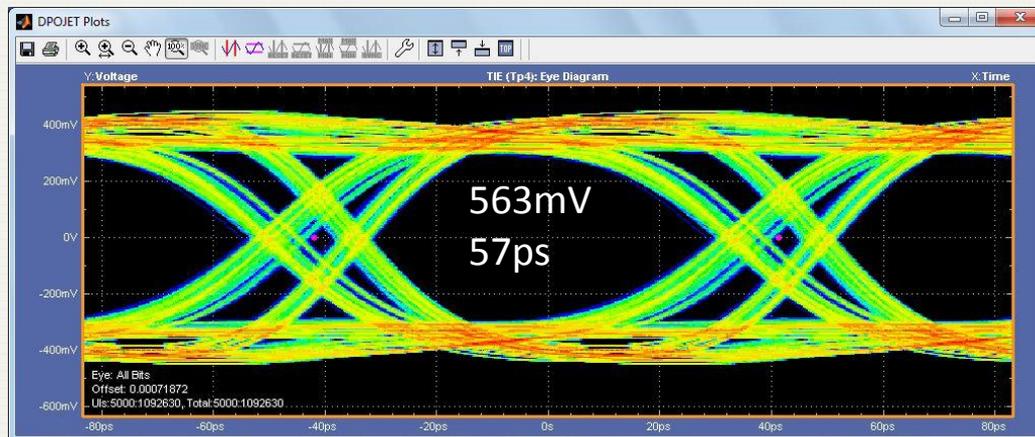
# Channel Model Insertion Loss



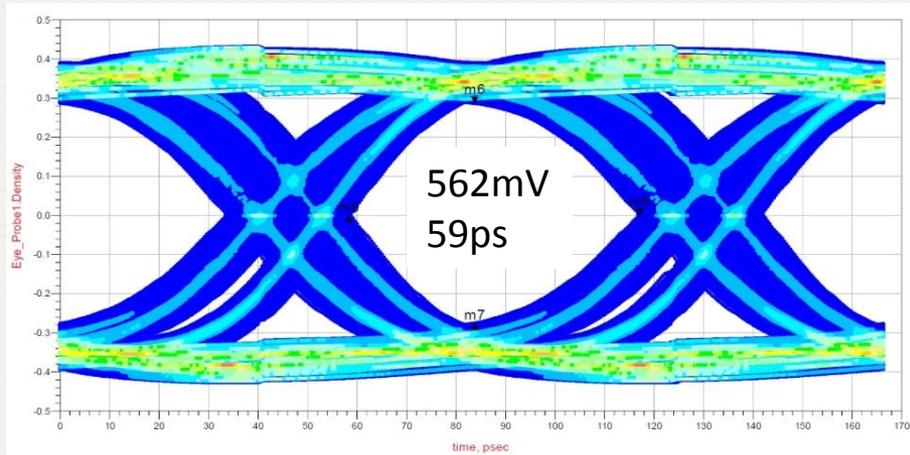
# No TX EQ with a Short Channel



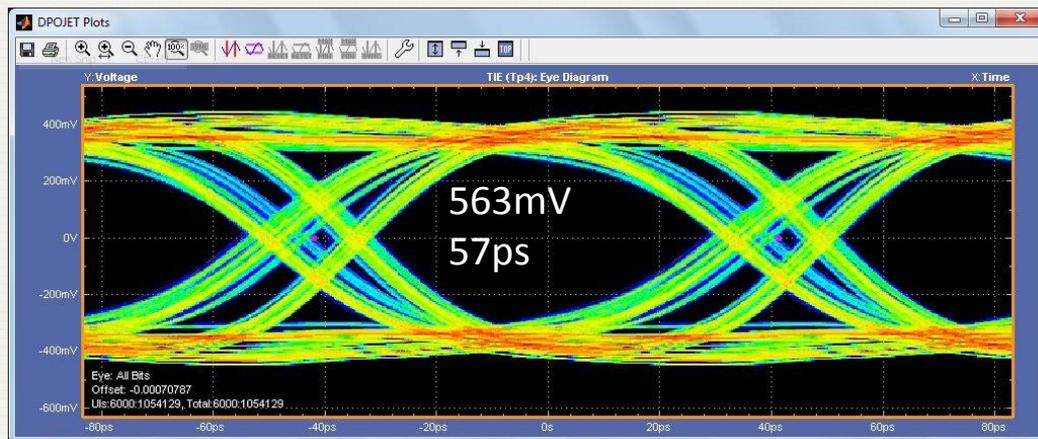
- All measurements taken after the RX equalizer



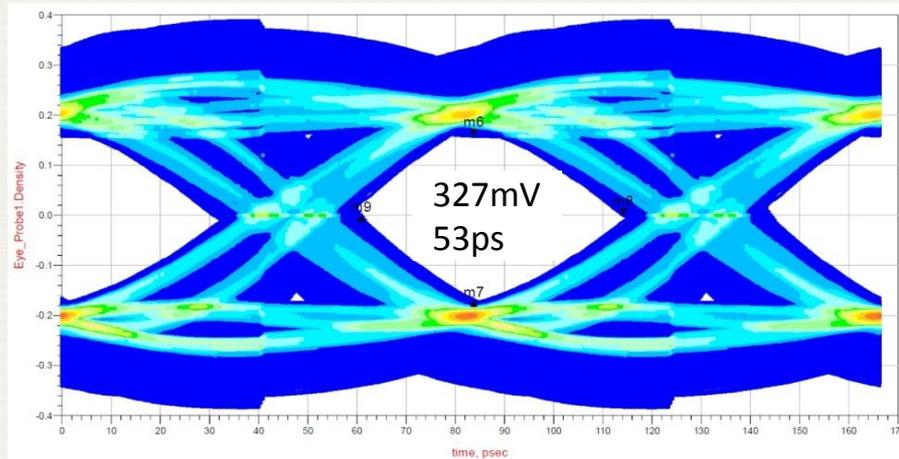
# TX EQ with a Short Channel



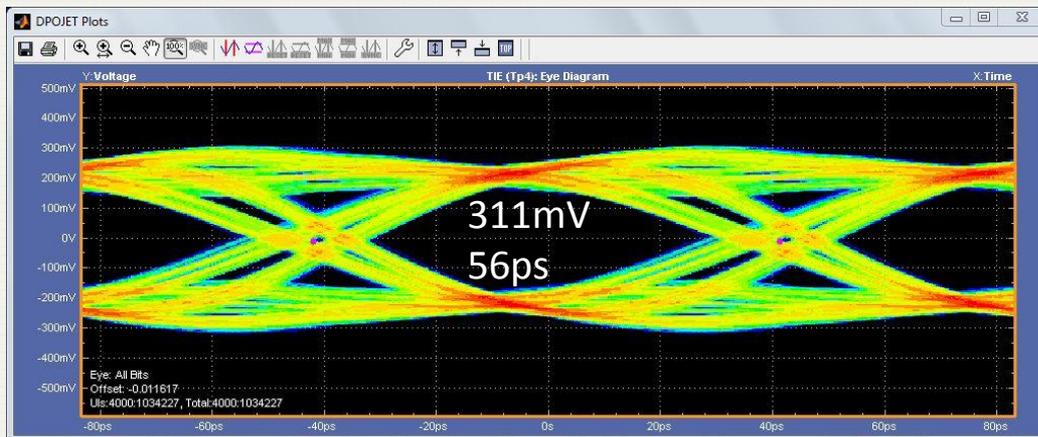
- TX Equalization settings
- All measurements taken after the RX Equalizer



# Tx EQ with a Long Channel

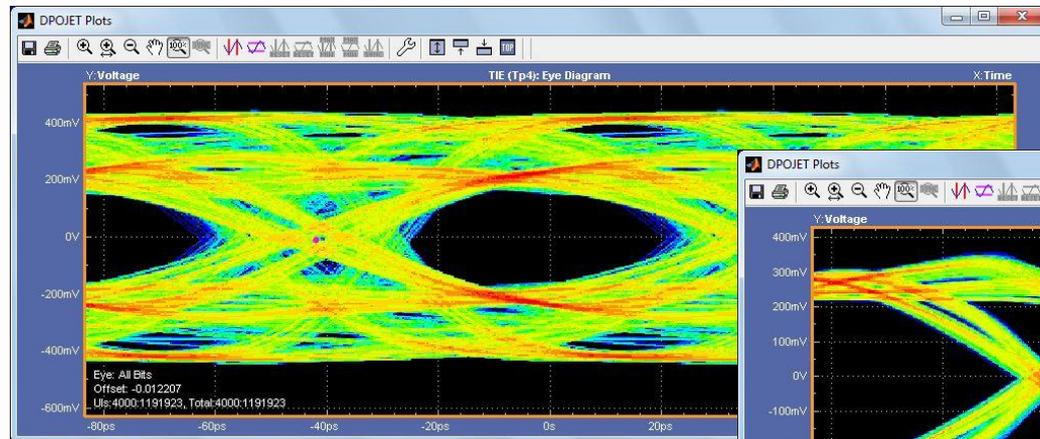


- All measurements taken after the RX Equalizer



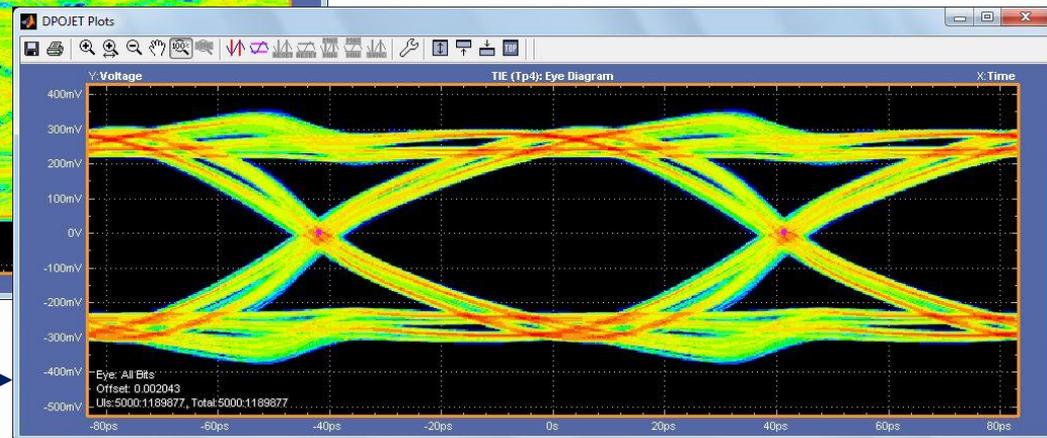
# Considerations when using IBIS-AMI in measurements

- IBIS-AMI models have an ignore bit parameter at the beginning of the waveform for settling time
- Measurement tools can be configured, so ignore bits are not included in measurements



← Eye diagram with ignore bits

Eye diagram without ignore bits →

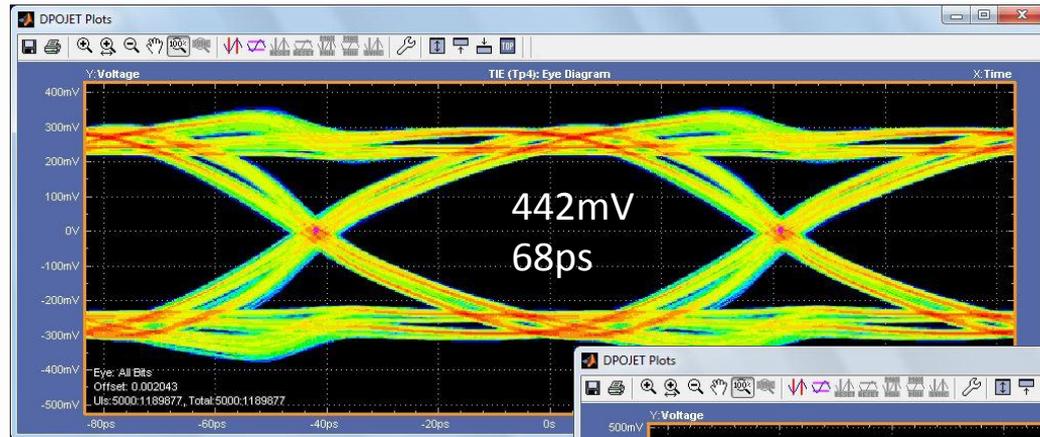


# Reference Equalizer vs. IBIS-AMI Models

- Reference equalizers represent an ideal mathematical model that can implement DFE as defined in the specification
  - Don't take into account exact clock recovery function, automatic gain control
- IBIS-AMI models are designed using the architecture of the actual receiver
  - Impairments to mimic jitter, voltage variation, temperature variation, and bandwidth limitations

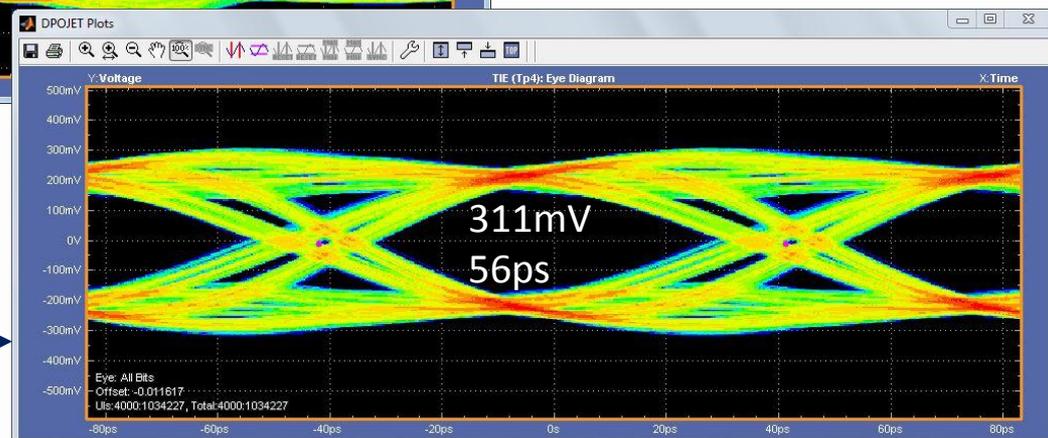
# Reference Equalizer vs IBIS-AMI Models

- Comparison done on with TX Equalization with the Long Channel



Reference Equalizer  
10 Tap DFE  
CR: Type II PLL JTF 7.2Mhz

IBIS-AMI Model



# Conclusion

- Good correlation can be achieved between measurement and simulation environments
- Good S-parameter models are required and taken into account at design time
  - For example, layout replicas of the breakout channel for easy S-parameter measurements
- Reference equalizers work for compliance testing, but IBIS-AMI models provide a truer representation of the device behavior