IBIS-AMI Modeling for Bi-directional D2D Links with Clock Forwarding and Echo Cancellation

Steven Parker, (Marvell)
Senior Staff Manager DSP Architecture
David Banas, Fangyi Rao, (Keysight Technologies)

*With **Foad Arvani** (Marvell), **Matthew Kelly** (Marvell), **John Ma** (Marvell), **Reza Mirzaei Nejad** (Marvell), **Davide Visani** (Marvell)*

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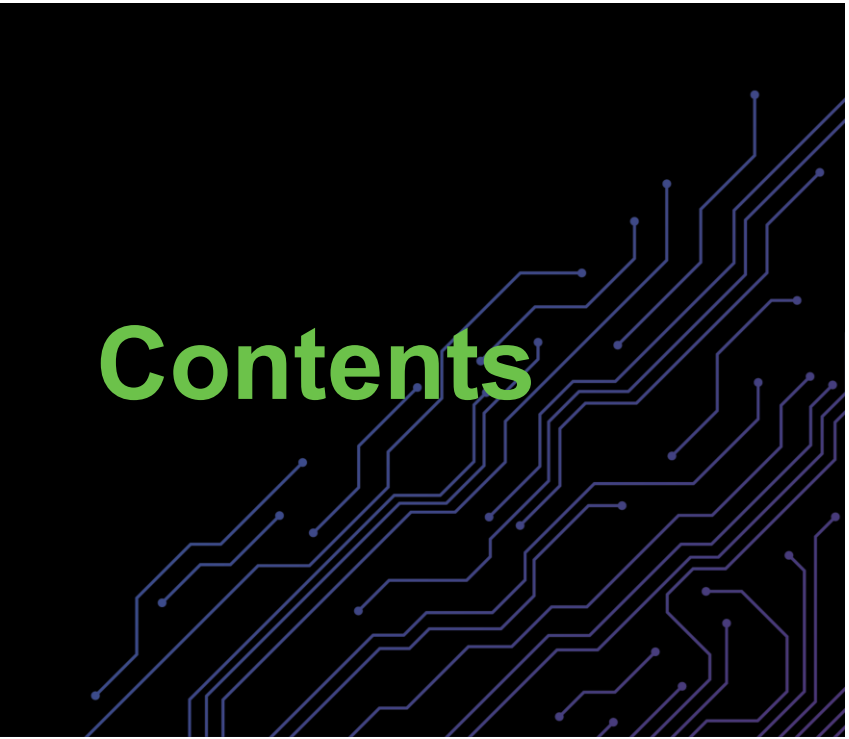
SPEAKERS

Steven Parker

Senior Staff Manager Architecture DSP, Marvell

sparker@marvell.com | marvell.com

Steven Parker is a Senior Staff Manager, DSP Architecture at Marvell. He received his M.S. from the State University of New York at Buffalo. He has worked for Marvell since its acquisition of Avera Semiconductors from GLOBALFOUNDRIES. Before that he was a Principal Member of Technical Staff for GLOBALFOUNDRIES in East Fishkill, New York, USA where he worked since its merger with IBM Microelectronics Division in 2015. Prior to the divestiture he worked at IBM Microelectronics on hardware development in Hard Drive Controllers, DDR3/DDR4 memory solutions, and High-Speed Serial Links. He represents the company in the IBIS Open Forum. Currently he leads the team which develops simulators and models for Marvell's High Speed SerDes and D2D PHYs.



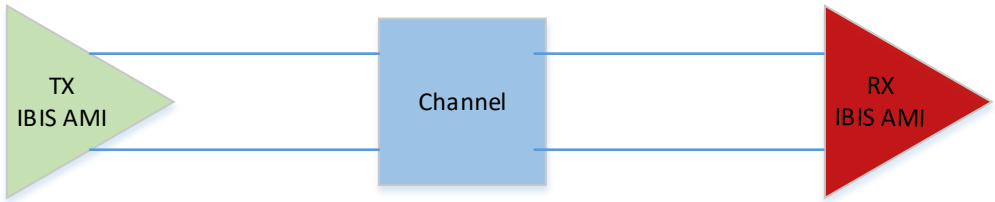
Introduction

Introduction / Motivation

- This work came out of joint development efforts between Keysight and Marvell in the development of a bi-directional D2D model.
- In order to create bandwidth densities, bi-directional signaling for D2D is seen as a way to double density at the expense of design complexity.
- This is a IBIS AMI modeling centric paper abstracting away specific design implementation details.
- It is intending to highlight modelling concepts important for bi-directional D2D (die to die) links and highlight some calls to action that may help the IBIS AMI standard evolve for this application.
- It is intended to demonstrate the concepts from a generic perspective

Traditional IBIS AMI Flow

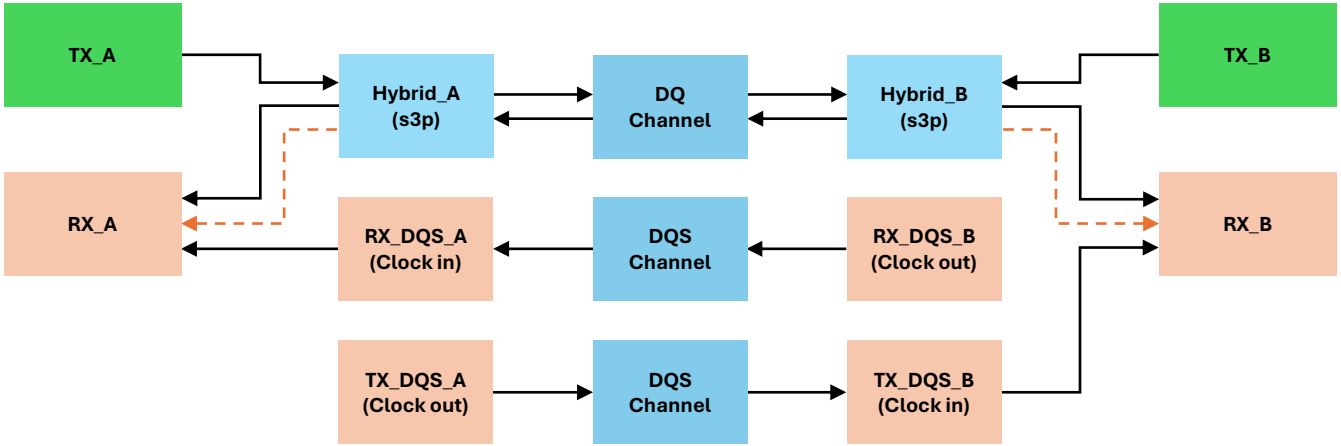
- Traditional IBIS AMI modelling focuses heavily on point to point topologies using clock-data recovery techniques



- Unidirectional signal flow
- Differential Signaling
- CDR for clock recovery

Why this matters

- Emerging architectures operate outside of the traditional IBIS AMI assumptions pushing the boundaries of modeling with IBIS AMI

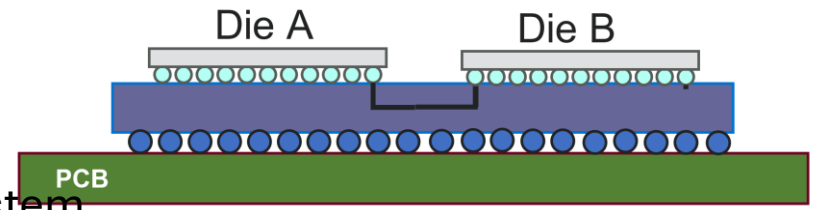


- This work explores strengths and weaknesses of IBIS AMI modeling for these architecture, makes recommendations on current practices, and a call to action for IBIS AMI:

Application

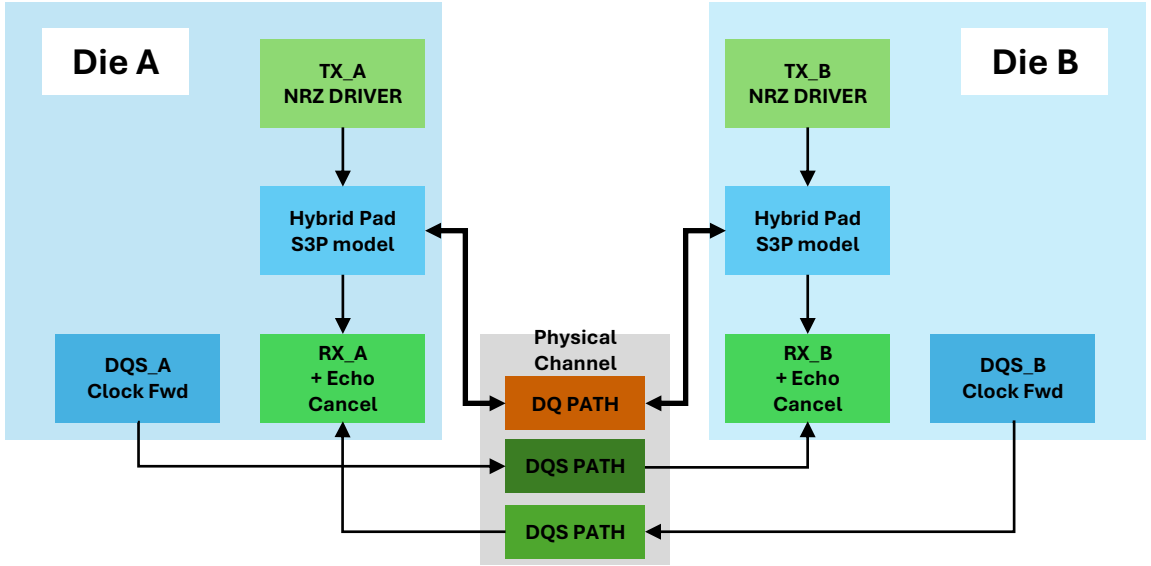
D2D System Application

- Die to Die chiplet interconnect technology for emerging applications
- This application has similarities to UCIe
- UCIe architecture well served by IBIS ecosystem with solutions available from several vendors
- However, because of the unique bidirectional requirements of this architecture we were unable to achieve our goals with pre-existing solutions

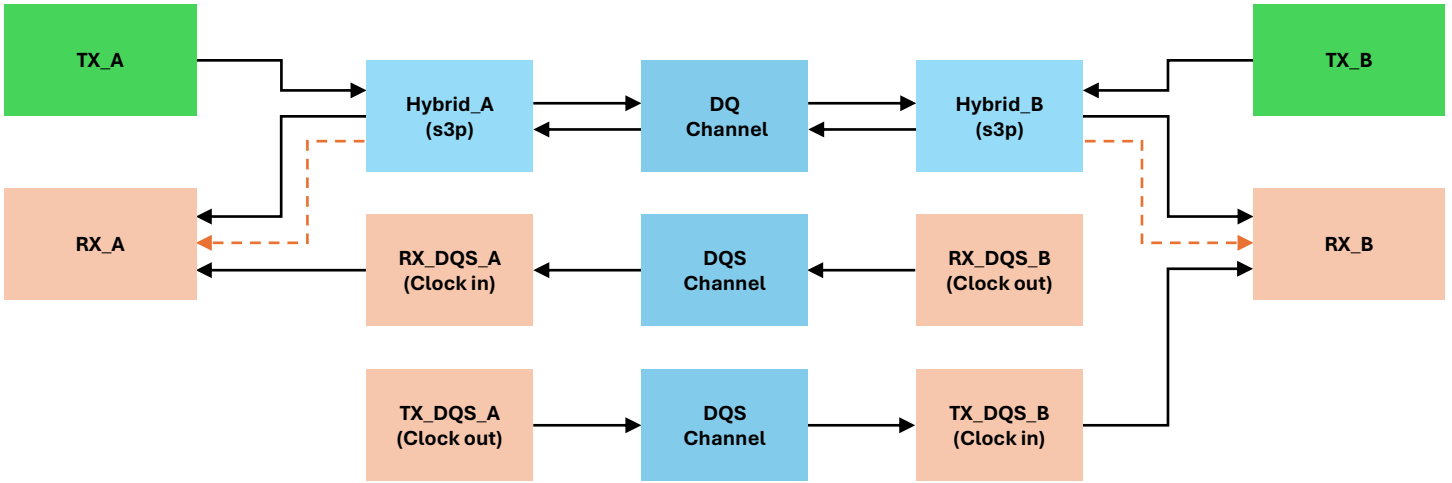


D2D System Block Diagram

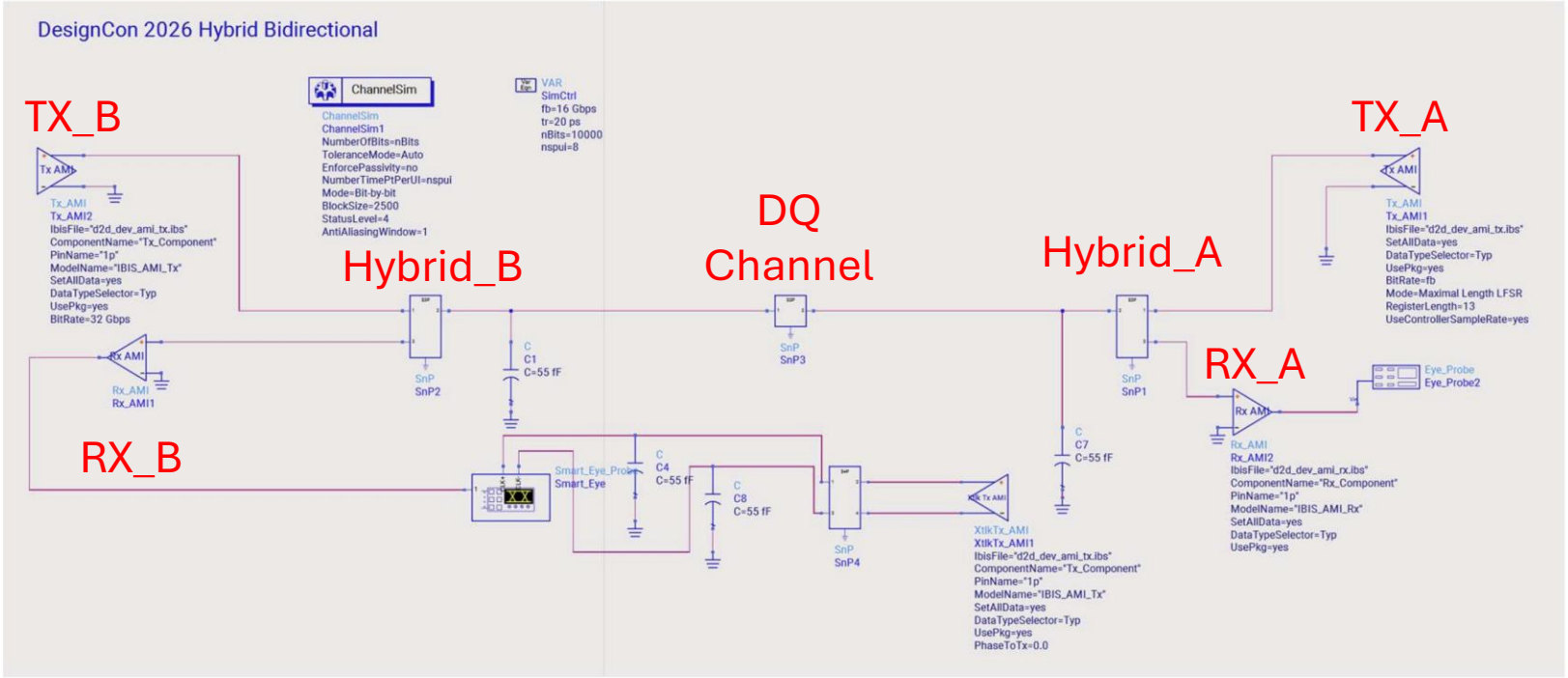
- The system consists of a single-ended DQ channel with bidirectional signaling running through it. Full duplex data path operation.
- Simultaneously forwarded clocks (DQS) are also sent in both directions.



Bidirectional D2D System Diagram



Simulation Workspace in EDA tool (DQ Path)



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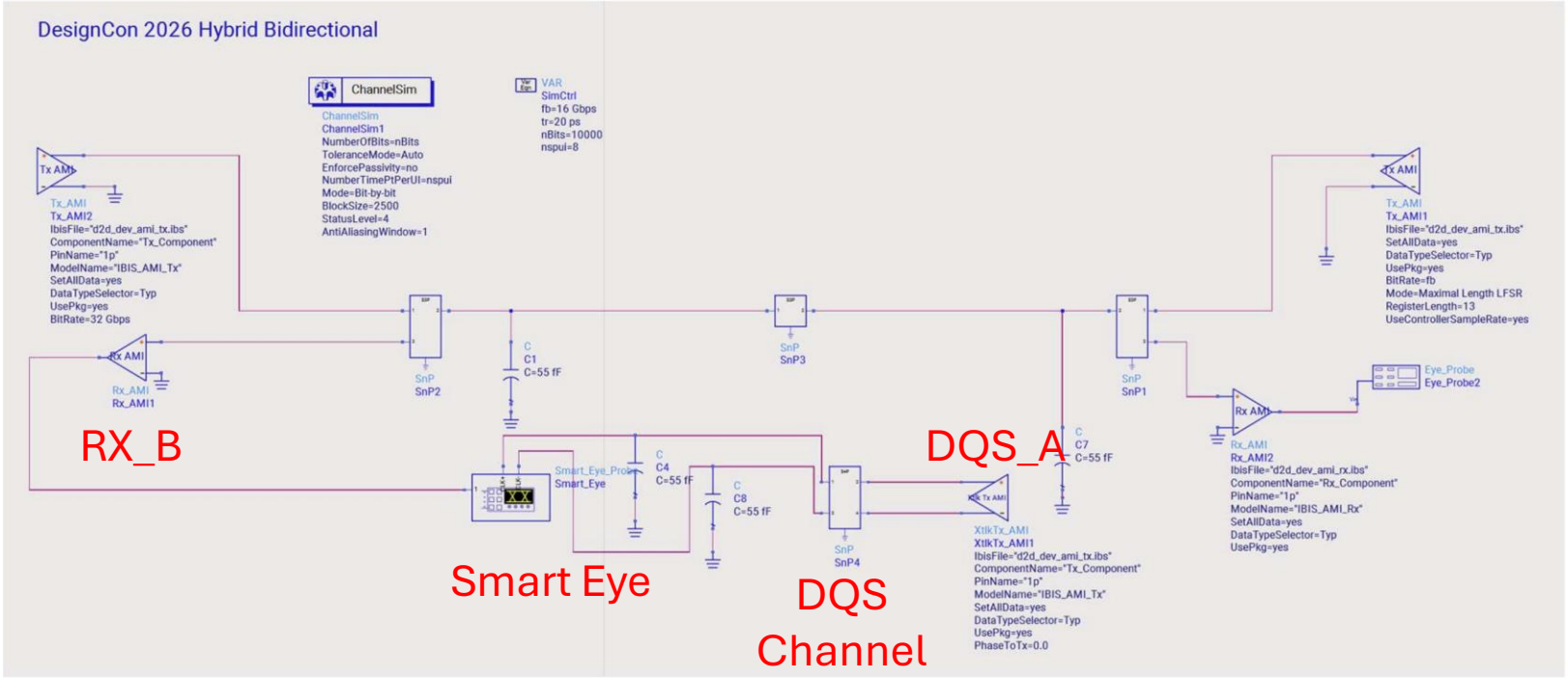
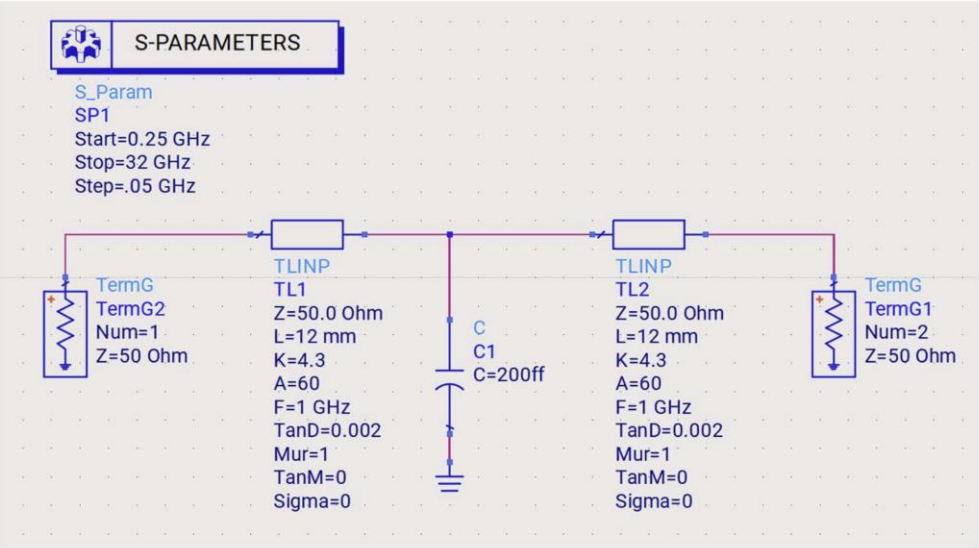
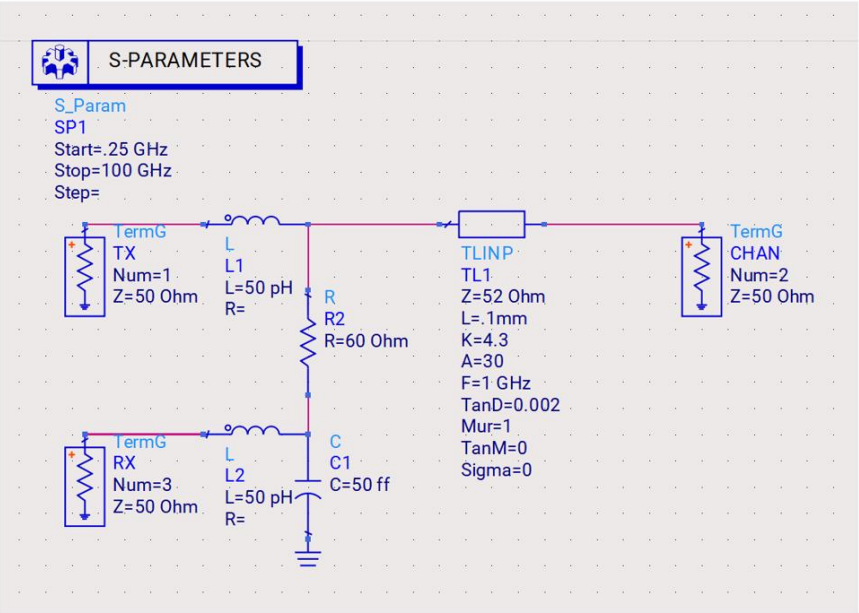


“DQ Channel Model”



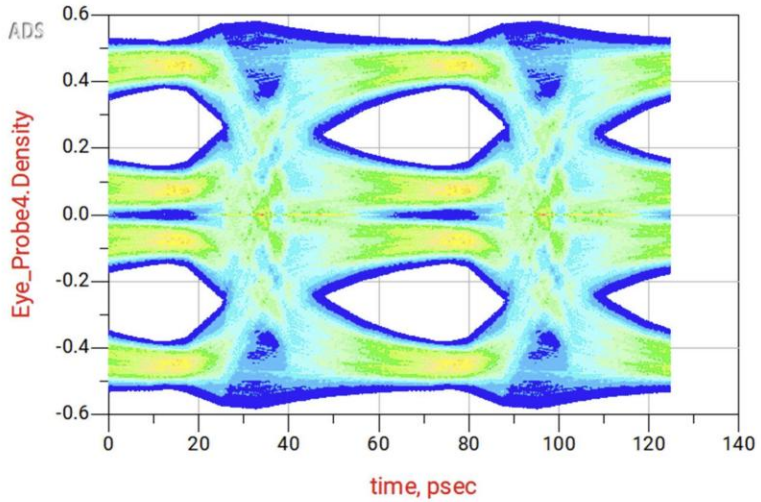
- DQ Model for illustration purposes
- In practice, model would be extracted from analog simulations

Hybrid Model



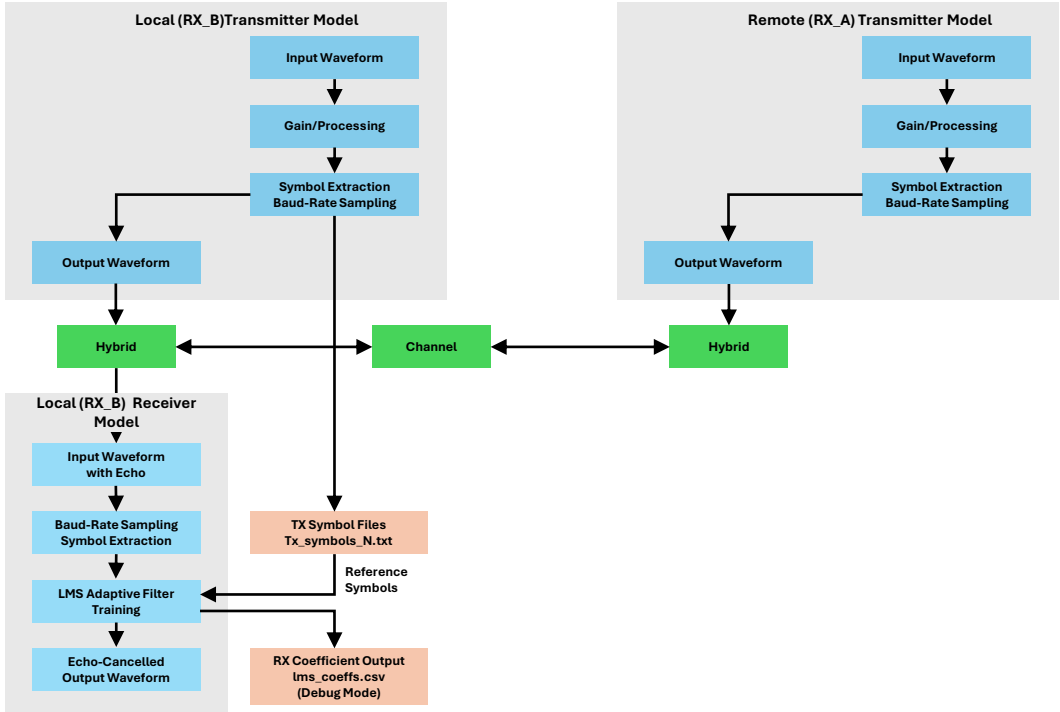
- Hybrid Model for illustration purposes
- In practice, model would be extracted from analog simulations

PAM3 Eye Seen at RX_B



- Seen here is the PAM3 eye at RX_B
- It consists of the super-position of two NRZ signals seen at the receiver input.

Model Architecture



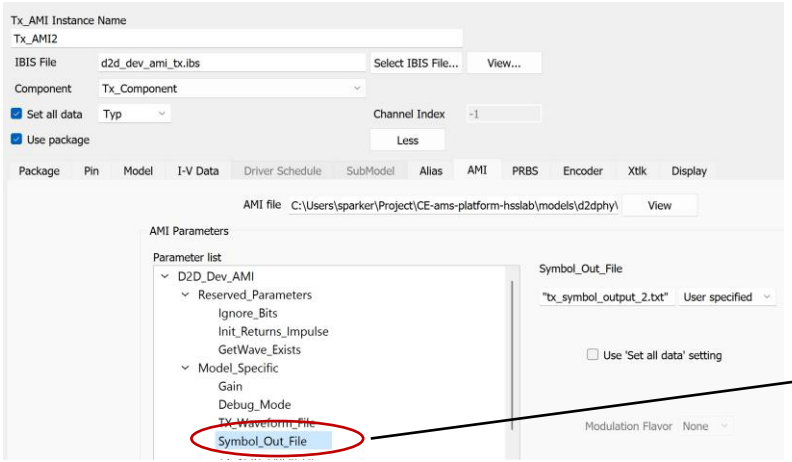
IBIS AMI Fundamentals

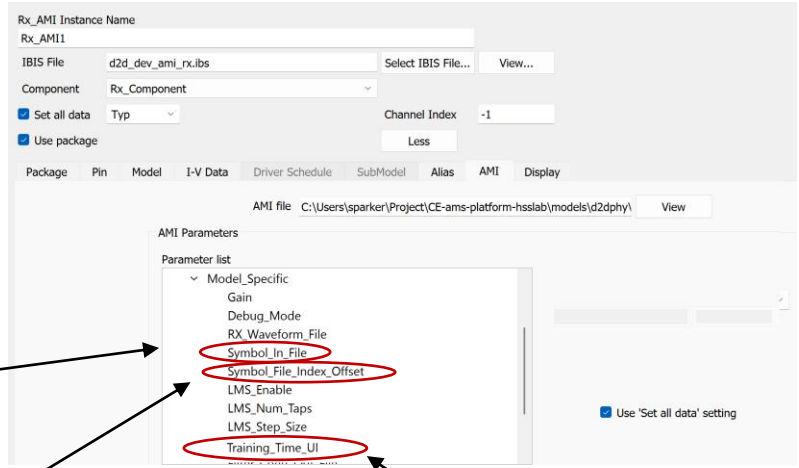
The Two Modes of AMI:

•**AMI_Init (Statistical):** This is the initialization function where the model processes the impulse response of the channel. It is used for statistical analysis and for the model to "adapt" its settings before the simulation begins.

•**AMI_GetWave (Time-Domain):** This function processes a continuous voltage waveform over time, bit-by-bit. It is essential for modeling non-linear behaviors, such as adaptive equalization and the echo cancellation loops used in this work.

IBIS AMI Model Parameters In Use





TX AMI Parameters

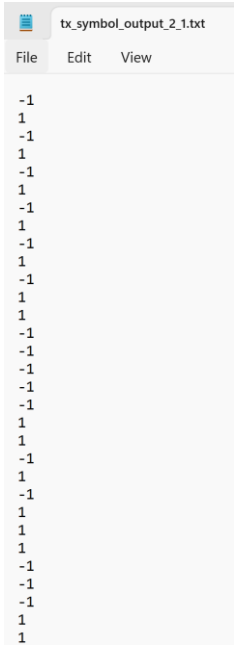
Parameter to control synchronication between TX and RX

RX AMI Parameters

Parameter to control training time in UI

File Transport and Synchronization

Here's an example symbol file: tx_output_symbol_2_1.txt

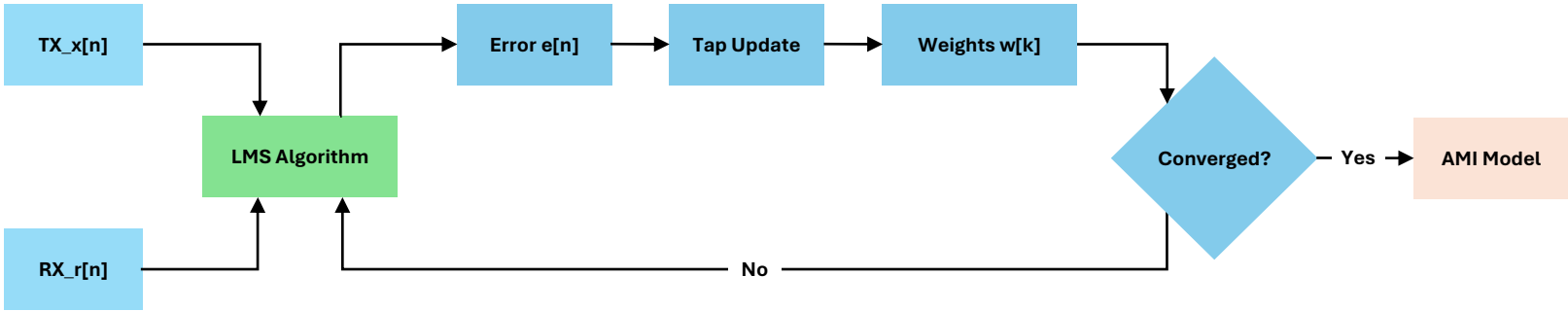


Die Index: 2 = "B"

Sequence Number

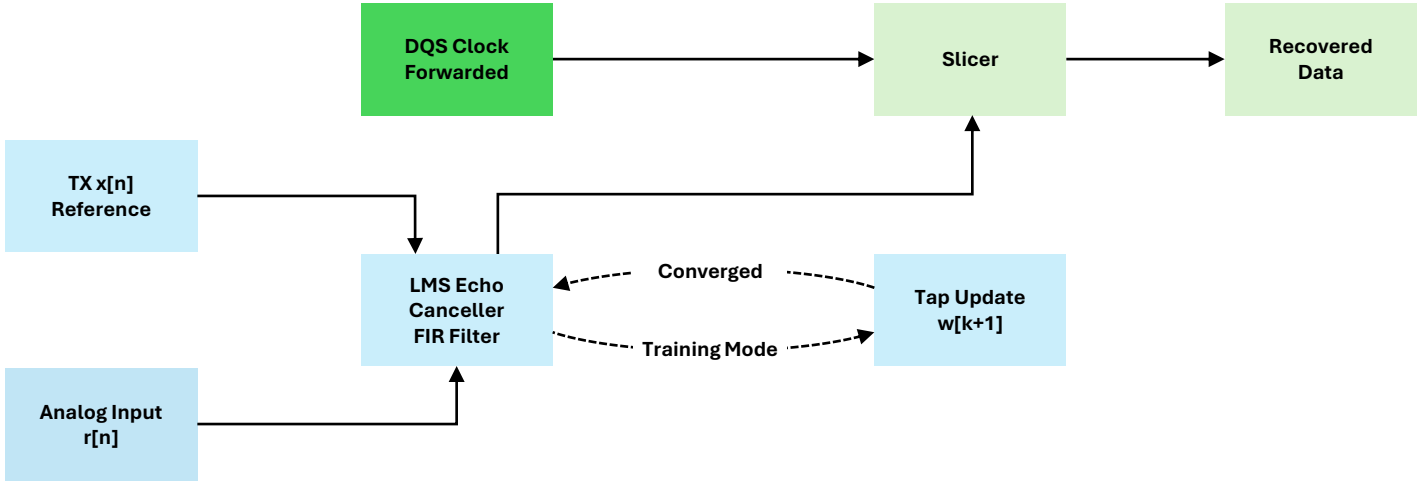
- Conventions used for efficient implementation and bring up.
- EDA tools do not guarantee Number of TX GetWaves and RX GetWaves are the same (count synchronication is not sufficient).
- Manual or possible automated alignment is needed.

LMS Echo Cancellation Training Flow

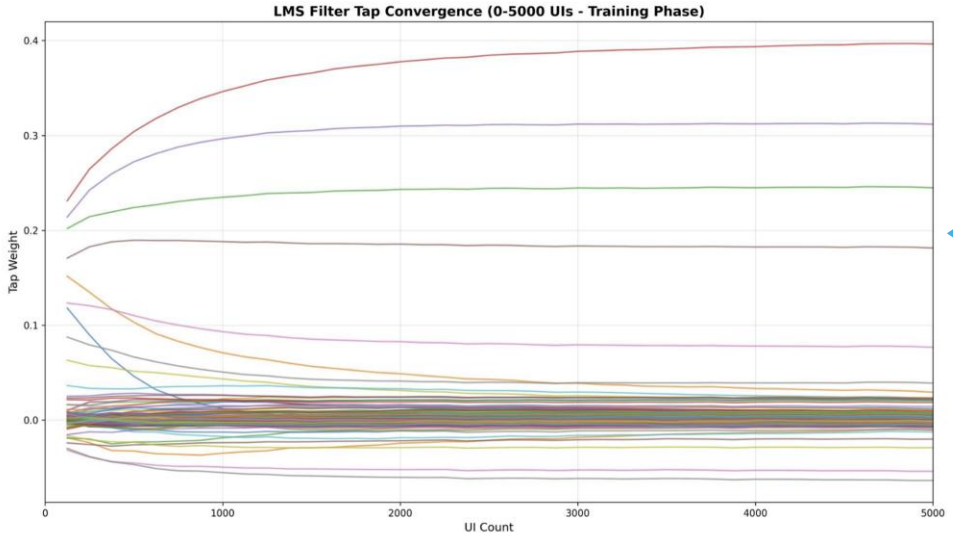


Convergence based on time

Receiver Front End



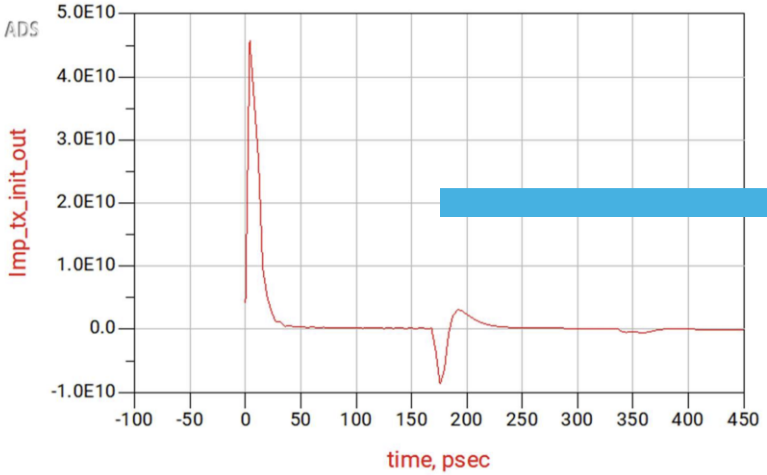
LMS Filter Tap

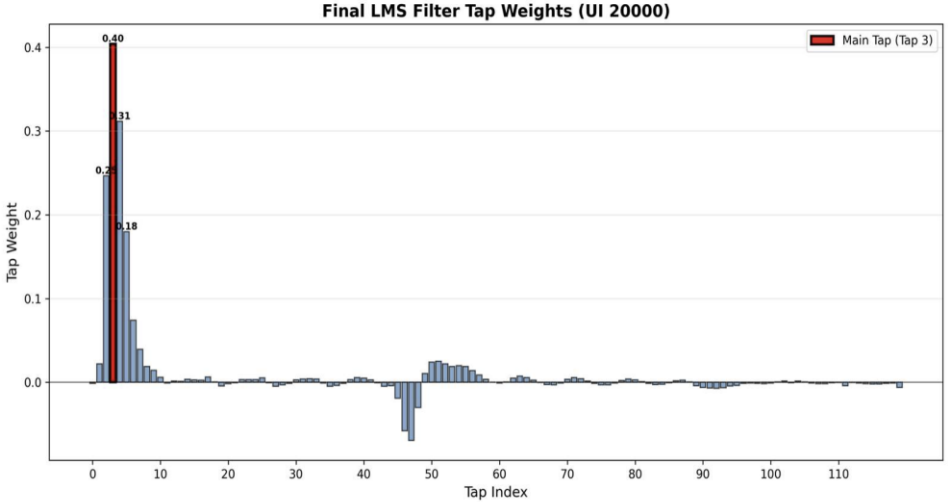


Internal LMS Filter Tap Adaption based on symbol stream handled via file drop (written to lms_taps_coef)

Training occurs with TX enabled only, remote TX disabled

LMS Filter Tap

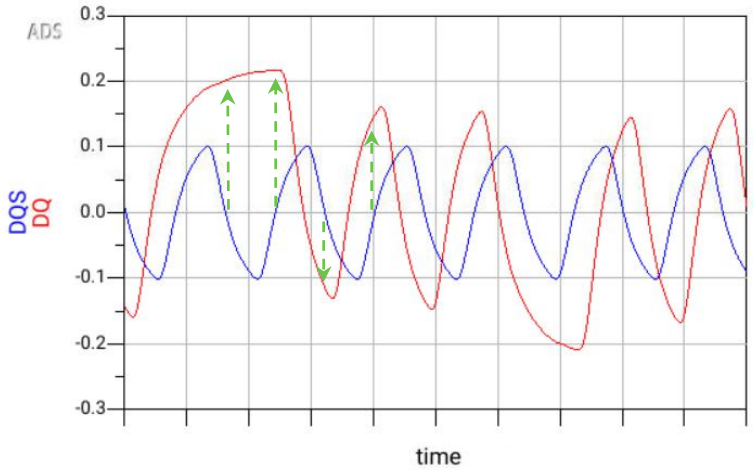




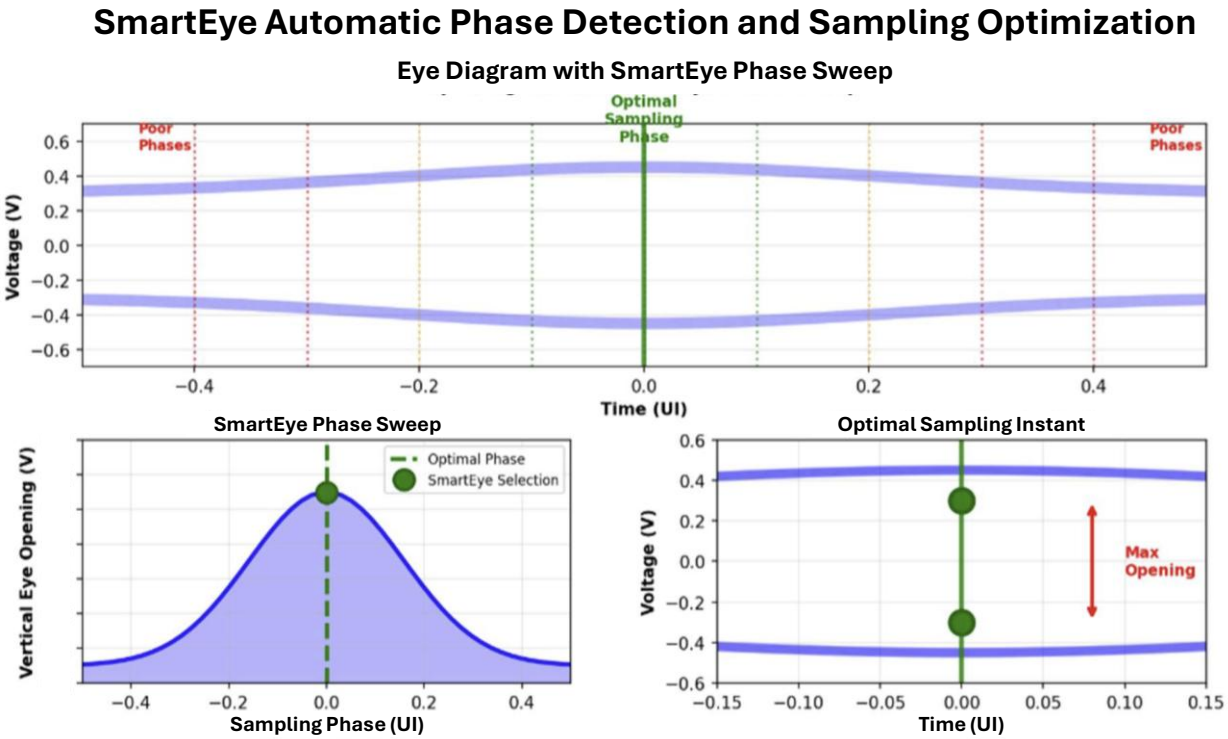
- Convergence of LMS to echo profile
- Oversampled waveform used for modeling illustration

Modeling Clock Forwarding with Enhanced Probe

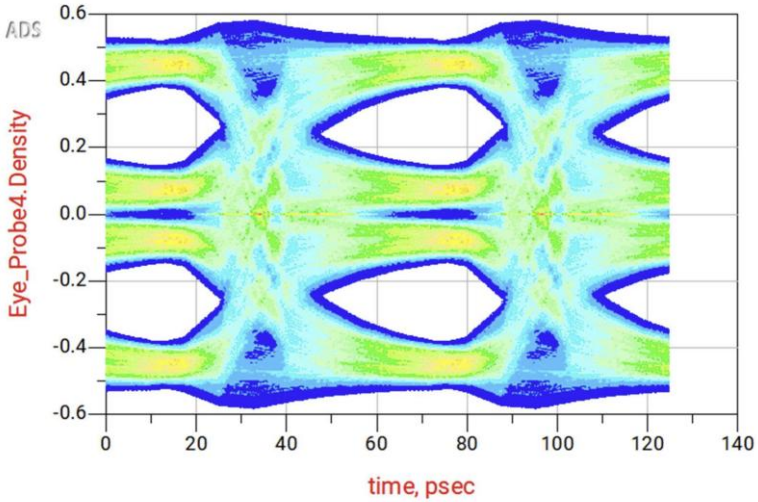
- Probe samples DQ signal at threshold crossing times of DQS signal
- Correlated jitters between DQ and DQS are tracked and canceled
- When constructing DQ eye, sampling times are placed at the eye center
- A uniform shift/phase can be added to DQS crossing times when sampling DQ signal
- The probe can automatically determine the optimal shift/phase



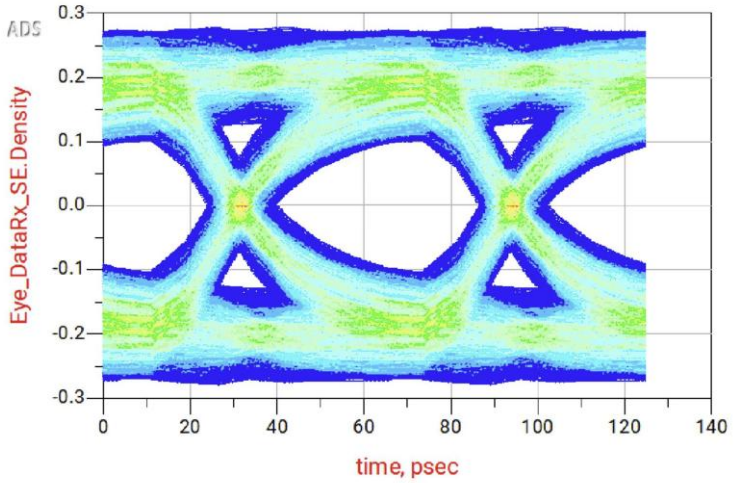
SmartEye Automatic Phase Detection



PAM3 -> PAM2 Eye Showing Cancellation



PAM3 Eye Highlighting Super Position of two NRZ eyes



Resulting NRZ eye showing slider input at the sampler

Calls for Action

We have a call to action for IBIS to consider start developing on a new BIRD (Buffer Issue Resolution Document) to:

1. **Introduce** a new IBIS keyword to associate TX and RX pins (models) of a bi-directional transceiver, similar to the [Repeater Pin] keyword in Repeater model

2. **Reserve** the 1st aggressor column of the impulse_matrix for echo signal to enable RX AMI_Init to optimize Rx echo cancellation setting and to support statistical simulation

Summary

- Recapping we highlight a methodology for modelling bidirectional
- Circuit modelling topology highlighting .s3p s-parameter described
- Model to model communication protocol proposed for active training of echo canceller in a file drop transport method.

MORE INFORMATION

- www.marvell.com
- Link to supporting material
- sparker@marvell.com

Thank you!

QUESTIONS?

Steven Parker

Senior Staff Manager Architecture DSP, Marvell

sparker@marvell.com | marvell.com