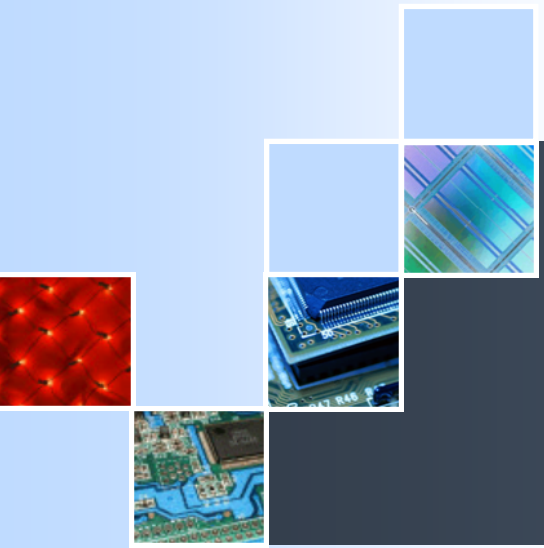


Recent Development of IBIS and Related EDA Technologies

Asian IBIS Summit

Shanghai China

November 4, 2009

Jinsong Hu, Raymond Y. Chen

Sigrity, Inc.

SIGRITY

Agenda

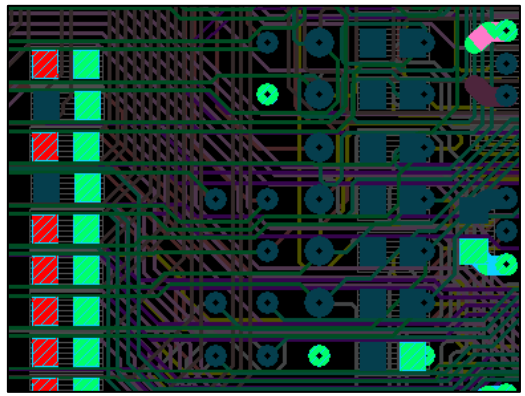
- Review IBIS's role in high-speed SI analysis, especially those new developments, from device modeling, interconnect modeling, and system level simulation automation perspectives.

- Discuss how IBIS as a standard, provides some of the leading technologies for the high-speed design, modeling and simulation industry; whereas in some areas, IBIS standards are lagging behind what industry is doing.

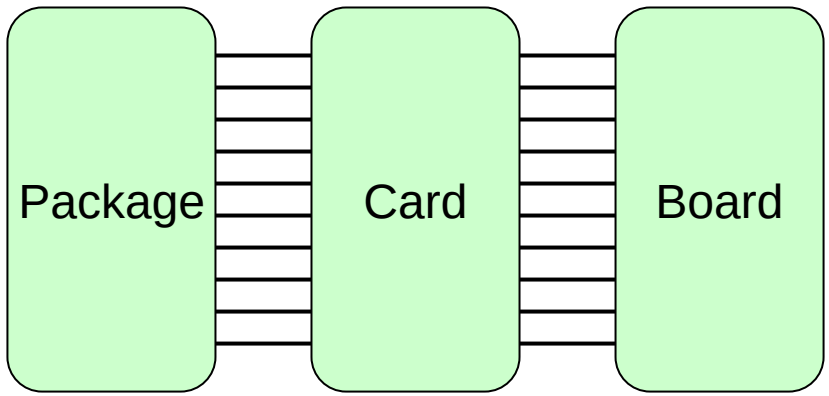
- Promote the thinking of what our current industry needs and what future technologies might bring us.

IBIS's Role in High-Speed SI Analysis

Device Modeling

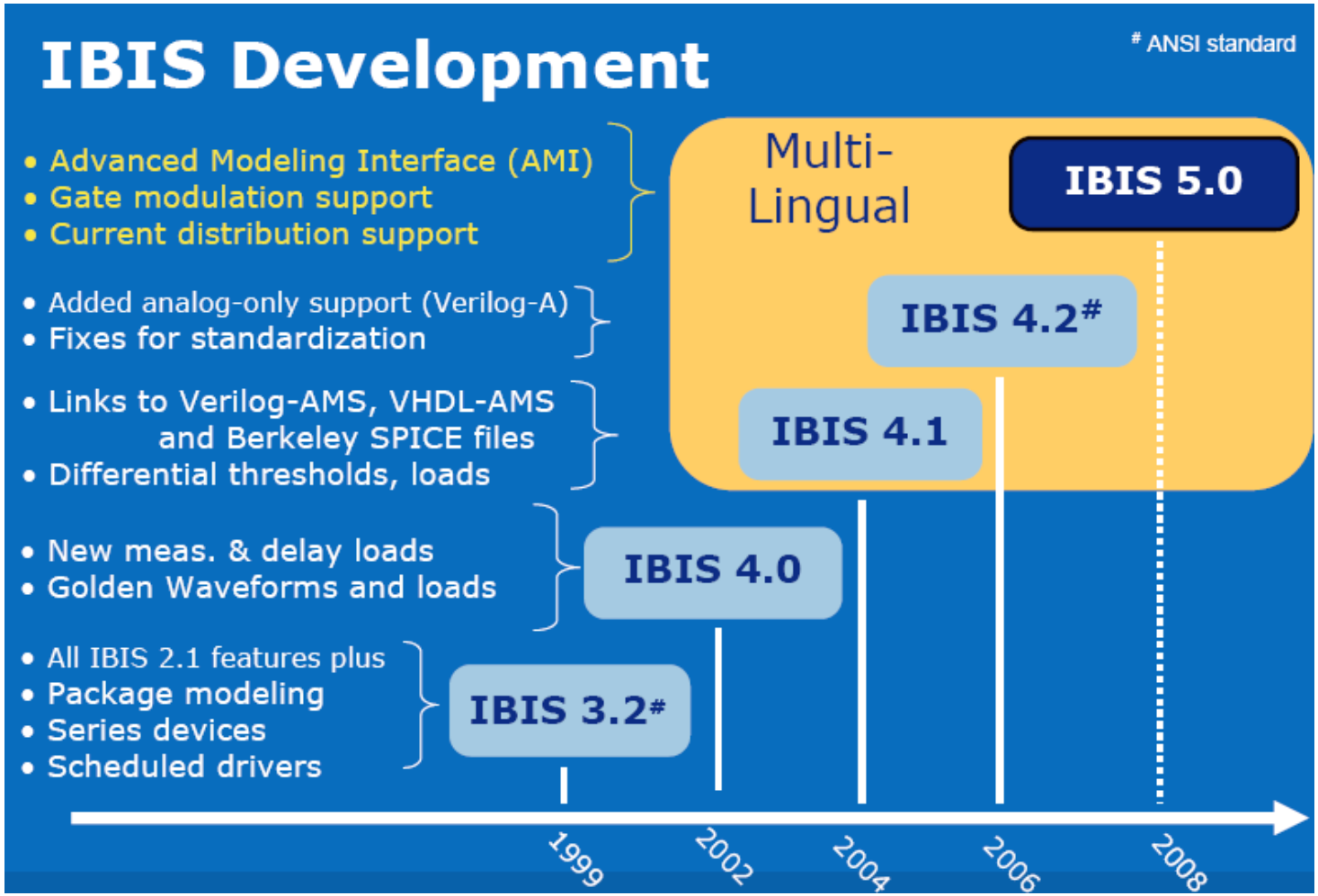


Interconnect Modeling



System Level Simulation Automation

IBIS Evolution



➢ Reference: New Table-based Keywords in IBIS 5.0, Michael Mirmak, 2008 IBIS Summit China

IBIS Latest Status in 2009

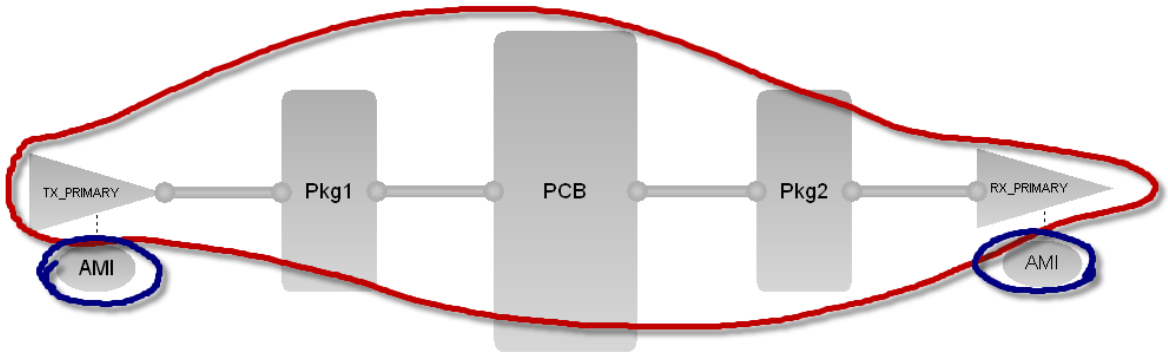
- Device modeling enhancement
  - BIRDs for IBIS 5.0
    - BIRD74.6 – EMI Parameters
    - BIRD95.6 – Power Integrity Analysis using IBIS
    - BIRD97.2/98.1 – Gate Modulation Effect
    - BIRD103.1 – [Model Spec] DDR2 Over/Undershoot
    - BIRD104.1 – Algorithmic Modeling API
    - BIRD107.2 – Update to Algorithmic Modeling API
    - BIRD108 – Fixing Algorithmic Modeling API Impulse Matrix Nomenclature

- Interconnect modeling enhancement
  - Touchstone 2.0 completed and released
    - Sparse matrices and node-port matching now under development
    - Parser development about to begin

IBIS Device Modeling – AMI Development

IBIS AMI Device Model Key Concepts

- Device models for high-speed channel simulations that need sophisticated FFE and DFE algorithms
  - The Tx –to– Rx pathway is composed of 3 separate entities
    Tx algorithmic part, Analog channel, Rx algorithmic part

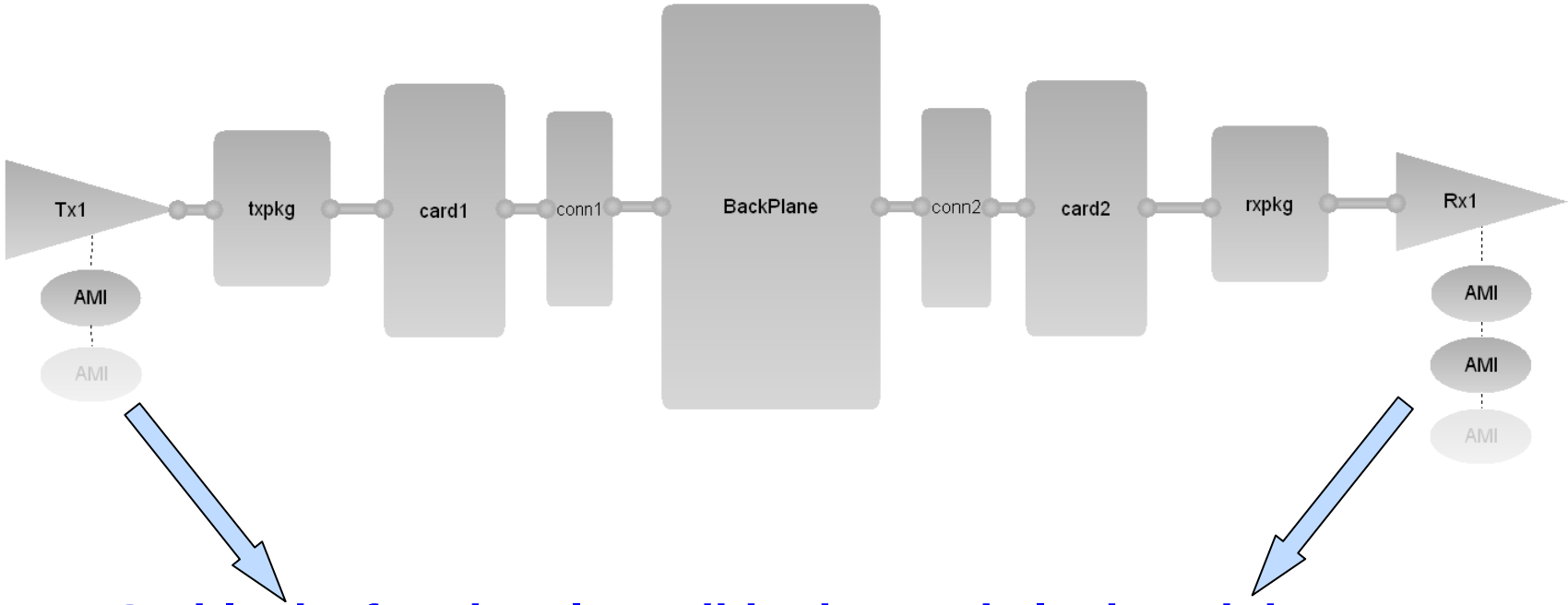


- Model delivered as a dynamically linked library (DLL)
  - Executable models contain and conceal IC company's advanced device algorithms

Observations

- IBIS AMI, a novel idea and technical approach that meets current and future modeling and simulation needs, and also fits the business model for IC company (who provides) and system company (who uses)
- IC technology advances fast, which requires more advanced IBIS AMI models beyond current standard to support existing designs
- The provided IBIS AMI models from some IC Companies are just part of the product line, not complete
- Many IC companies are yet to have the practice or know-how to deliver IBIS AMI models

Advanced feature needed - Cascaded AMI



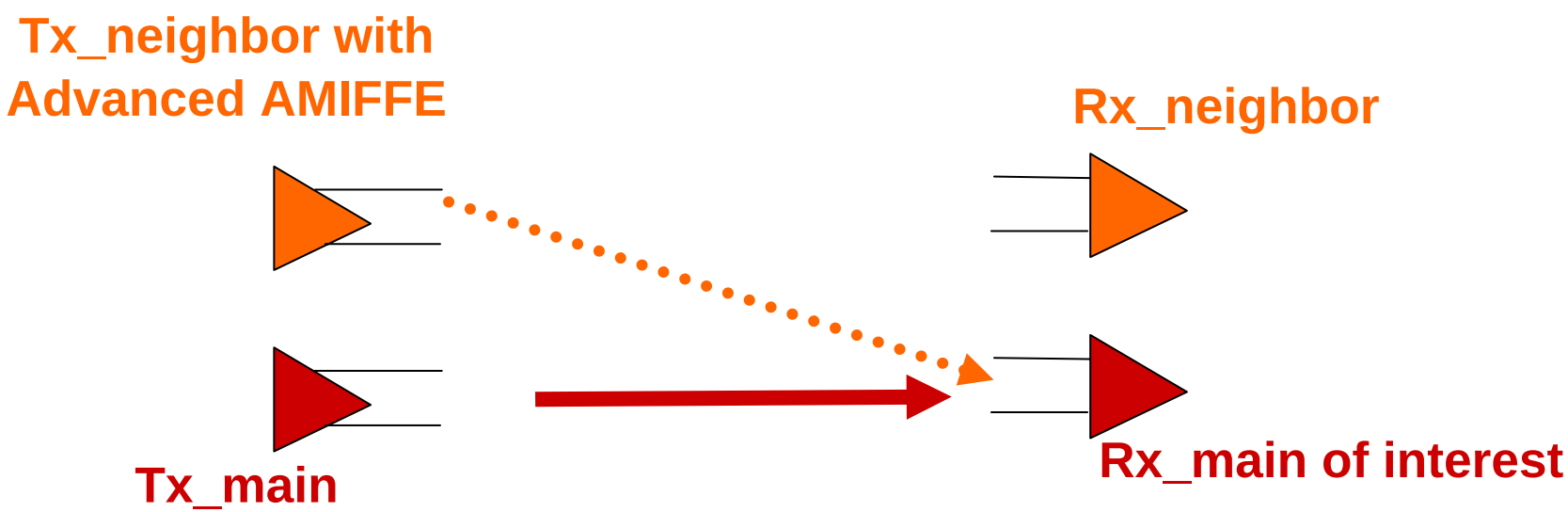
DSP blocks for signal conditioning and clock and data recovery

Cascaded AMI → Allows flexible Modeling and debug

Example: cascade equalizer model with stand alone CDR

Advanced feature needed: Xtalk aware

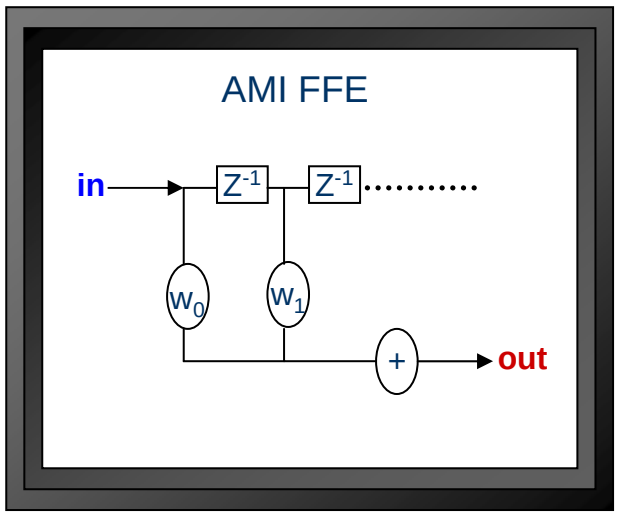
- Standard IBIS AMI models are only required to filter the main channel
- Advanced AMIFFE models will optimize the filter coefficients for the main channel, and has the capability to filter the xtalk channel using those coefficients

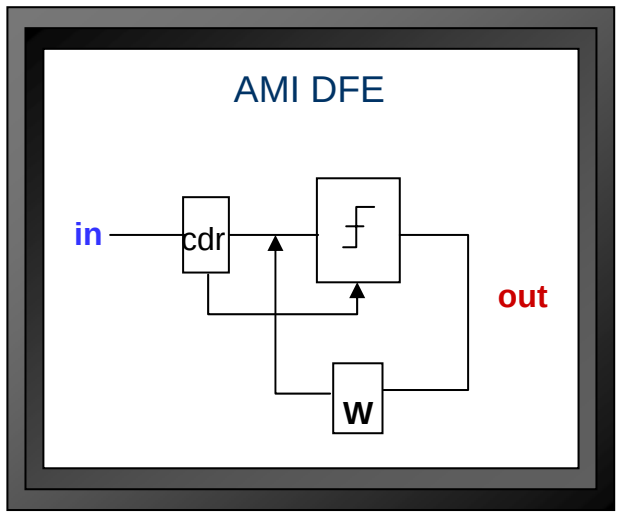


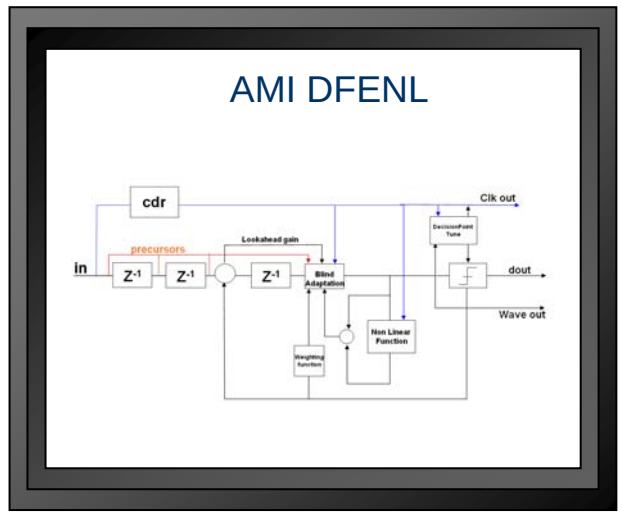
Advanced IBIS AMI Function Blocks

Advanced AMI implementations with highly customizable configurations can model the real world devices

- AMI CDR2 – Stand alone clock data recovery
- AMI FFE – Feed forward filter model (tap optimization)
- AMI CTF – Analog filter model
- AMI DFE – DFE with blind adaption
- AMI DFENL – DFE with look ahead equalizer

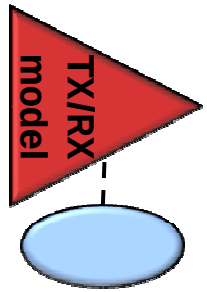


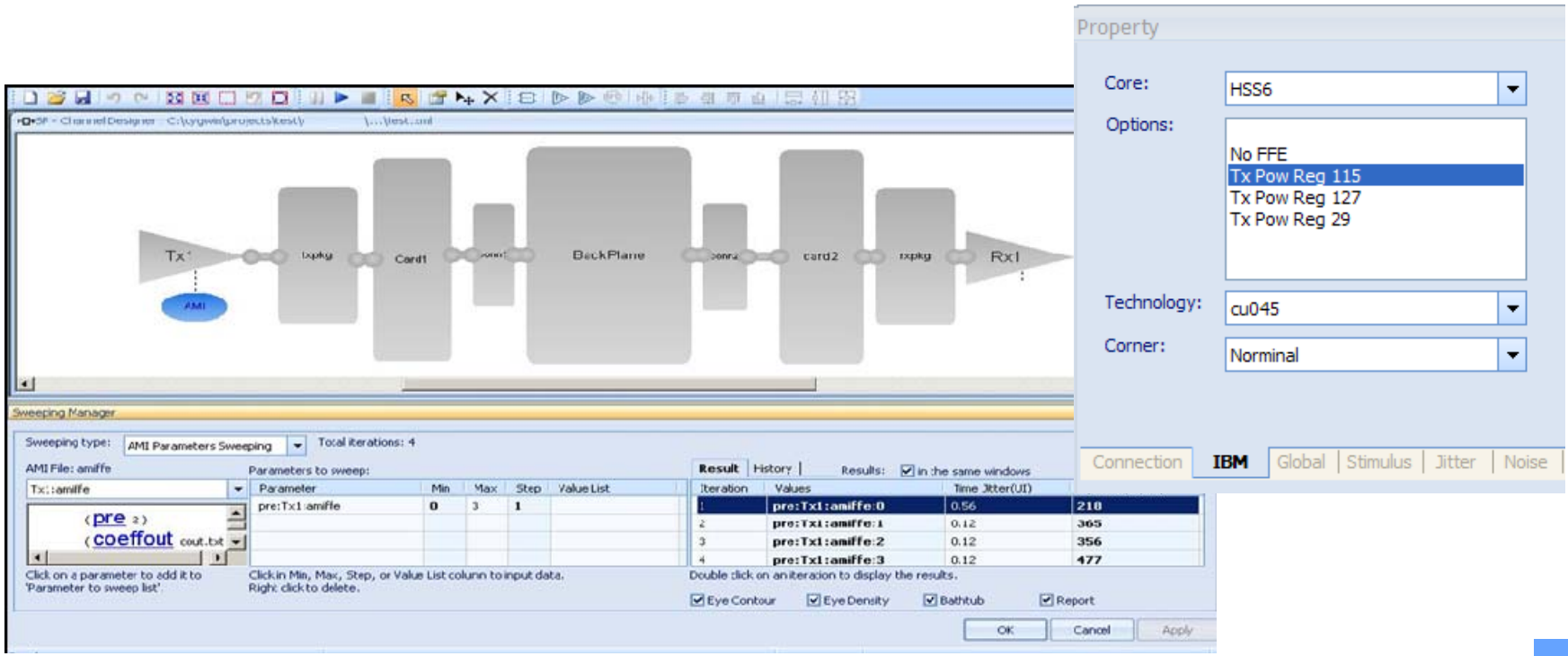




Beyond IBIS AMI - Hybrid Model Support

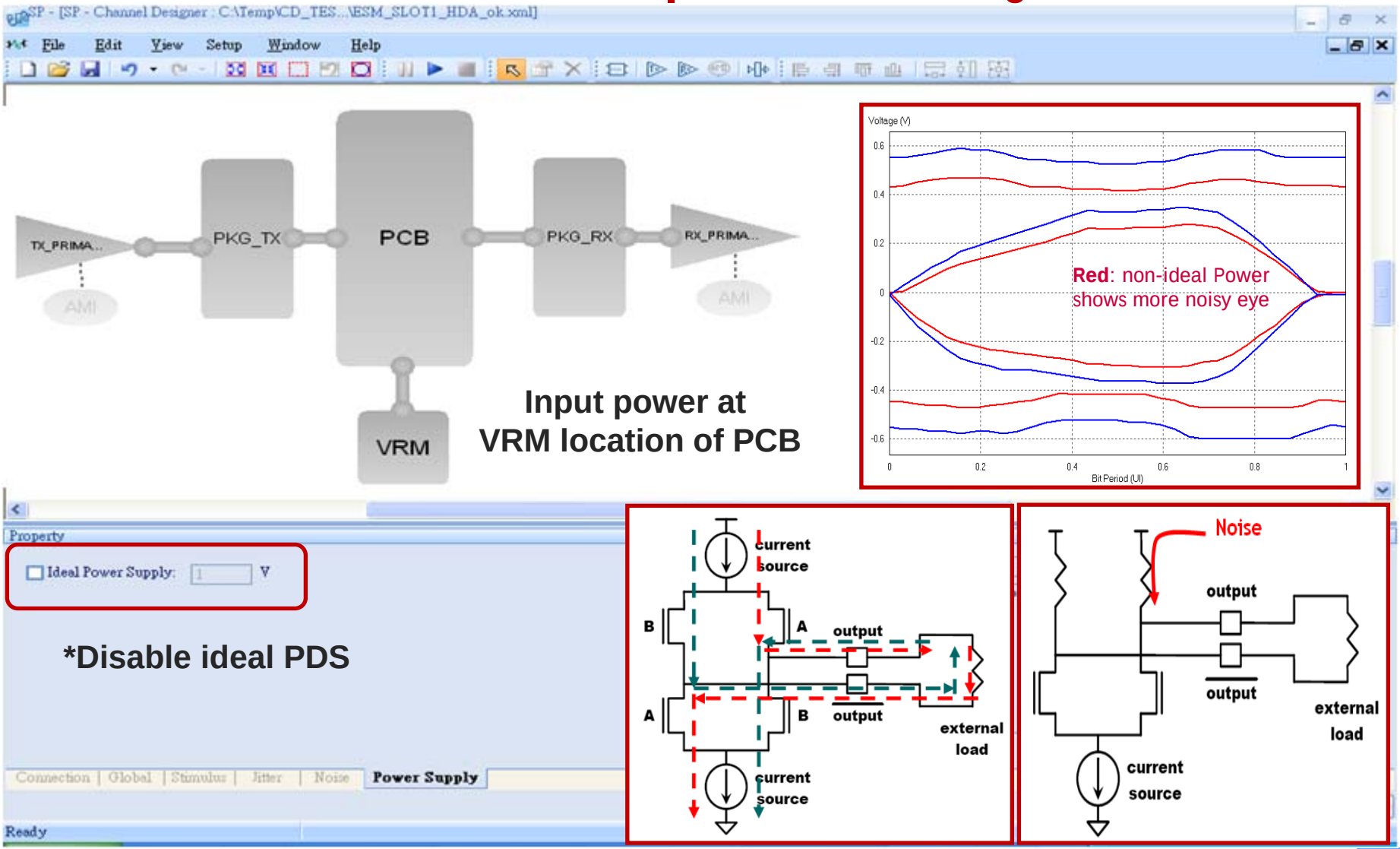
- **IBIS-AMI**
- **IBIS with driver schedule**
- **HSPICE/Encrypted HSPICE**
- **Verilog-A**
- **IC companies' proprietary models (C or Matlab based), such as those in IBM HSSCDR**



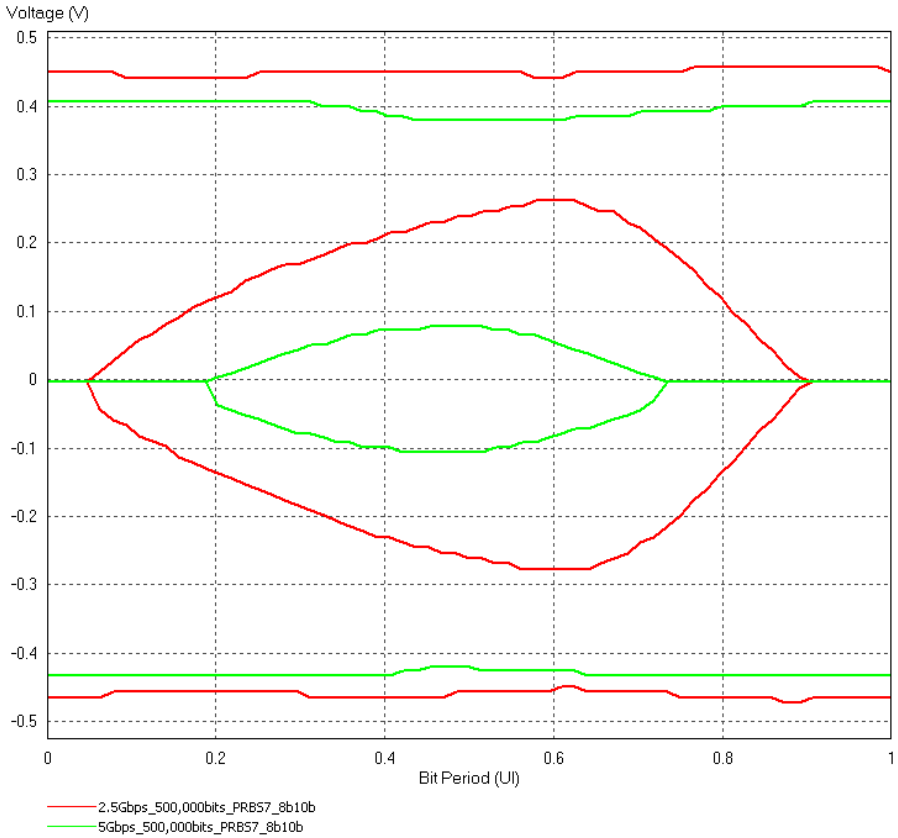


Beyond IBIS AMI – Non-Ideal PDS SI Analysis

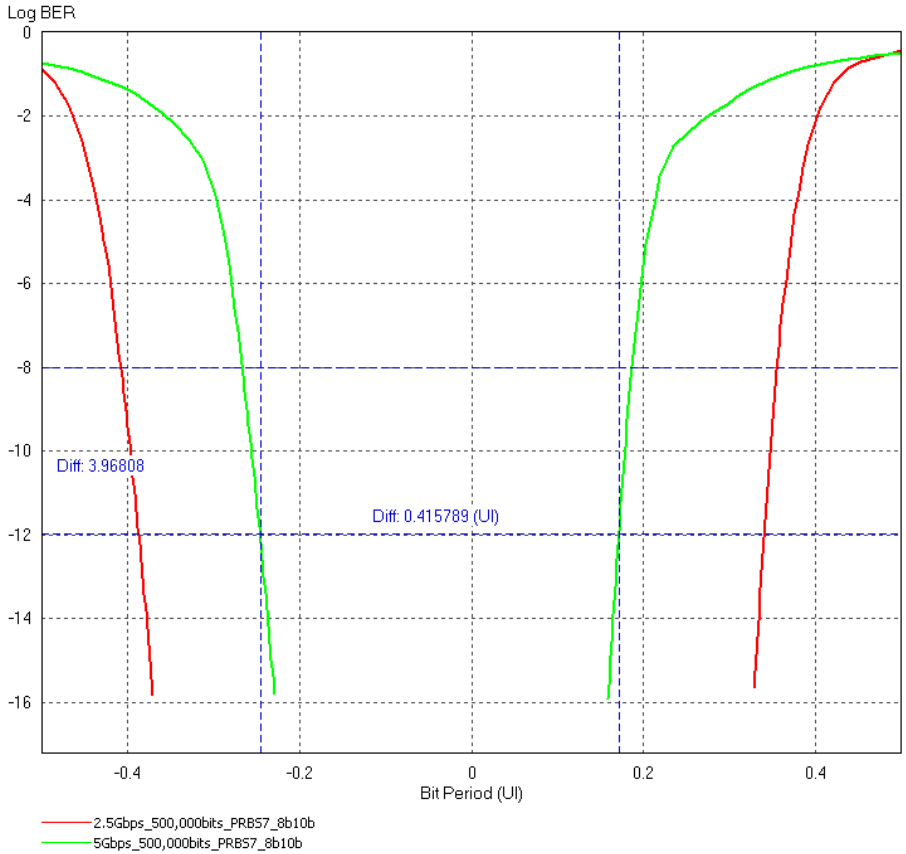
AMI models can be powered through real PDS



High-speed Gigabit Serial Simulation with AMI models (2.5Gbps Vs 5Gbps)

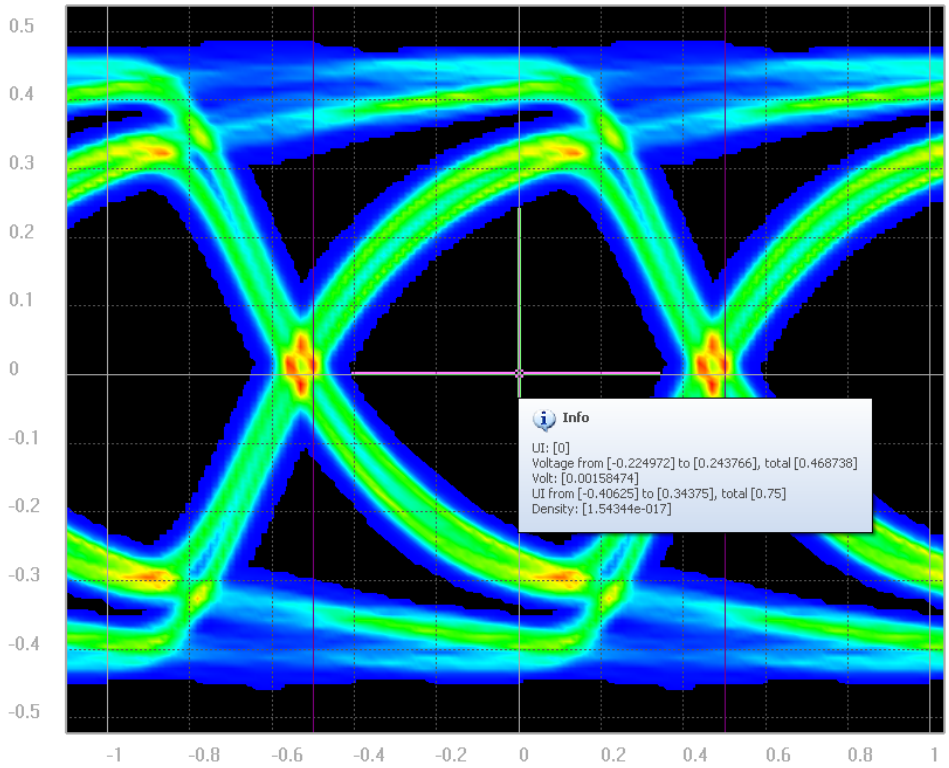


Eye Contour

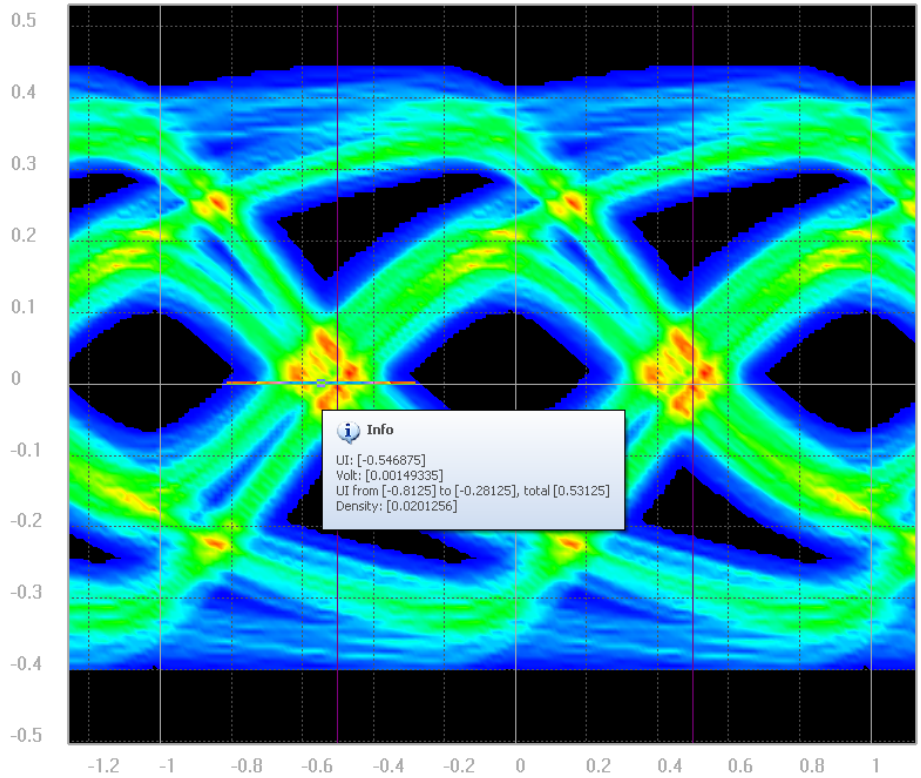


Bathtub

High-speed Gigabit Serial Simulation with AMI models (2.5Gbps Vs 5Gbps)



2.5Gbps Eye Diagram



5Gbps Eye Diagram

IBIS Interconnect Modeling – S Parameters

Package RLC models, EBD and S Parameters

- IBIS **PKG** (IC Package Model) RLC (per pin matrix) is OK for electrical short structures such as IC packages and the frequency response is needed within a few GHz.
  see reference paper at IBIS Shanghai 2006
  http://www.vhdl.org/pub/ibis/summits/oct06a/chitwood.pdf

- IBIS **EBD** (Electrical Board Description) is designed for electrical long structures but the lack of coupling and return path descriptions makes it unsuitable for high-speed SI
  see reference paper at IBIS Shanghai 2008
  http://www.vhdl.org/pub/ibis/summits/nov08a/xu.pdf

- **S-Parameter**
  widely used for accurate high frequency simulation, though has its own issues, is the most popular for interconnect model
  see reference paper at IBIS Shanghai 2008
  http://www.vhdl.org/pub/ibis/summits/nov08a/huang.pdf

IBIS Touchstone ver2.0 for S-Parameters

- Complete backward compatibility with Touchstone 1.0, released in July 2009.

- Mixed-mode support (single ended + diff. signals), which enables SI analysis with the impact of the PDS

- Per-port impedance references. This facilitates power to signal port modeling of coupling and Power Integrity simulation.

- Removal of upper limits on number of data points and number of ports. This facilitates modeling of large ICs.

- Some minor fixes and clarifications. In Touchstone 1.0, Z and Y were normalized with respect to Z0. In Touchstone 2.0, Z and Y are non-normalized and independent of Z0.

  - Reference: http://www.semiconductorsimulation.com/IBIS%20Committee.pdf

Beyond Touchstone 2.0

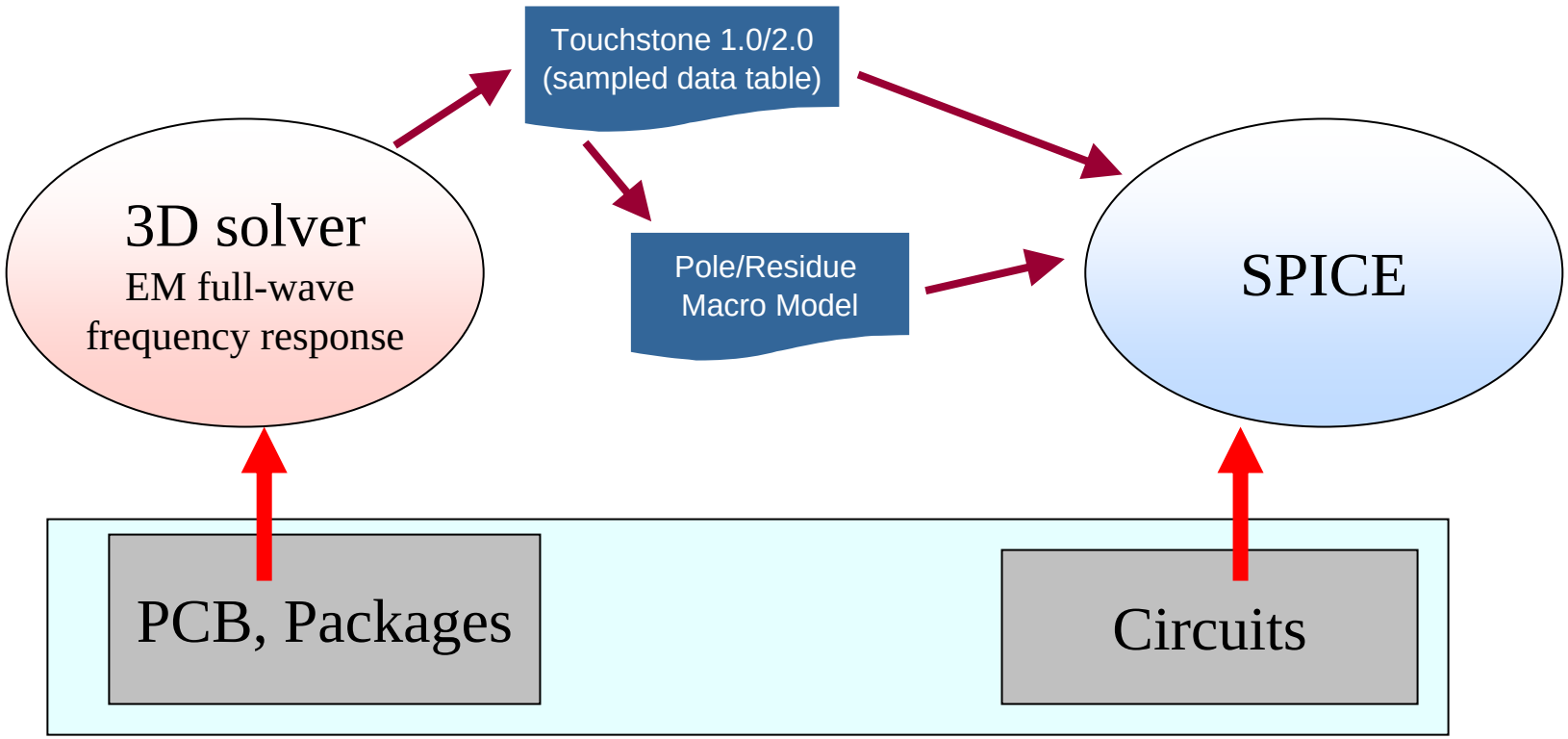
- For a large S matrix (model for many signal and/or power/ground nets), the Touchstone data file could be huge (few hundreds of MB)

- New format under IBIS task team investigation – Pole/Zero format
  - Extreme compact, only store poles and residues for the rational function approximation
  - Highly efficient simulation, using recursive convolution
  - S-parameter data are stored as vector fitted curve so it is an approximation

- Proprietary format – Sigrity BNP API for S-parameter
  - Very Compact and extremely accurate
  - Do not store tabulated data, provides raw data on demand

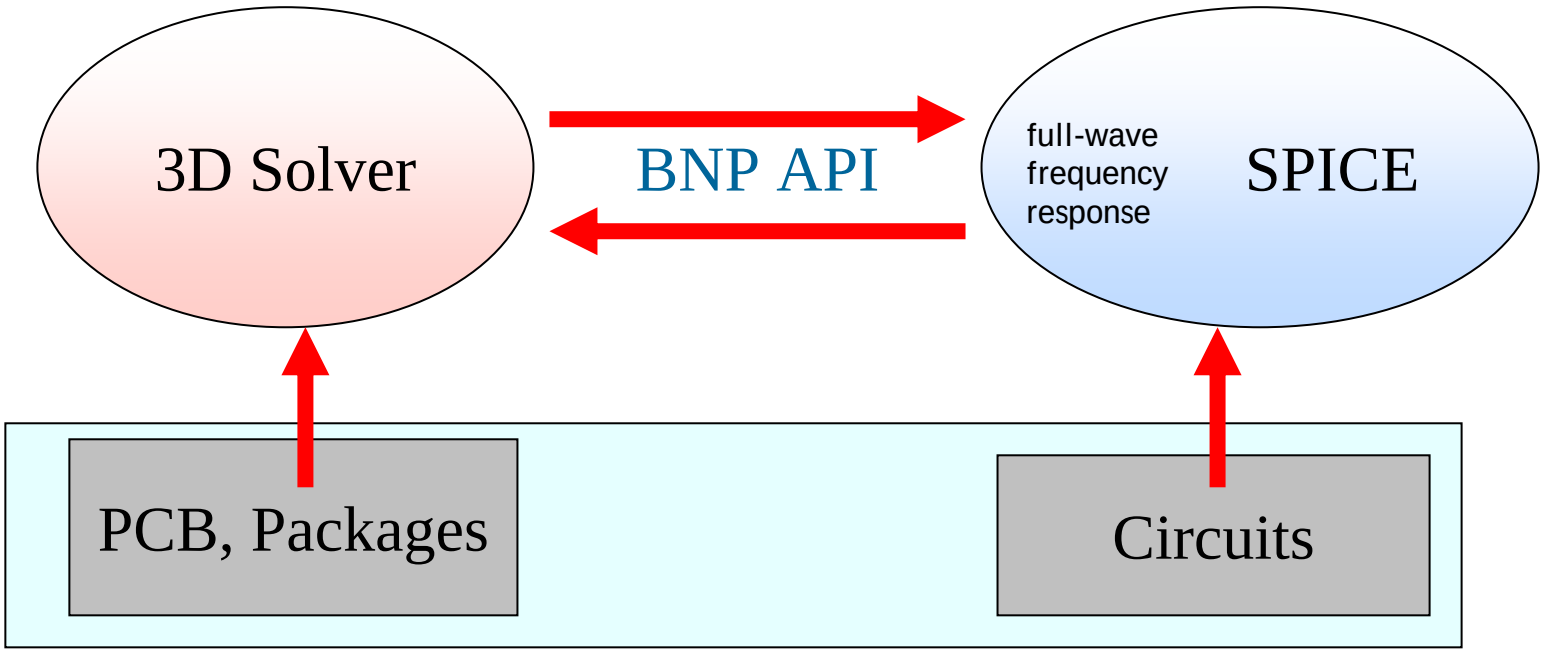
Current Simulation Flow

- Through TouchStone (TS) S-parameter file



Proprietary Flow for Enhanced Integration

- Frequency domain data exchange through API with broadband response
  - BNP data file does ***not*** store the frequency data points as does in a Touchstone file. It calculates any requested frequency point whenever the API is called within the simulation band. Therefore, the need to interpolate S-parameter tabulated data is completely eliminated. Since the API transports raw data, no pole/zero approximation needed.



S-Parameter Usage Example

Using S-Parameter in both TouchStone and BNP formats in HSPICE

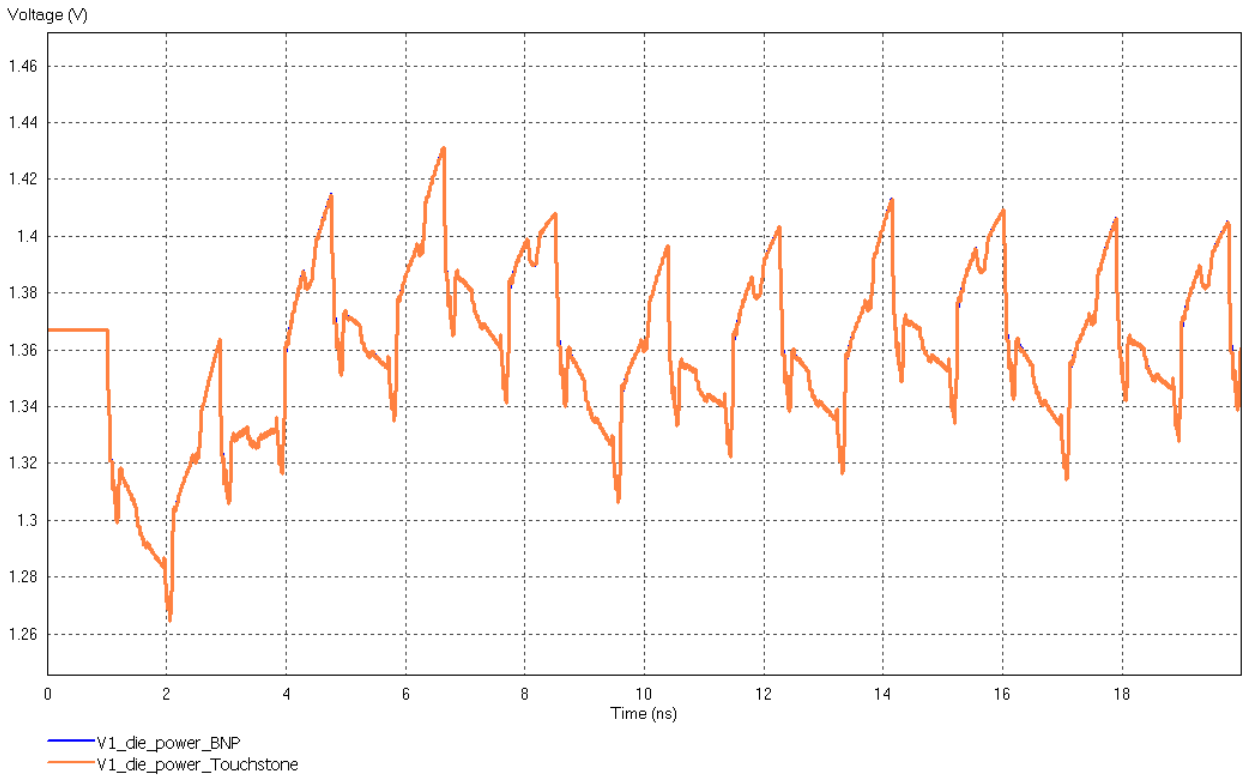
.model Smodel_name S TSTONEfile=file or BNPfile=file

TS file: xyz.snp BNP file: xyz.bnp

BNP file is much smaller than TS file, but yields higher simulation accuracy and convergence

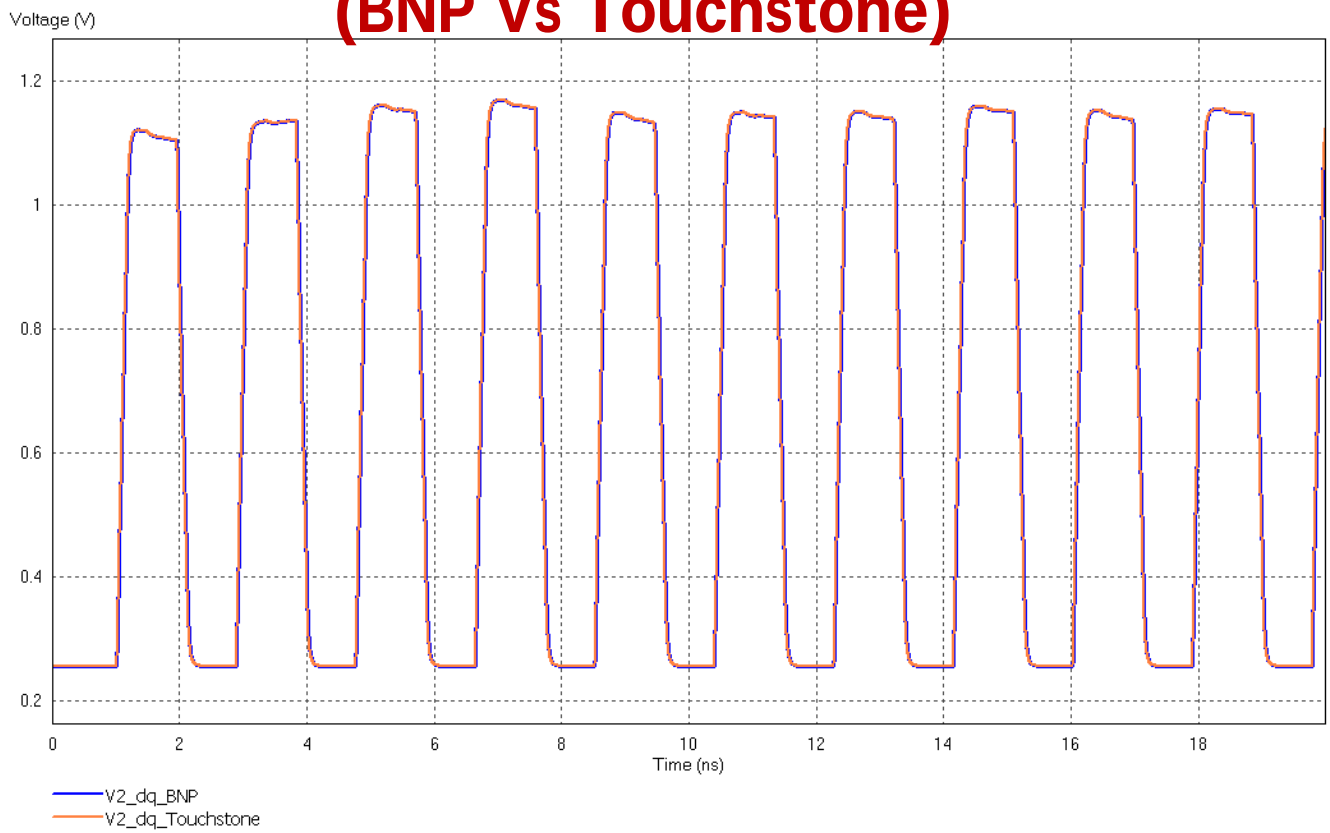
Test Case	Freq #	Touchstone File	Touchstone File Zipped	BNP File
psi_pkg_wb_pre-layout.spd (example folder)	646	1,388 KB	406 KB	24 KB
mixed_extraction.spd (advanced training)	886	10,211 KB	2,771 KB	62 KB
mixed_extraction.spd (all nets enabled)	886	311,105 KB	116,306 KB	1,920 KB

High-speed 1066Mbps Source Synchronous Simulation (BNP Vs Touchstone)



- VCC Power @ Die waveform with BNP Vs Touchstone model
- BNP model simulation has higher efficiency, better convergence and accuracy

High-speed 1066Mbps Source Synchronous Simulation (BNP Vs Touchstone)



- DQ @ Board waveform with BNP Vs Touchstone model
- BNP model simulation has higher efficiency, better convergence and accuracy

Summary

- Reviewed IBIS device model - AMI and its support
- Reviewed S-parameter as the interconnect model, introduced IBIS Touchstone 2.0 and Sigrity BNP
- Next review will be on how device models and interconnect models are connected for system level simulation automation.

Thank You!