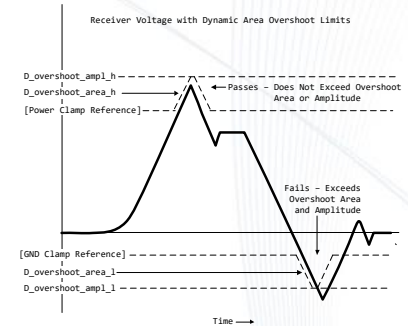# IBIS-AMI Post-Simulation Analysis

Mike LaBonte,

Todd Westerhoff

SiSoft

DesignCon IBIS Summit

February 2, 2018

Santa Clara, California

IBIS Simulation Post-Processing Support

- IBIS 1.0: Vinl/Vinh

- IBIS 2.0: vdiff, Vmeas/Rref/etc.

- IBIS 3.0: [Model Spec]

- IBIS 4.0: [Receiver Thresholds], [Test Load]/[Test Data]

- IBIS 4.1: Rref_diff/etc.

- IBIS 5.0: clock_times, Rx_Receiver_Sensitivity, AMI_parameters_out (non-standard)

- IBIS 6.0: Rx_Clock_Recovery_*, Rx_DCD

- IBIS 6.1: PAM4_*Threshold, PAM4_*EyeOffset

- IBIS Accuracy Handbook (correlation FOM)

Receiver Voltage with Dynamic Area Overshoot Limits

D_overshoot_ampl_h
D_overshoot_area_h
[Power Clamp Reference]

Passes – Does Not Exceed Overshoot Area or Amplitude

Fails – Exceeds Overshoot Area and Amplitude

[GND Clamp Reference]
D_overshoot_area_l
D_overshoot_ampl_l

Time

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Post-Processing Methods Not Specified By IBIS

- Timing
- Eye metrics (other than Rx_Receiver_Sensitivity)
- Seed for AMI jitter processing rand() function
- Clock recovery without clock_times (other than jitter)
- Bit Error Rate (BER) calculation
- Forward Error Correction (FEC) gain
- Any other special analyses prescribed for a particular model (IEEE, JEDEC, vendor, …)

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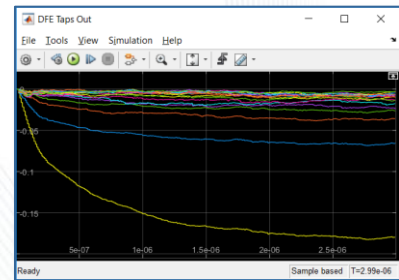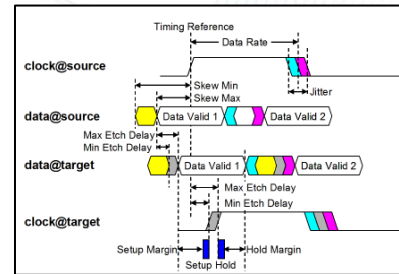
This Was Intentional

- Until IBIS-AMI, IBIS files conveyed only *data* from which tools could build an internal model

- With IBIS-AMI, the algorithmic behavior is delivered in the form of a functional model

1   STATEMENT OF INTENT

In order to enable an industry standard method to electronically transport IBIS modeling data between semiconductor vendors, electronic design automation (EDA) tool vendors, and end customers, this template is proposed. The intention of this template is to specify a consistent format that can be parsed by software, allowing EDA tool vendors to derive models compatible with their own products.

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Unspecified Post-Processing Methods

- PRO: Tools can innovate new analyses!
- CON: Tools can produce different results for the same analysis!
- CON: Tools might not implement some analyses prescribed for a particular type of buffer until IBIS support is explicit, or at least until the analysis is widely recognized

Interoperability and Portability

- **Interoperable**: Models from different vendors run in the same simulator
  - Theory: True, if models and simulator are IBIS-compliant
  - Reality: Mostly true, with some rough spots
- **Portable**: The same model runs in multiple simulators
  - Theory: True, if models and simulators are IBIS-compliant
 - Reality: They mostly *run*, **but users get some incorrect/differing results**

V1 model → EDA1

V2 model → EDA1

EDA1 ← V1 model → EDA2
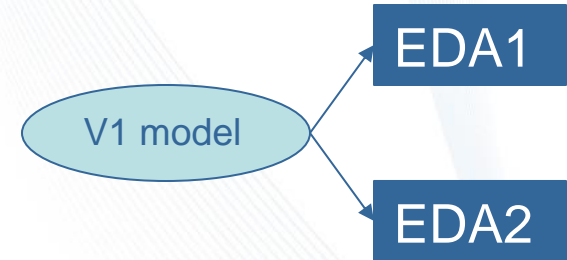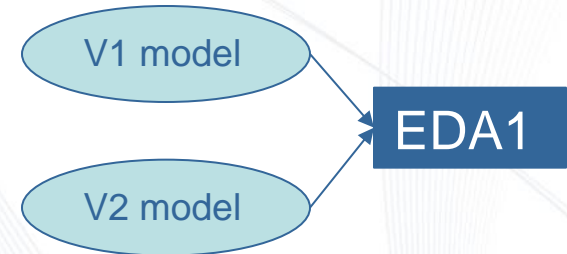
Users expect to see the same results in different tools

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Different Tool, Different Results

1. Simulation results of simulator A and simulator B differ ...
> Our simulation results and customers' simulation results did not correlate well

? ? ?
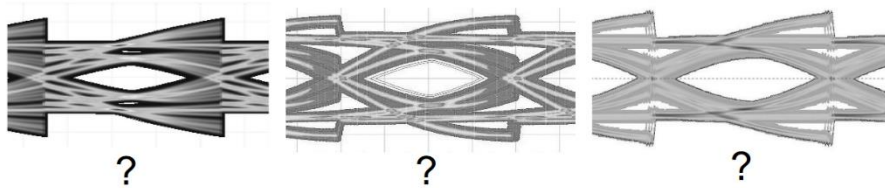
Which result should we believe ?

Page 7   © Copyright 2017 Xilinx   Ξ XILINX > ALL PROGRAMMABLE.

- Might be due to simulation differences
- Might be due to post-processing differences

- Either way it's a user expectation issue

What's Expected for IBIS-AMI from the Perspective of End-User Support,
Nakane, Masao, Tokyo IBIS Summit, Nov 2017

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Proposal 1: Specify Post-Processing Methods

- Examples:
  - Support specification of methods for eye height measurement
  - Support specification of seed for clock jitter modeling

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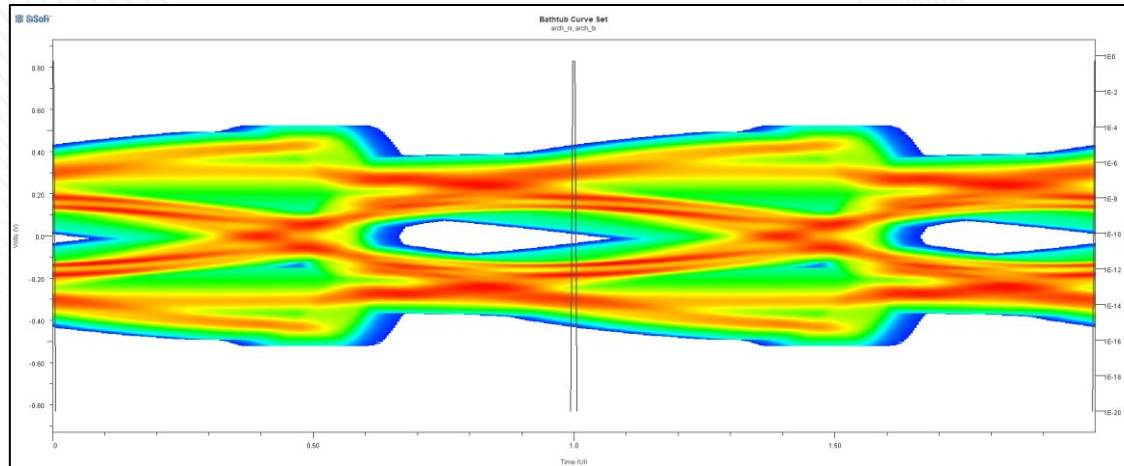# Example: Determining Eye Height

- Let's say an AMI Rx model returns these waveforms and clock ticks:
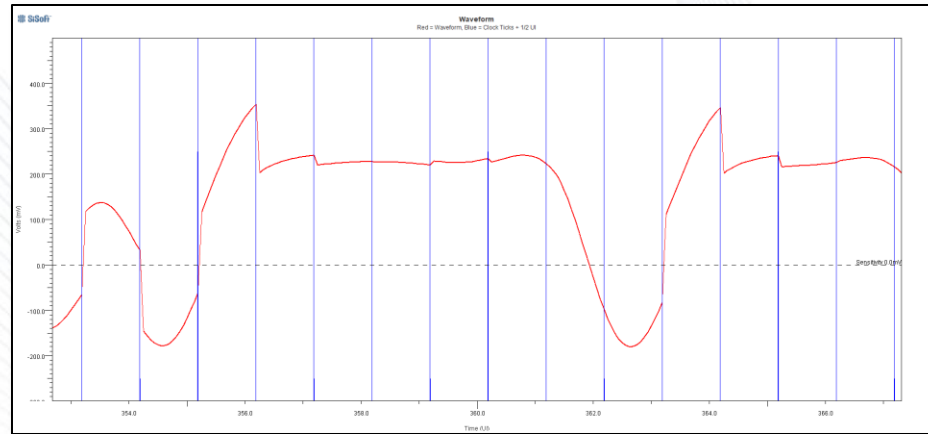
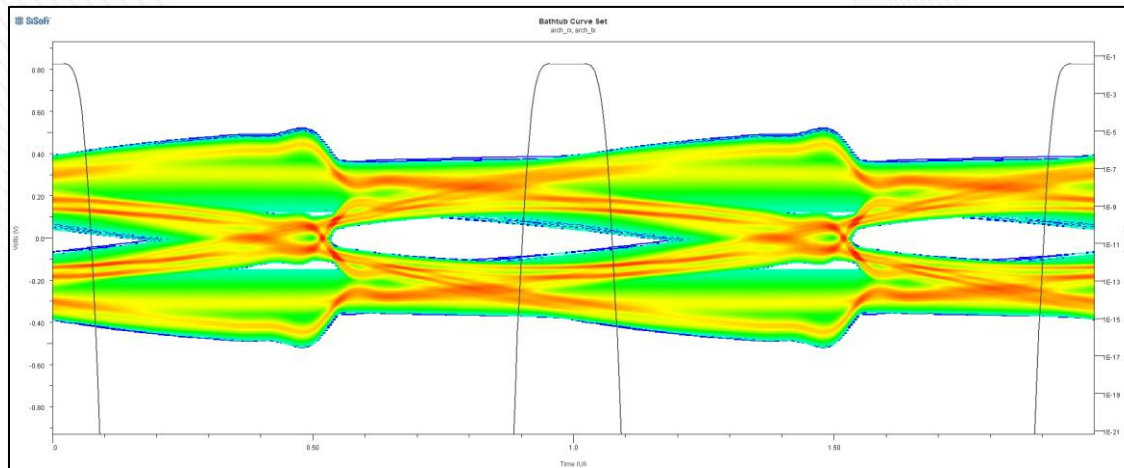- Q1: What should the eye diagram look like?

Accumulating The Eye Diagram

- Method 1: Clock ticks are used to accumulate the eye diagram on a trace by trace basis, similar to the way a triggered scope works:
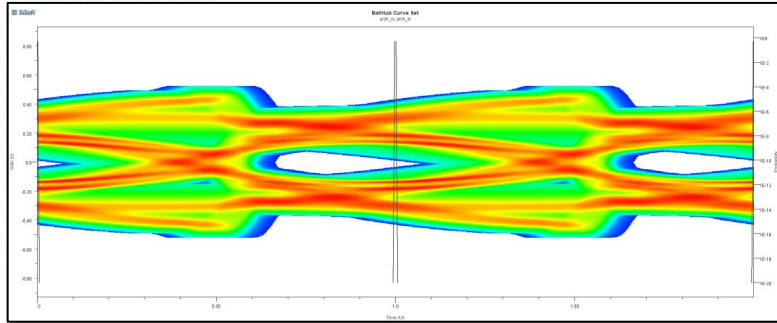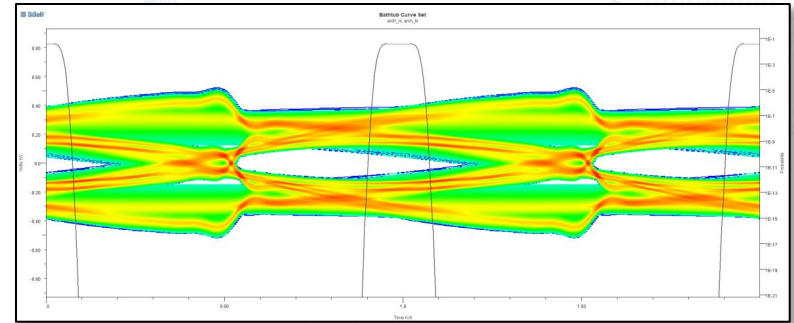
Accumulating The Eye Diagram

- Method 2: Both the waveform and clock ticks are accumulated with respect to an "ideal clock" operating at the channel data rate:
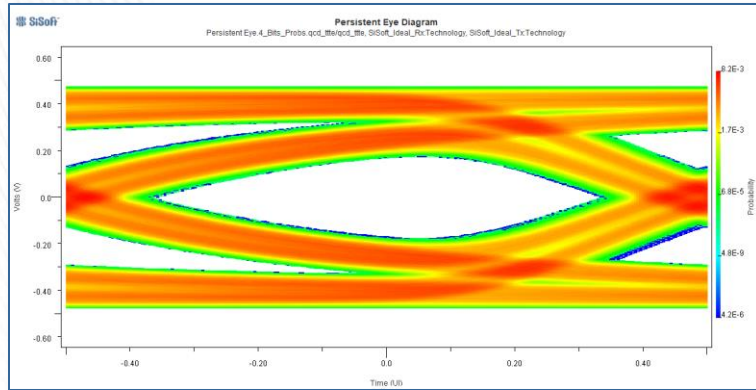
Accumulating The Eye Diagram

Triggered Scope

Ideal Clock
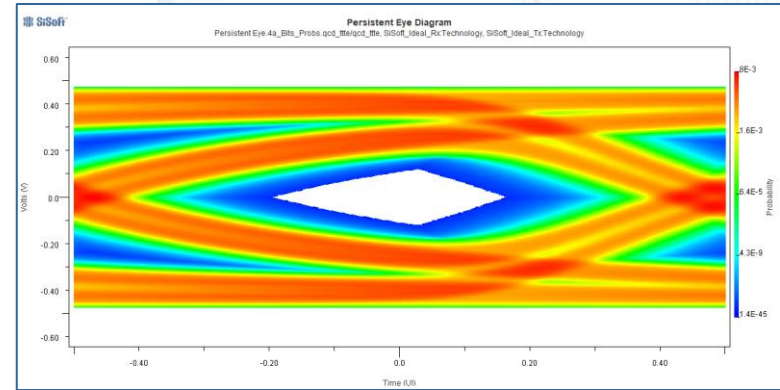
- Q2: Which method should be used to accumulate the eye diagram to be measured?

Accumulating The Eye Diagram

Time Domain Only

Extrapolated

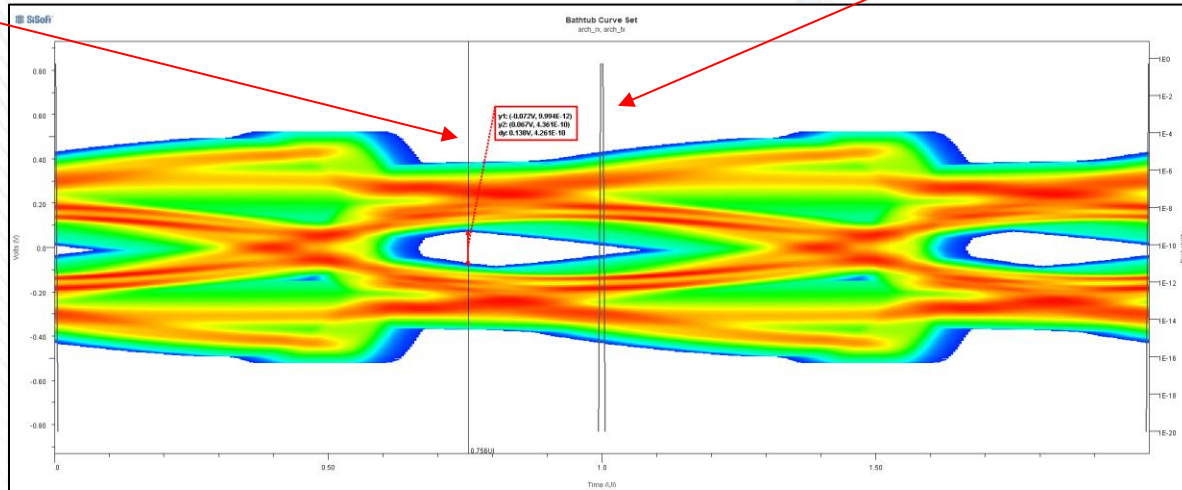- Q3: What method(s) should be used to extrapolate the time domain eye to get a statistically significant eye?

Measuring Eye Height

Best eye height

Sampling time indicated by model's clock ticks

- Q4: Where should eye height be reported?

Measuring Eye Height
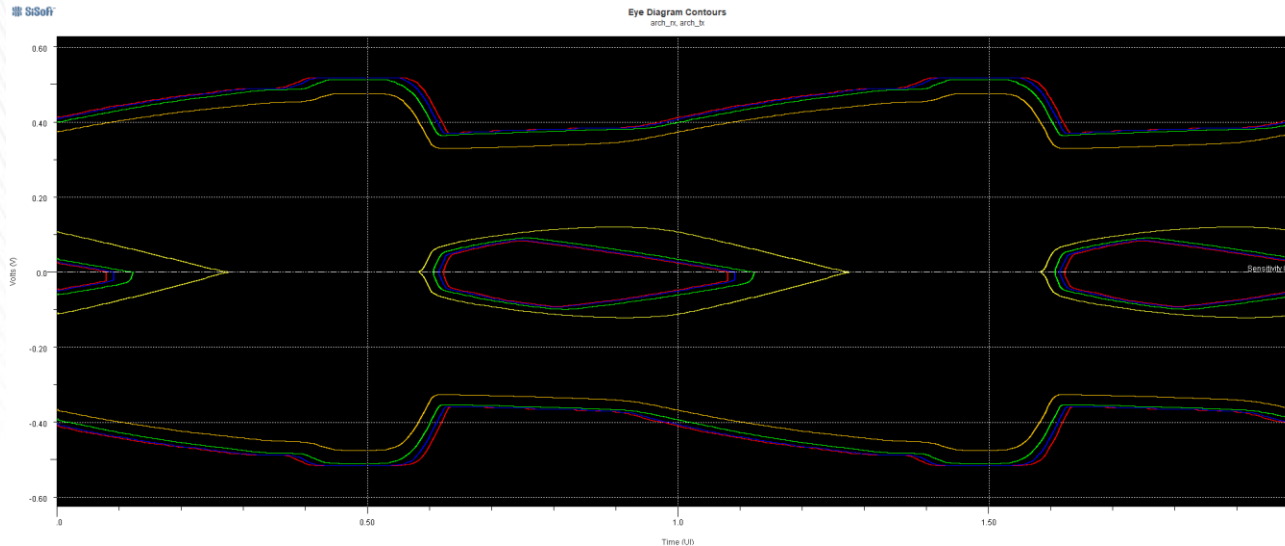
Red   = 1e-12
Blue   = 1e-9
Green   = 1e-6
Yellow   = 1e-3

- Q5: At what probability level should eye height be measured?

Determining Eye Height

- Should users expect eye height measurements across EDA tools to be consistent?

- Should IBIS do more to ensure reporting consistency across EDA tools?

Same Rx Jitter, Different Start Points

$$actual\_time = time + 2.0 * Rx\_Dj * rand()$$ ⟵ Seed value?

Rx_Dj = 0.2UI, red = srand(1) clock, blue = srand(2) clock

seed = 1
seed = 2

17

But We Also Have Requests for More FEC Support in IBIS-AMI
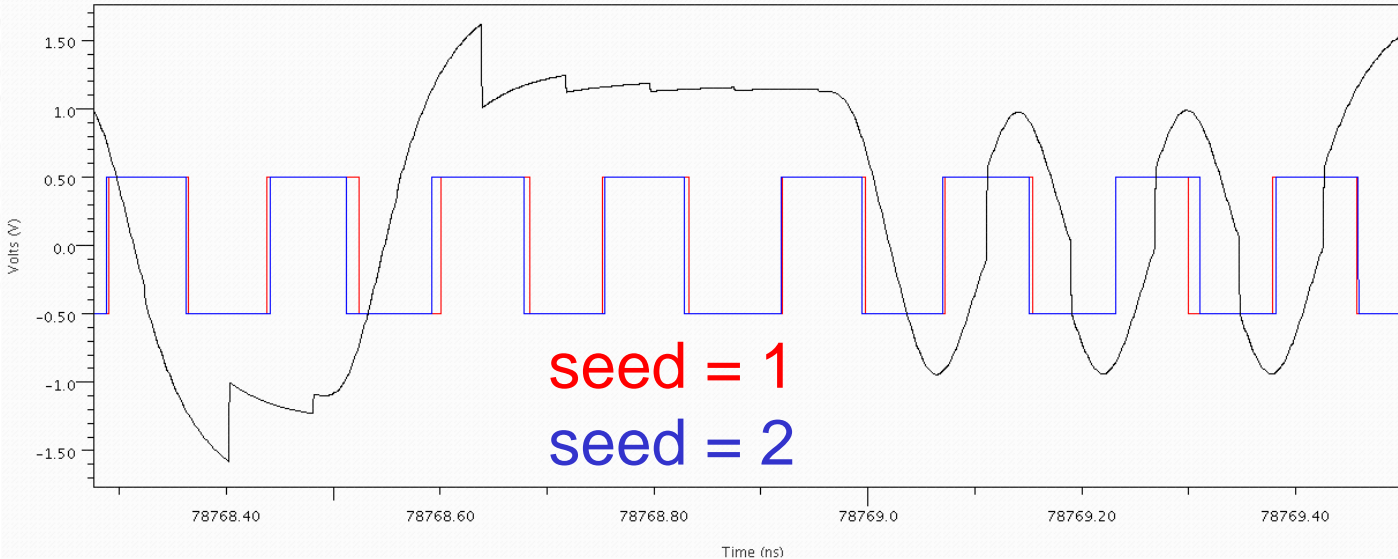
Necessity for Integrating FEC Functionality for PAM4 in AMI Simulations	Xiaoqing Dong* and Nick Huang**	Huawei Technologies* and Shenzhen Zhongzeling Electronics**	Feb 3, 2017 DesignCon IBIS summit
Necessity for Integrating FEC Functionality for PAM4 in AMI Simulations	Xiaoqing Dong and Nick Huang	Huawei Technologies	Nov 11, 2016 Shanghai IBIS summit
FEC Applications for 25Gb/s Serial Link Systems	Tao Guo and Shunlin Zhu	ZTE Corporation	Nov 09, 2015 Shanghai IBIS summit
Introduction of FEC IL Gain Estimation Method In High Speed Link	Xiaoqing Dong and Chunxing Huang	Huawei Technologies	Nov 15, 2011 Shanghai IBIS summit

IBIS supports FEC only through PAM4_Mapping

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Most FEC Requests Are For Deterministic FEC Gain Calculation Support

- The requests are for FEC gain *post-processing*, ***not simulation***

- FEC gain can be estimated, given:
  - RX eye probability bathtub curve
  - DFE coefficients
  - Possibly other model-specific parameters

- FEC gain calculation algorithms exist today, but are not made public

"Current EDA tools can process time domain and statistical analysis very well, but the lack of DFE coefficients outputting function and lack of voltage bathtub sometimes makes FEC analysis inconvenient."

"FEC gain analysis method is recommended to be supported by EDA tools (IBIS Specification), including error propagation analysis function."

-- Xiaoqing Dong, Chunxing Huang

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FEC Has a Data Separation Problem

- FEC gain calculation requires:
  - AMI parameter values including DFE coefficients
  - Probability curve from simulation
  - FEC gain algorithm

Simulator Has (or could have)

- Bathtub probability curve
- All coefficients and settings

Rx Has (or could have)

- All coefficients and settings
- FEC gain algorithm

Simulator Lacks

- FEC gain algorithm

Rx Lacks

- Bathtub probability curve

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Proposal 2: Help Models Report Post-Processing Results

- Some models want to convey additional analysis results to users:
  - Adaptation or training results
  - FEC gain calculation
  - Future IEEE, JESD requirements, etc.
- Tools can implement these, but there is less incentive to implement analyses that are specific to one or a few models
- In some cases tools only need to understand file and AMI_parameters_out model outputs

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Rx Models Could Calculate FEC Gain

- Pass simulation outputs to a new AMI_Report() function
- Must be called after last AMI_GetWave(), before AMI_Close()
- Tools need only show HTML report, not necessarily understand it
- Could support any specialized calculation, not just FEC

Simulator

- AMI_memory_handle
- Time domain waveforms
- Statistical probabilities

- Show report data

Rx AMI_Report()

- All final coefficients and settings
- FEC gain algorithm
- Produce HTML report, or
- Return CSV table
- Use DLL_ID
- Has AMI_parameters_out

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AMI_parameters_out HTML Display
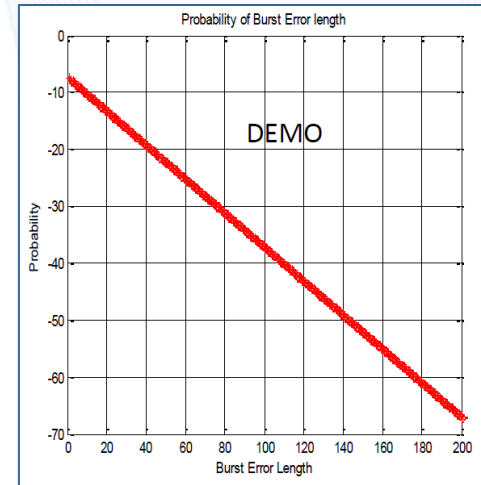
(FEC_Gain   (Usage Out) (Type String)
               (Format Value "") | Not used for Out
               (ParamOutType HTML_File))

(Model(FEC_Gain "sim1_RX1_FECGain.HTML"))

From new AMI_Report function

Probability of Burst Error length

DEMO

* http://ibis.org/summits/feb17/dong.pdf

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AMI_parameters_out Data Display

(CDR_Phase (Usage Out) (Type Float)
          (Format Value 0.0) | Not used for Out
          (ParamOutType CSV_XYLine)
          (ParamOutUnits "seconds,UI"))

(Model(CDR_Phase "0,0.03125"))

(Model(CDR_Phase "3.10E-09,0.03125"))

(Model(CDR_Phase "6.20E-09,0.03125"))

(Model(CDR_Phase "9.30E-09,9.18E-05"))
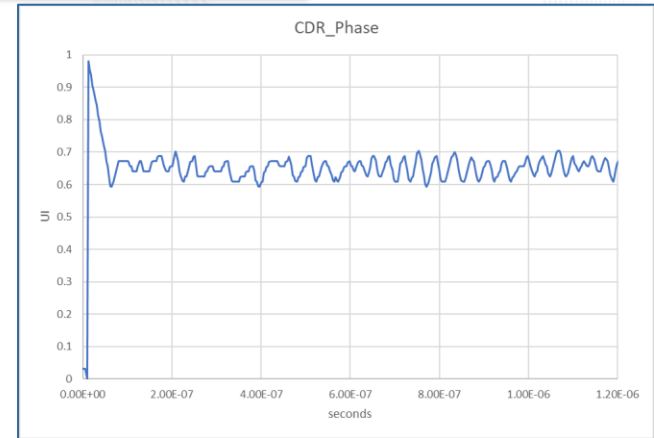
Using AMI_GetWave, no new function required

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Summary

- IBIS specifies relatively little about post-processing
  - Some portability issues are actually due to differences in post-processing implementation
  - We could better meet users' expectations of portability by specifying additional post-processing details
- New post-processing analyses such as FEC gain are desired but not yet fully supported by IBIS
  - A new AMI_Report() function could calculate FEC gain and other new analysis products
  - AMI_parameters_out could be made more useful for displaying analysis data

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