Free On-Line SerDes System Channel Simulation April 8, 2022

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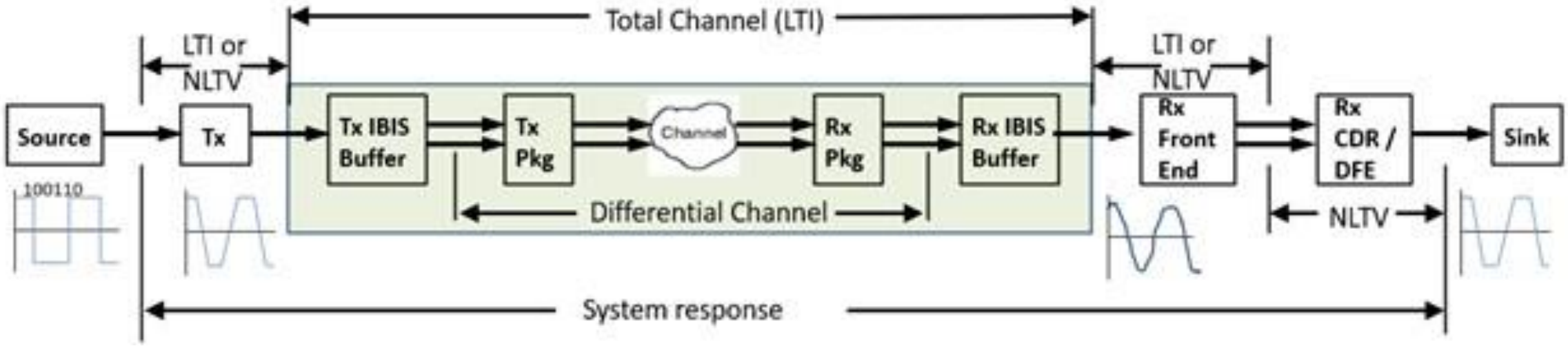
Introduction

- High Speed Digital (HSD) transmit (Tx) and receive (Rx) circuits must be converted by signal integrity (SI) engineers to IBIS-AMI models per the IBIS specification to be used in SerDes Channel simulators to evaluate their system margins.
- Most commercial IBIS-AMI simulators are expensive.
- SerDes channel simulation technology and the SerDes Tx/Rx modeling process has matured so that both are available for free using cloud-based tools at SerDesDesign.com.

Modeling SerDes Systems

- SerDes systems are represented in channel simulators with SerDes channels and IBIS-AMI models per the IBIS Open Forum specification (currently at revision 7.1).



Modeling SerDes Systems

- TX IBIS-AMI:
  - Typically contains an equalizer - often in the form of a feed-forward equalizer (FFE) with differential IBIS buffer output to the channel.
  - The IBIS buffer can be a simple circuit representation or a 4-port S-parameter file.
- Tx package (Tx Pkg), Channel, Rx package (Rx Pkg):
  - These pieces represent the differential channel.
  - Each part is optional and may be represented using S-parameter files.
- RX IBIS-AMI:
  - Typically contains a continuous time linear equalizer (CTLE), a clock and data recovery unit (CDR) and decision feedback equalizer (DFE) with differential IBIS buffer input from the channel.

The Free Channel Simulator

- The popular commercial channel simulators (CS) in the market provide SerDes signal integrity (SI) engineers a valuable tool for evaluating their SerDes system designs to understand how their systems perform under different conditions
- Sometimes, an SI engineer might not have access to their company CS tool due to unavailable licenses or the need to time-share access to their tool with others in their company.
- When the SI engineer needs to evaluate their Tx/Rx IBIS-AMI models under various test conditions with a given total channel, then there is a free option available.
- The SI engineer can use the cloud-based SerDes system channel simulator available at: https://www.serdesdesign.com/home/serdes-system-tool/
- Free user registration on the web site is required to use the tools.

Supported Characteristics

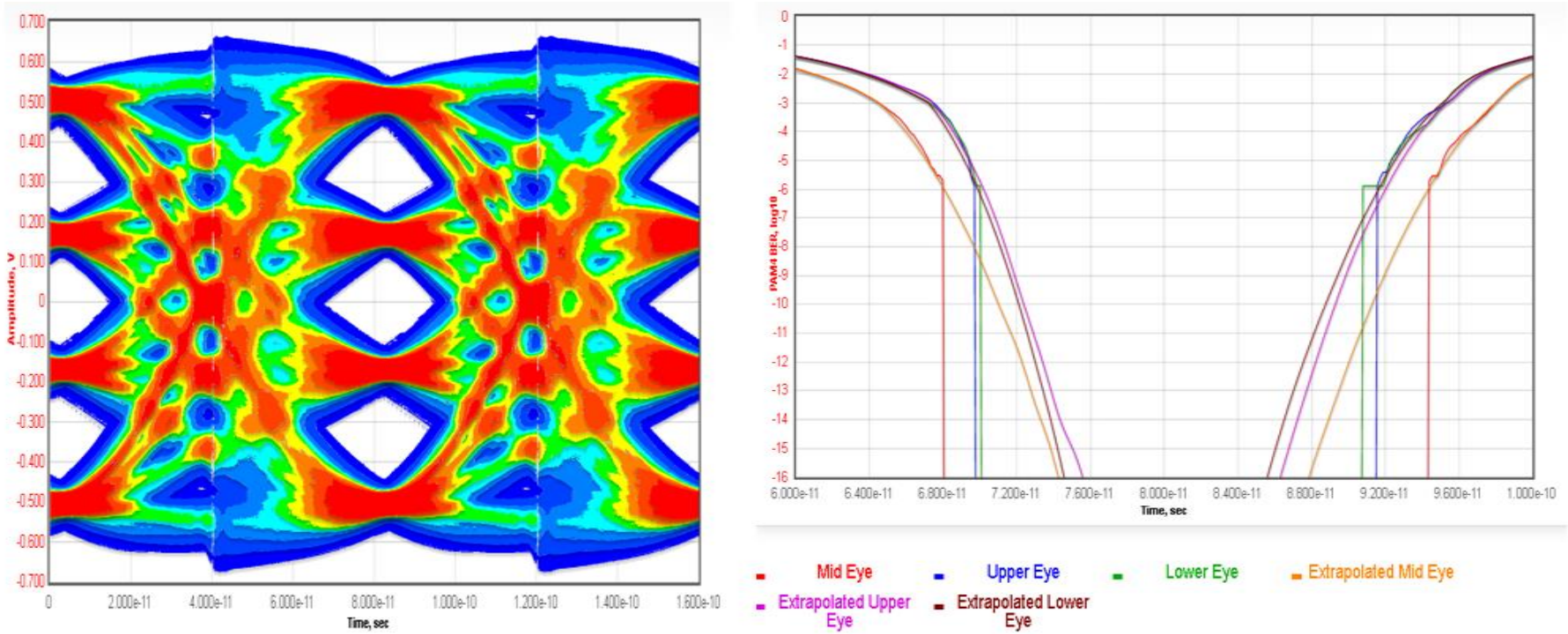
- Single channel, repeater systems, Electrical-Optical-Electrical repeater systems
- NRZ and PAM-4 signaling.
- Tx/Rx parameterized behavioral models for FFEs, CTLEs, CDRs, DFEs.
- Generation of IBIS-AMI models from Tx/Rx behavioral models.
- Tx/Rx LTI and NLTV IBIS-AMI models (IBIS 7.0 or earlier).
- Tx/Rx jitter (based on IBIS 7.0 or earlier).
- Corner cases: IBIS (typical, min, max); AMI (typical, slow, fast)
- Use of S-parameters: Tx IBIS buffer, Tx Pkg, Channel, Rx Pkg, Rx IBIS buffer.
- Channel simulation Statistical mode and Bit-by-bit mode (up to 100e9 symbols).
- Channel simulation speed enhancement using multiple parallel processors.
- Channel simulation plots: eye density, BER (timing/amplitude bathtub BER), BER extrapolation, BER contours, various eye metrics.
- Dedicated user remote-server; includes FTP access.

Example PAM-4 SerDes System

- Example based on built-in behavioral Tx/Rx models; using PAM4 signaling at 12.5 GBaud.
- The Tx behavioral model is an FFE with taps that can be automatically set for optimal eye opening during the model initialization with optional jitter.
- The Rx behavioral model contains a continuous time linear equalizer (CTLE), a clock and data recovery circuit (CDR) and a decision feedback equalizer (DFE).
  - The CTLE has 64 states defined with circuit time domain waveform data for each state.
  - The CDR is defined with its Observed Jitter Transfer Function (OJTF) corner frequency.
  - The DFE is defined with taps that can be automatically and continuously adapted to achieve optimal output eye opening.
- The total channel includes the Tx IBIS, Tx Pkg, Channel, Rx Pkg, and Rx IBIS.
  - The channel in the middle has 16 dB loss at Nyquist (6.25 GHz).

PAM-4 Results

- 1,000,000 symbols were used in this example.

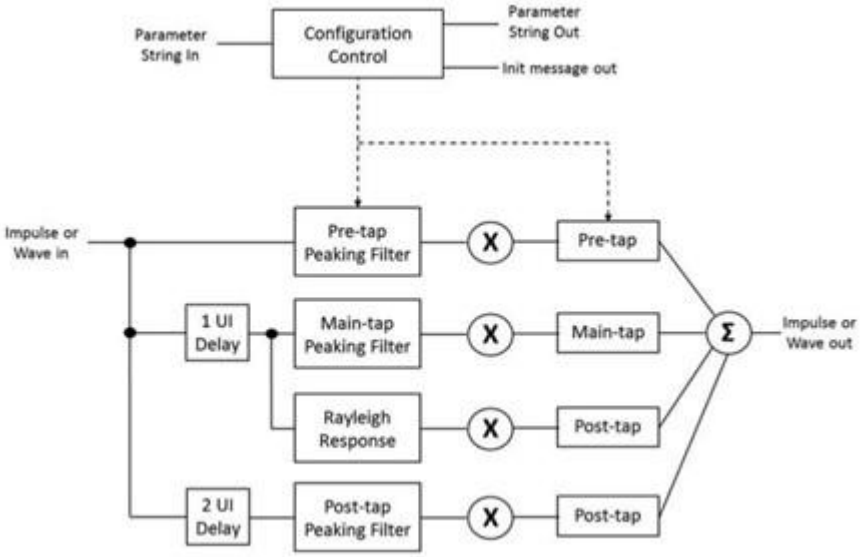


- This example is documented at Example_PAM4_SerDes.

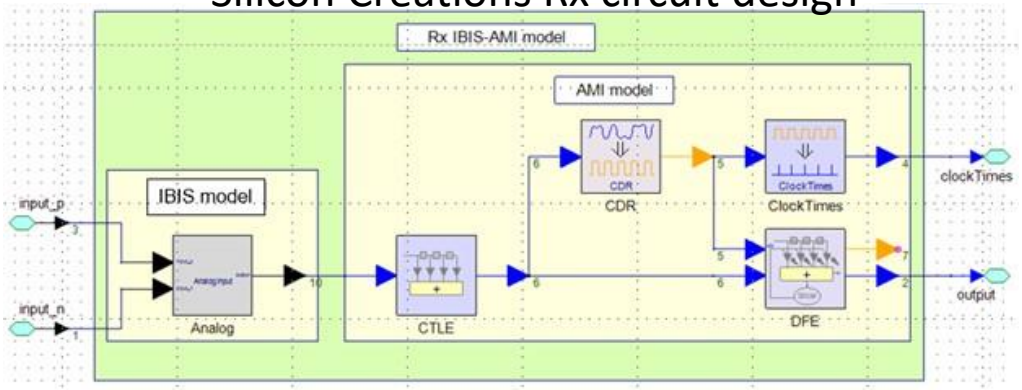
NRZ Example using IBIS-AMI Models

- Example based on IBIS-AMI models.
  - Tx IBIS-AMI model developed for NXP Semiconductor Inc with three corner cases.
  - Rx IBIS-AMI model developed for Silicon Creations LLC with three corner cases.
  - Usable with NRZ rates from 1 Gbps to 28 Gbps; the example is at 25 Gbps.

NXP Tx circuit design

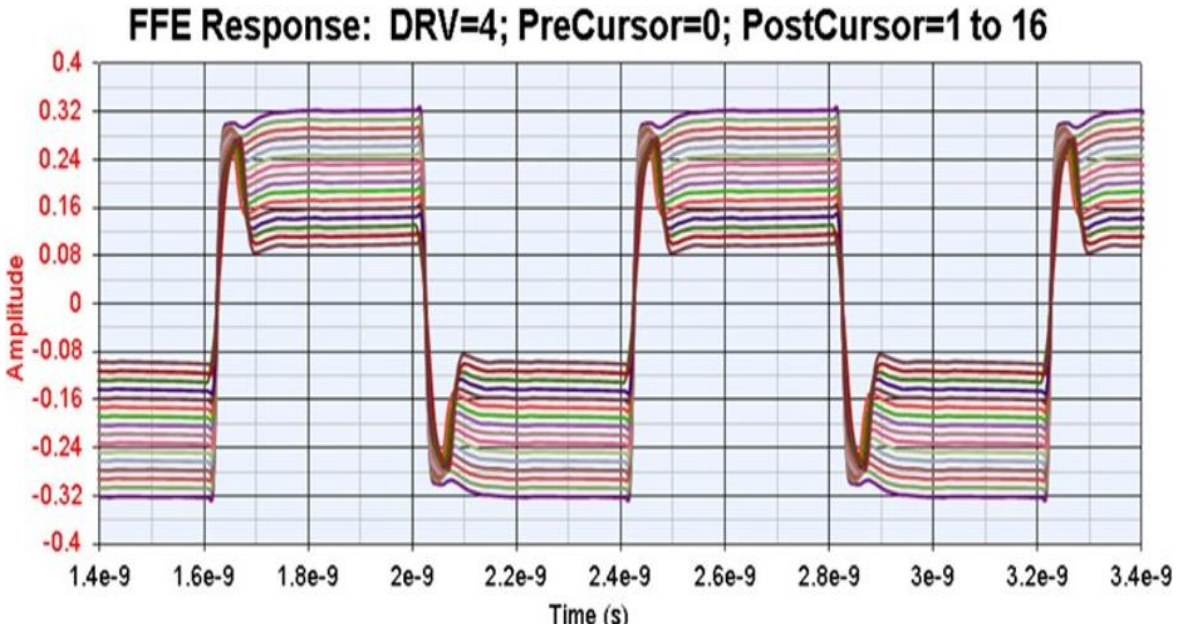


Silicon Creations Rx circuit design



Tx IBIS-AMI Model

- The Tx circuit was treated as a black-box.
  - Tx circuit output sdd11 (S2P) data used to derive the IBIS model.
  - Output waveforms were collected for various FFE state conditions.
  - 14 swing states; 25 pre-cursor states; 33 post-cursor states; 5 bit-rate ranges; 3 corner cases.
  - For any given bit rate and samples per bit, the model builds the FFE model from the waveform data: tap gains and tap filters.



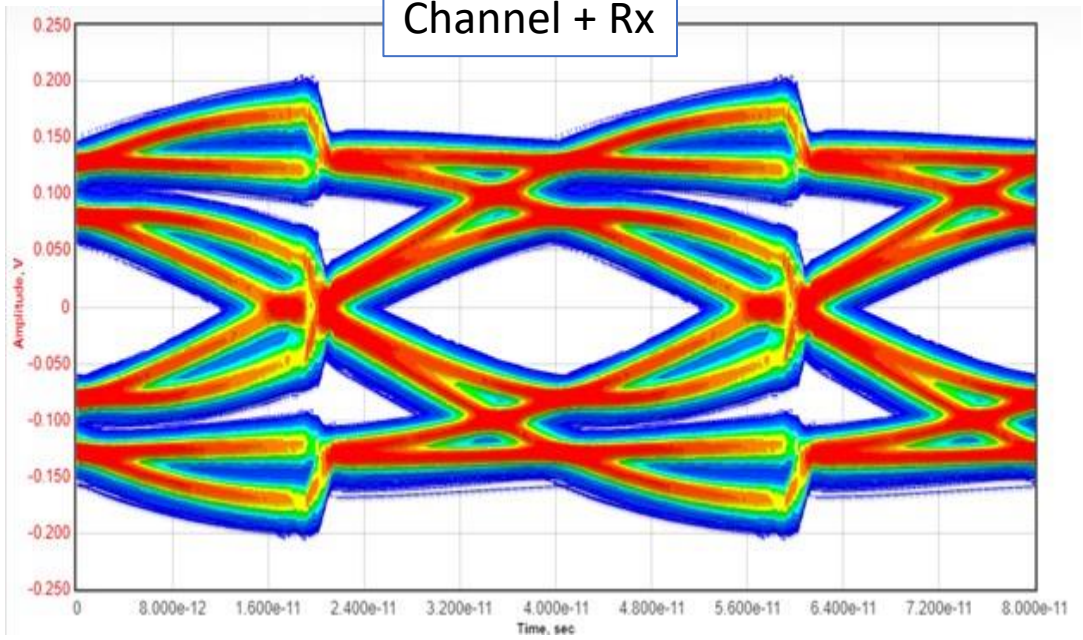
Rx IBIS-AMI Model

- The Rx CTLE circuit was treated as a black-box.
  - Rx circuit input sdd11 (S2P) data used to derive the IBIS model.
  - CTLE output waveforms were collected at all CTLE states for 3 corner cases.
- The CDR is defined with its Observed Jitter Transfer Function (OJTF) corner frequency.
- The DFE is defined with taps that can be automatically and continuously adapted to achieve optimal output eye opening.
- The total channel includes the Tx IBIS, Tx Pkg, Channel, Rx Pkg, and Rx IBIS.
  - The channel in the middle has 25 dB loss at Nyquist (12.5 GHz).

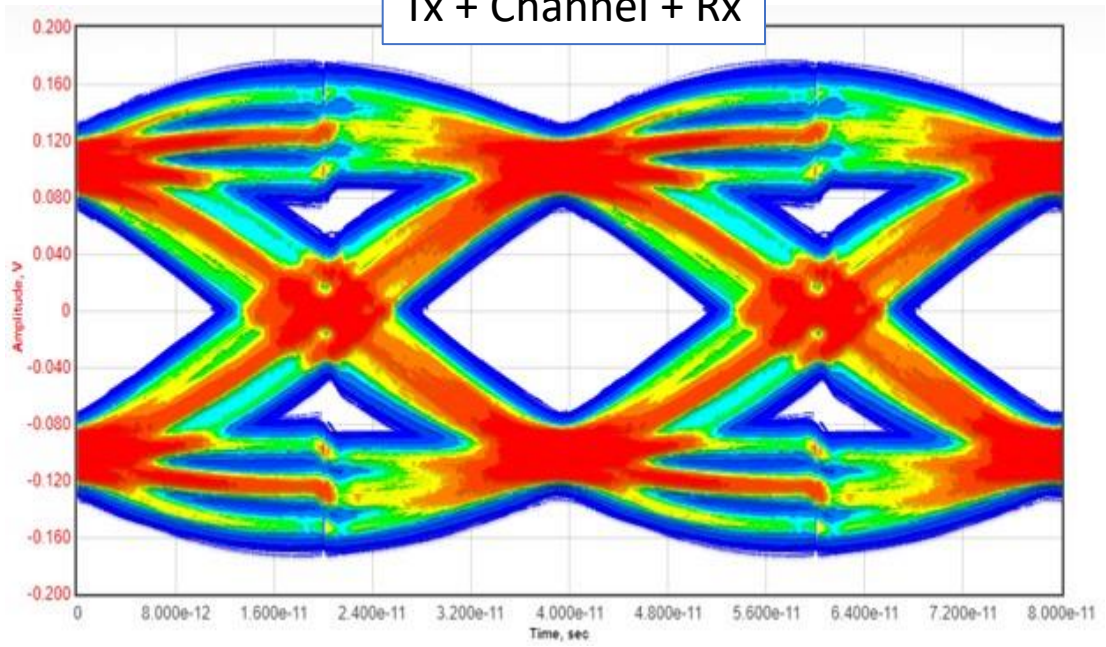
NRZ Results

- 100,000 symbols were used in this example.

Channel + Rx



Tx + Channel + Rx



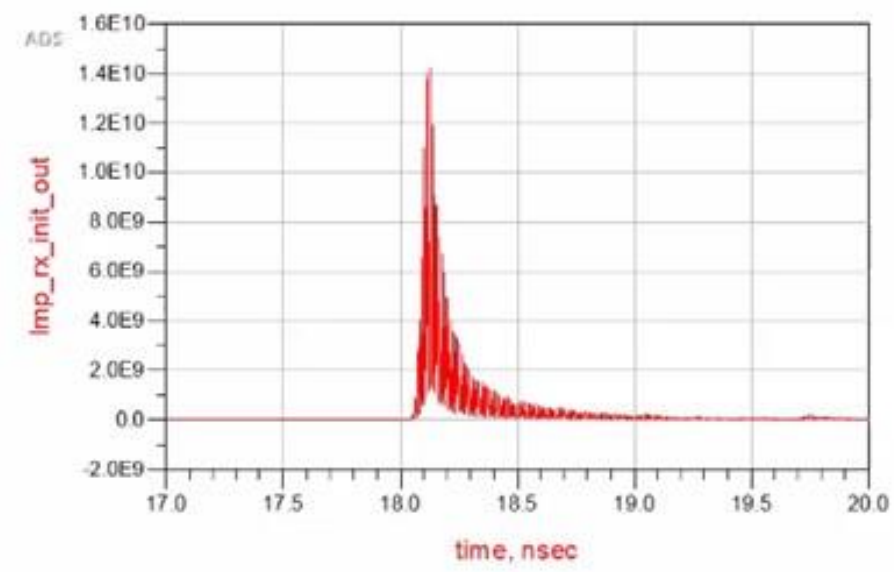
- This example is documented at Example_NRZ_IBIS_AMI_SerDes.

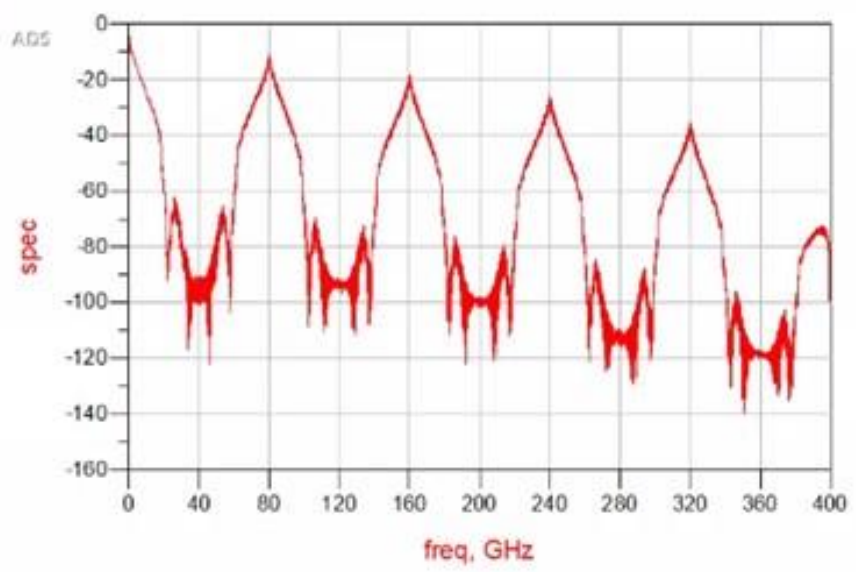
Using Another Channel Characterization

- The SI Engineer may have their SerDes system setup with Tx/RX IBIS-AMI models in another Channel Simulation (CS) tool, but all licenses are in use.
- One key problem in using a different CS tool is that each CS tool provides a different channel impulse response.
- The SI Engineer can export their CS tool channel impulse response and use in the SerDesDesign.com channel simulator.
- The Tx/Rx AMI models are fully deterministic. Thus, when using the same channel impulse, the SerDes system channel simulation results will be the same as in their original CS tool.

The Channel Impulse Response

- Consider that the SerDes system was setup in a commercial EDA Channel Simulator.
- Ideally, the total channel impulse response has no distortions.
- Unfortunately, for this NRZ example, the channel impulse response has a lot of high-frequency aliasing as shown here.

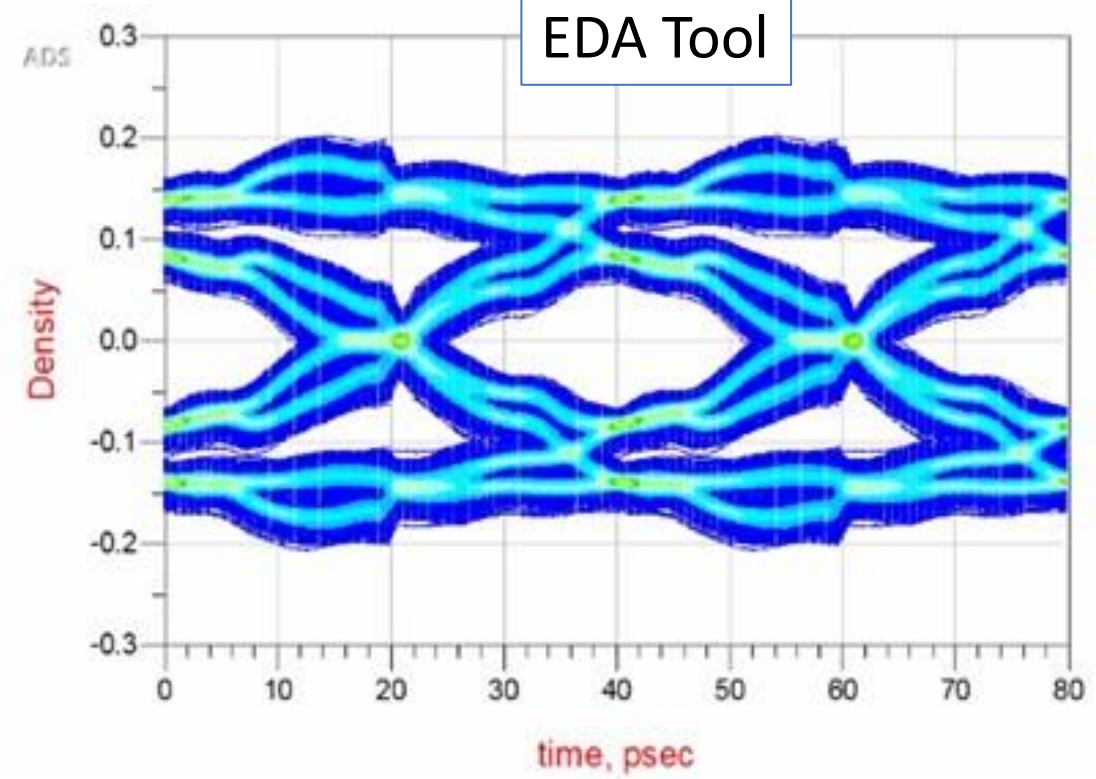




The Eye Density Plot

- The Channel+Rx eye density plot with channel impulse response in both CS tools.

EDA Tool



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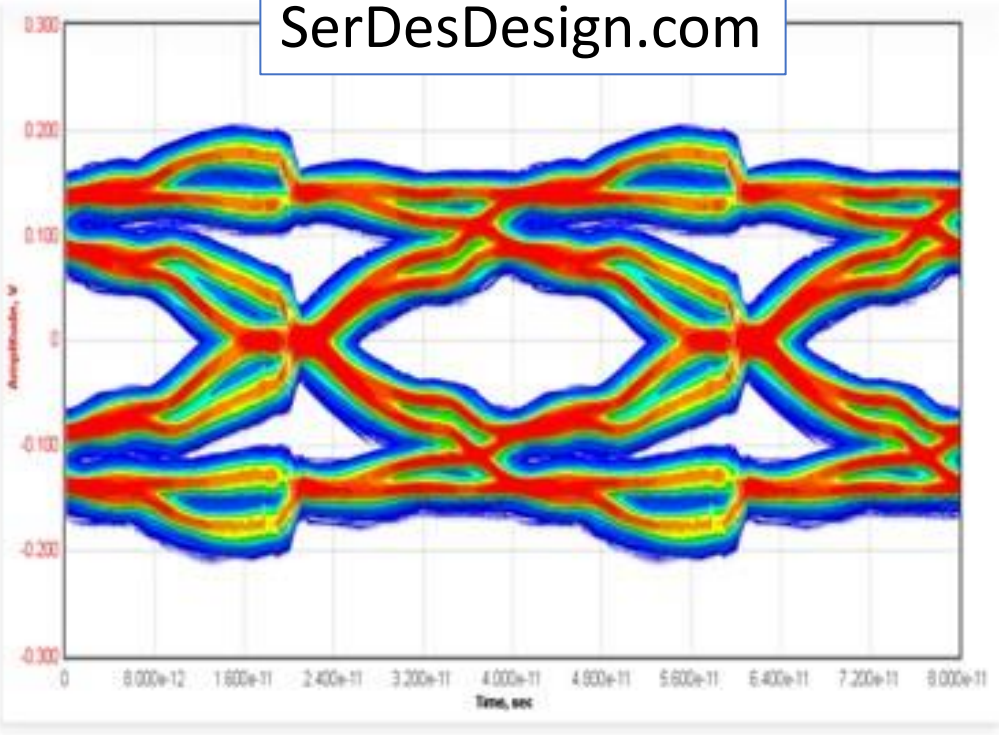

Correcting for High Frequency Aliasing

- IBIS-AMI models created by SerDesDesign.com have optional anti-aliasing built-in.
- Additionally, within SerDesDesign.com, anti-aliasing can be applied to the imported impulse response.
- Within the EDA tool, when the Rx IBIS-AMI model anti-aliasing is turned on, the results are the same as shown earlier for the SerDesDesign.com eye density.

Conclusions

- SerDesDesign.com offers a free path for modeling and simulating SerDes systems.
- This can be useful when the SI engineer internal CS tool is not available due to unavailable licenses or the need to time-share access to their CS tool with others in their company.
- When their CS tool channel impulse response is used along with their Tx/Rx IBIS-AMI models, the SerDesDesign.com CS tool will give the same results as their internal CS tool.
- https://serdesdesign.com

SerDes Design.Com

Acknowledgment

- Acknowledgment is given to Jon Burnett and NXP for permission to reference the IBIS-AMI models created for them and use of their commercial EDA channel simulator copy.
- Acknowledgment is given to Blake Gray and Silicon Creations for permission to reference the IBIS-AMI models created for them and use of their commercial EDA channel simulator copy.