# Analysis of 30dB Channel Using IBIS-AMI Models

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# Overview

- The 30dB Channel
- Tx and Rx IBIS-AMI Buffer Models
- Statistical Flow Results
- Time Domain Flow Results
- Bathtub Floor vs UI Using Statistical Flow
- Summary

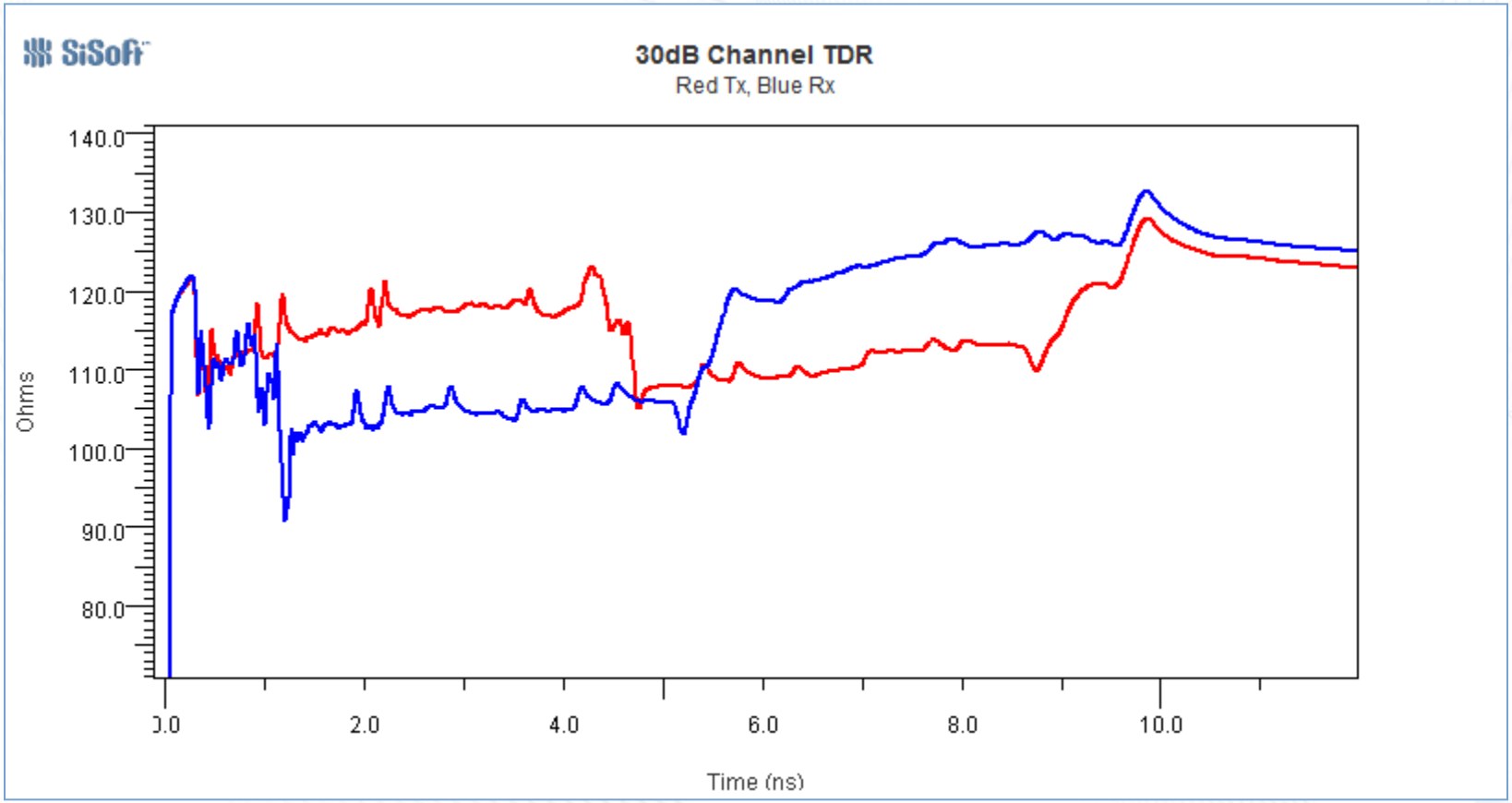
# Simulation Results for 30dB Channel

- Based on 30dB Channel in healey_01_0911.xls
- Crosstalk is not included
- Uses IBIS-AMI Models
- Work done on a commercial simulation tool
- Bit Time 38.788ps
- Data Rate 25.781 Gbps
- Nyquist Frequency 12.890 GHz

# 30dB Channel Characterization Slides

- Channel Models
  - Channel
    - 30db_Loss_Channel/THRU.s4p
  - Package
    - Pkg35mm_T21mm115ohmLoXtalk_BGALoXtalk.s8p
- TDR (Differential)
  - Applied 4th Order Bessel Thompson Filter at maximum frequency in Touchstone files to TDR.
  - Channel With Package
  - Channel Without Package
    - Recommendation: s4p should contain data to 30GHz
  - Package
    - Observation: Package model appears to be pessimistic
- Insertion Loss
- Return Loss

# 30dB Channel TDR With Package



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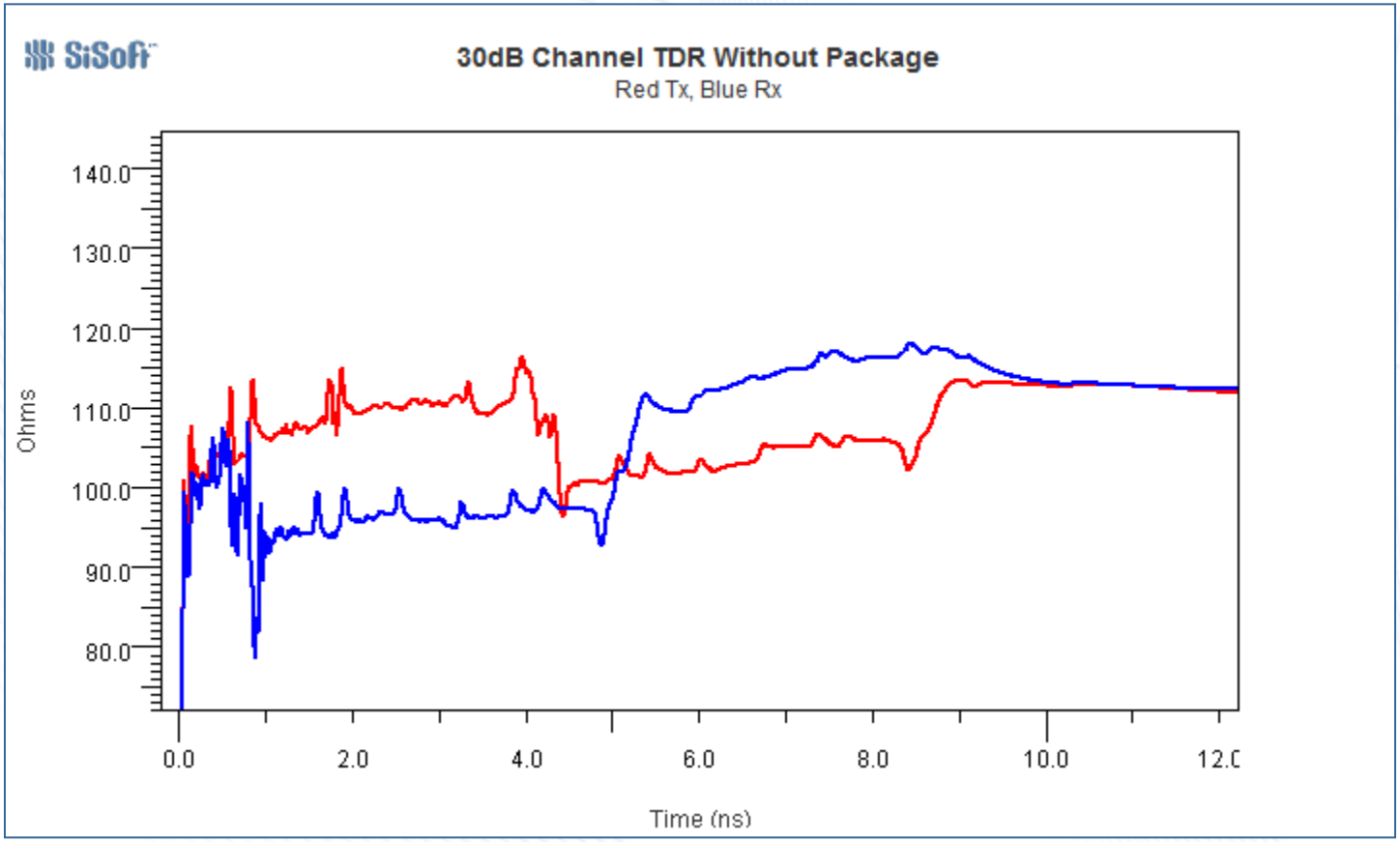
# 30dB Channel TDR Without Package



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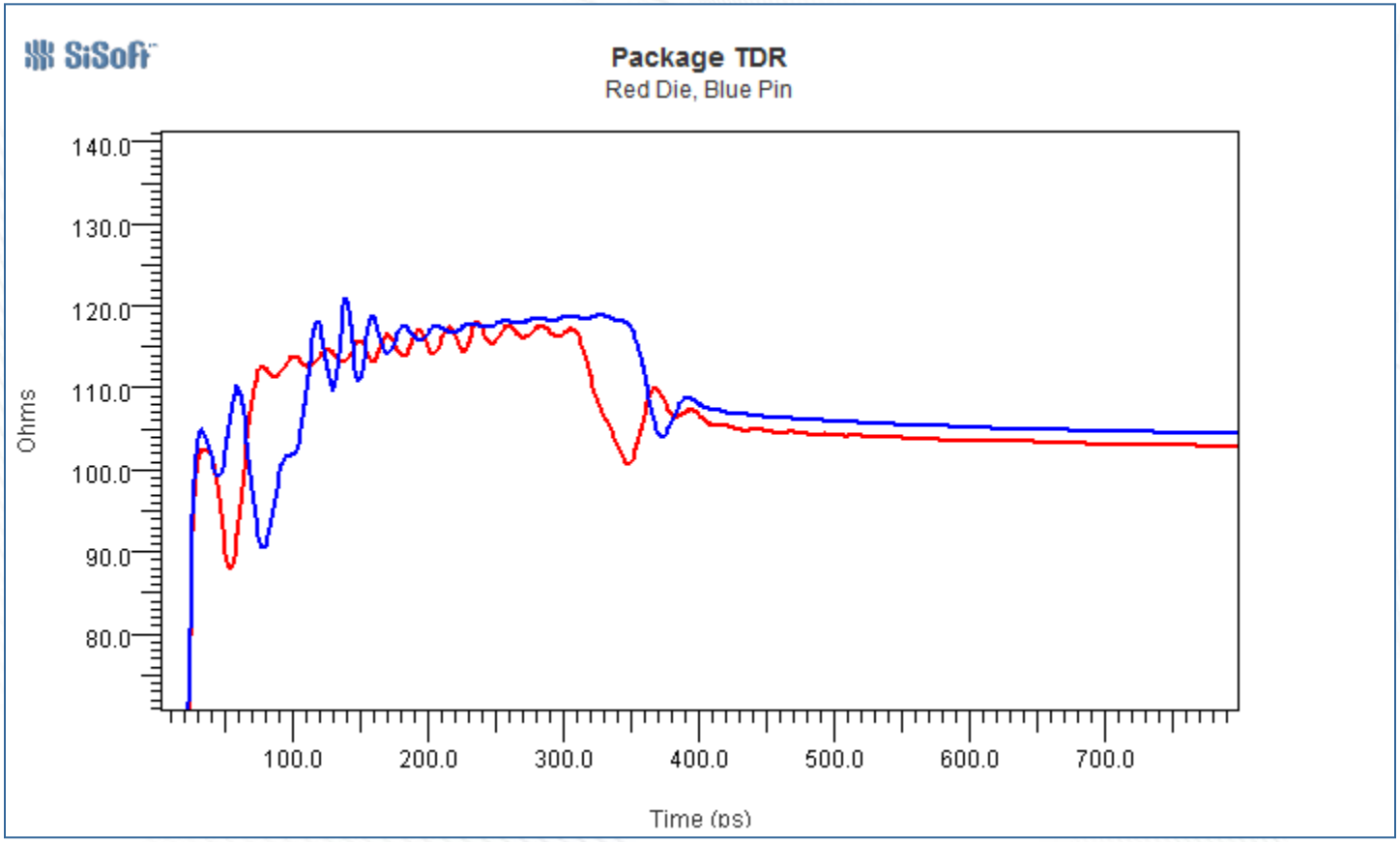
# Package TDR



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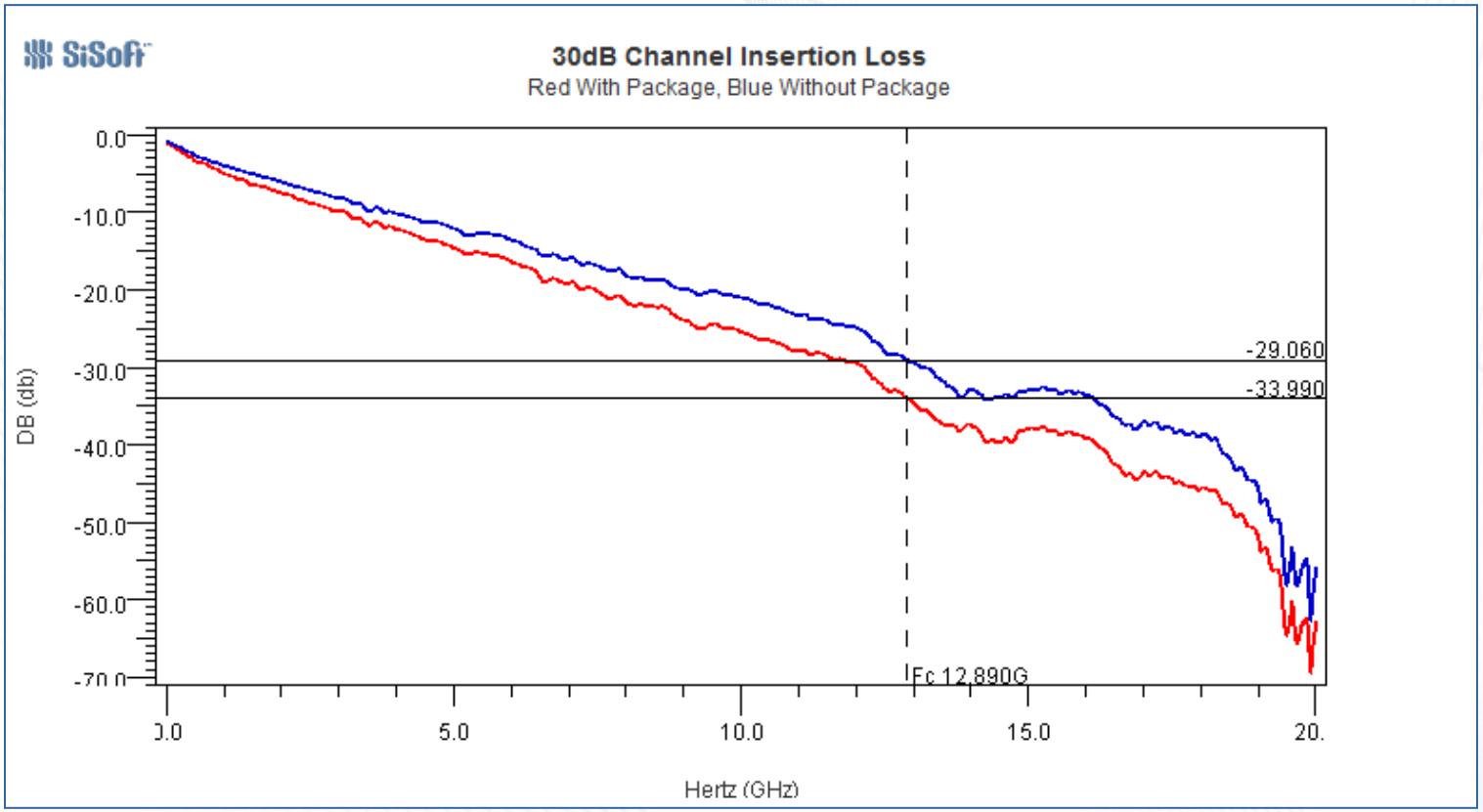
# 30dB Channel Insertion Loss



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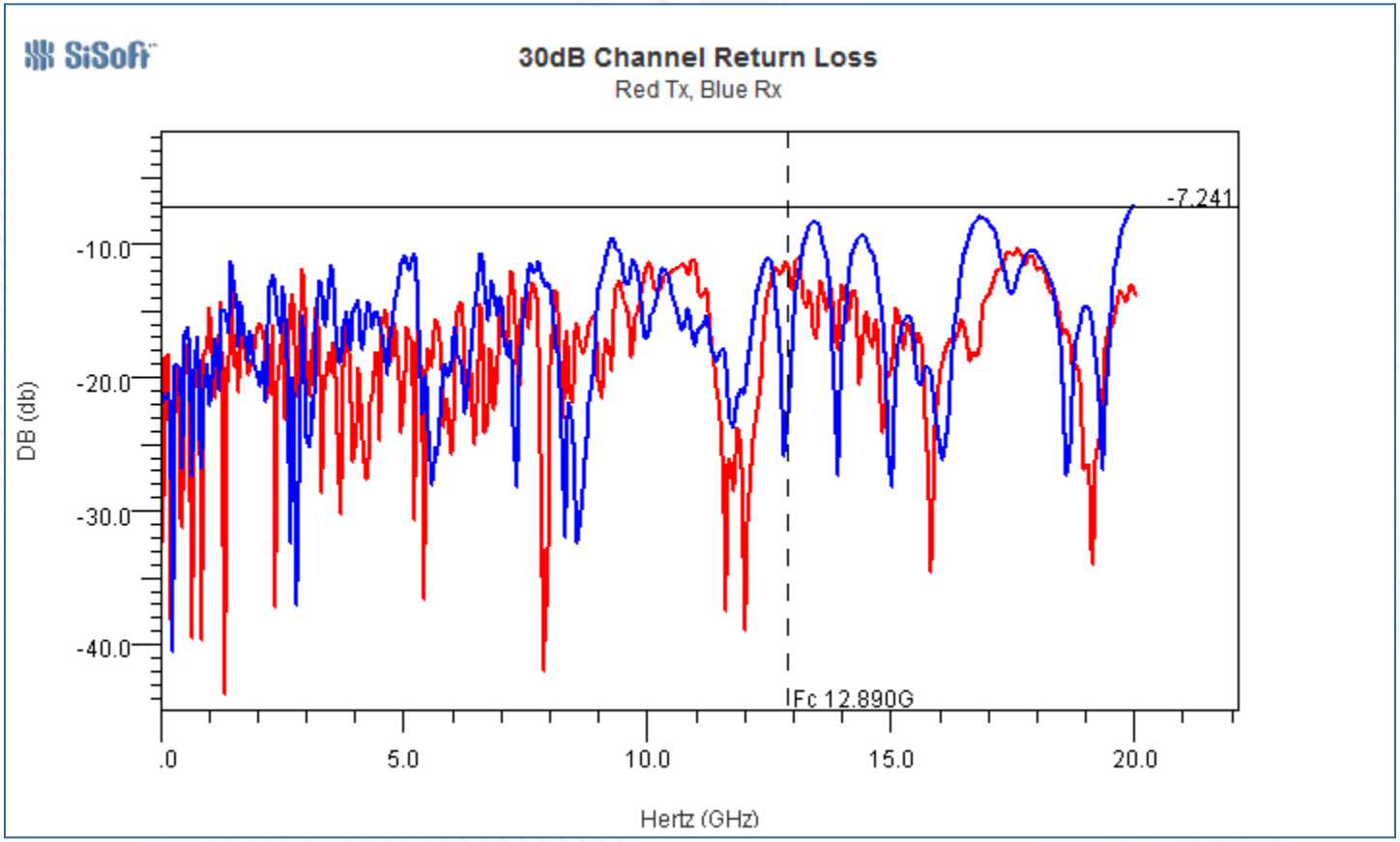
# 30dB Channel Return Loss



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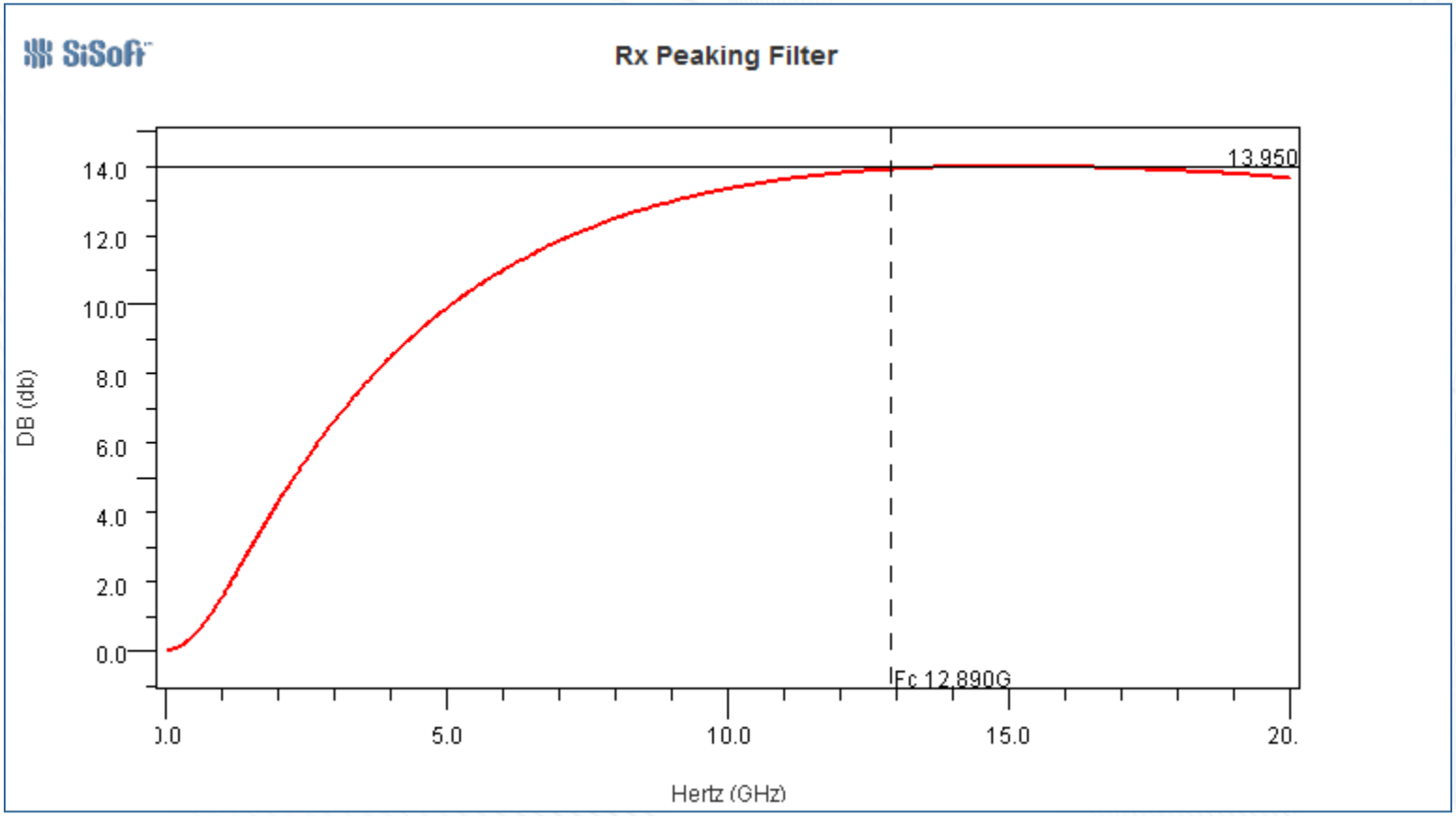
# Tx IBIS-AMI Model

- Analog Model
  - Equivalent Thevenin Model
    - C_comp 250fF
    - Impedance 50 Ohm
  - Recommendation: Use broadband Touchstone models.
- Algorithmic Model
  - 3-Tap FFE
    - 1 Pre-Cursor Tap, 1 Post-Cursor Tap
    - Used -.17, .69, -,14 for simulations
  - Jitter
    - Sj .05UI (Peak) = .5*.1UI (Sj Peak to Peak)
    - Sj Frequency 100MegHz
      - Recommendations: Use Jitter Spectral Density
    - DCD .02UI
    - Rj .3ps
    - Recommendation: Separate Jitter Budgets for Tx and Rx

# Rx IBIS-AMI Model

- Analog Model
  - Equivalent Thevenin Model
    - C_comp 250fF
    - Impedance 50 Ohm
  - Recommendation: Use broadband Touchstone models.
- Algorithmic Model
  - Peaking Filter (CTLE)
    - “Up to 14 dB peaking at 12.89 GHz”
    - Recommendation: Represent CTLE as Poles and Zeros
  - 14-Tap FIR DFE
    - Recommendation: Use advanced equalization techniques
  - Jitter and Noise
    - Rx_Noise .002V
    - Rj .3ps
    - Recommendation: Separate Jitter Budgets for Tx and Rx

# Rx Peaking Filter



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# Three Types of Simulation

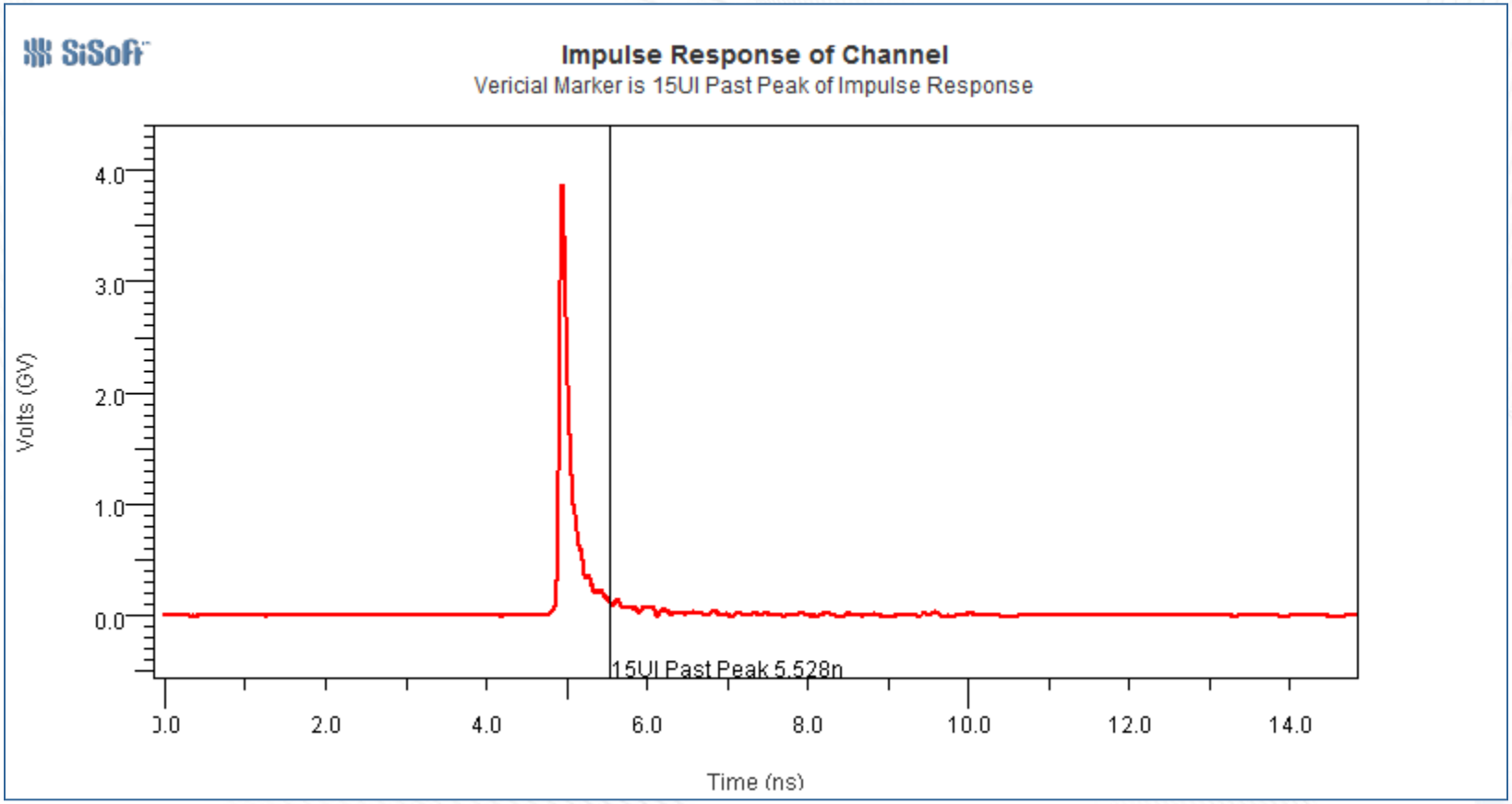
- Statistical
  - ~Seconds per simulation
  - Eye has large dynamic range, probabilities >~ e-30
  - Approximates behavior of Jitter, CDR, and DFE
- Time Domain
  - ~Minutes per simulation
  - Limited to ~ 1 Million Symbols
  - Eye has small dynamic range, probabilities >~ e-6
  - Accurate behavior of Jitter, CDR, and DFE
- Time Domain with Statistical Extrapolation
  - ~Minute per simulation
  - Eye has small dynamic range, probabilities >~ e-30
  - Accurate behavior of Jitter, CDR, and DFE
  - Fills in center of center of eye based on statistical analysis of waveforms

# 30dB Channel Results Using Statistical Flow

- Input to AMI models
  - Impulse Response of Channel
    - Vertical marker indicates region that 14 Tap (UI) DFE can equalize
    - Pulse Response of Channel
- Output from AMI models
  - Equalized Pulse Response
  - Equalized Impulse Response
    - Graphically shows DFE Tap settings
  - Statistical Eye, and Bathtub Curves
    - Jitter applied to Clock
    - Jitter applied to Data

# Impulse Response of Channel

## Vertical Line at 15UI Past Peak of Impulse Response



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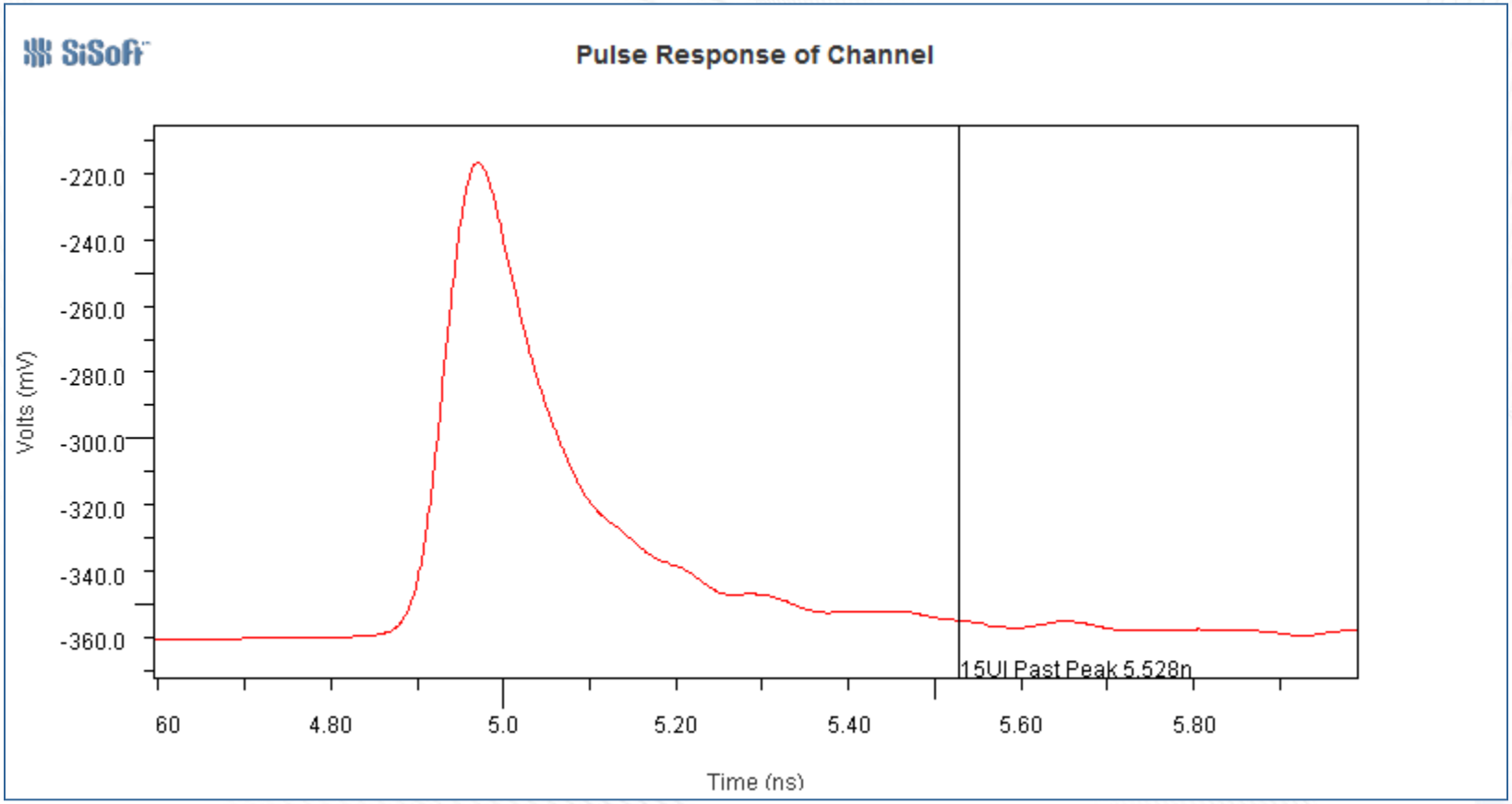
# Pulse Response of Channel



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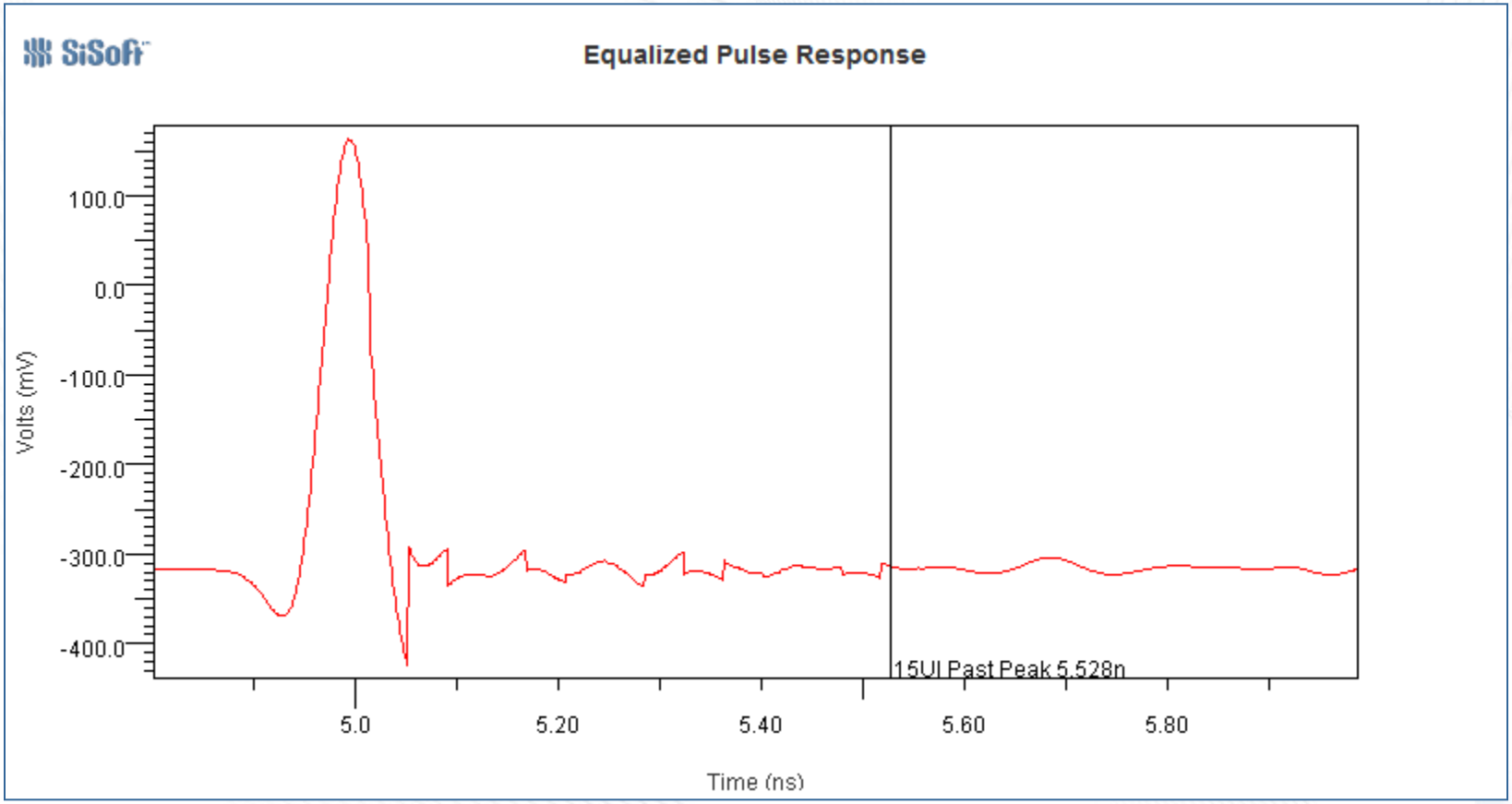
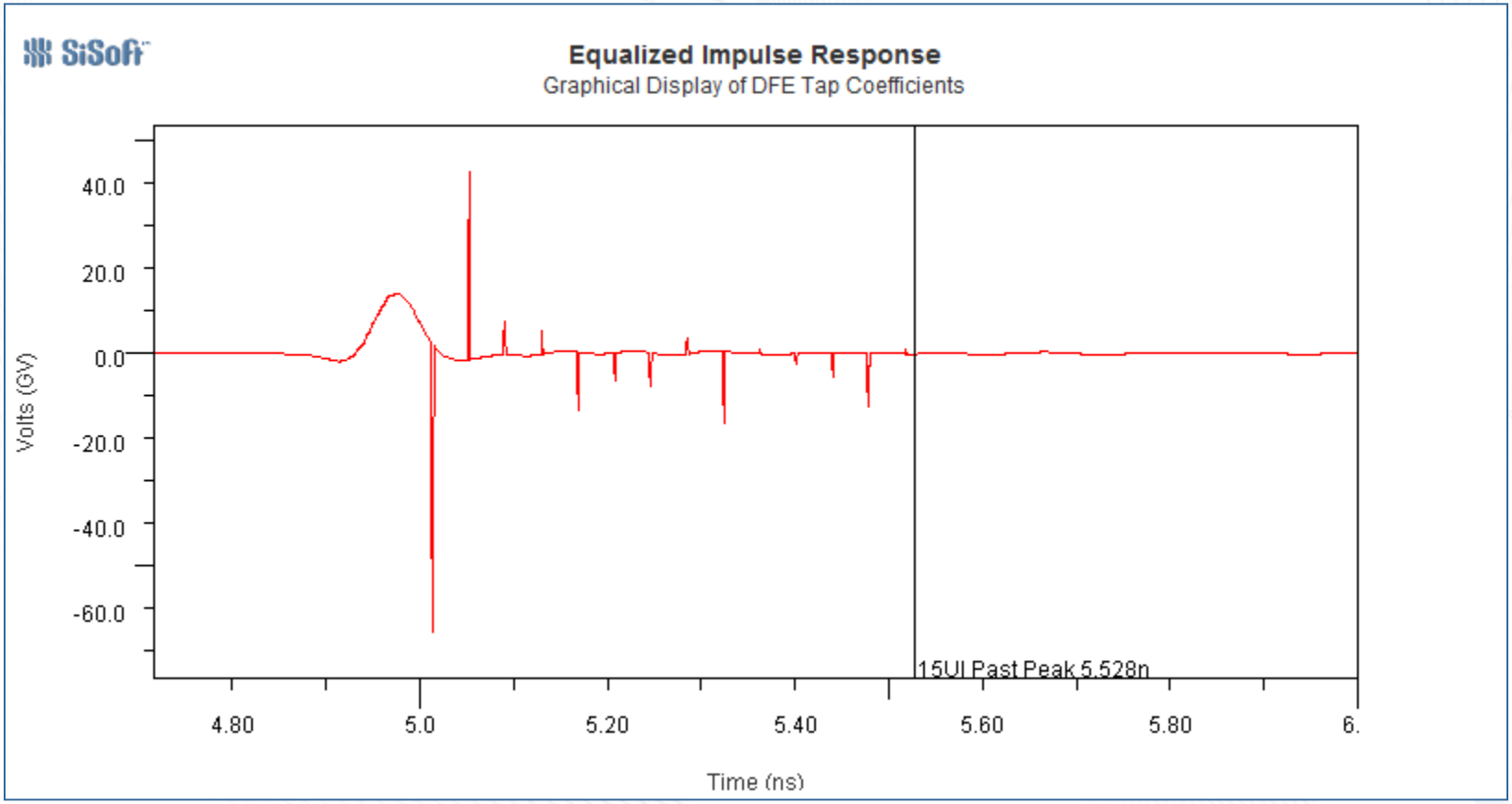
# Equalized Pulse Response



# Equalized Impulse Response



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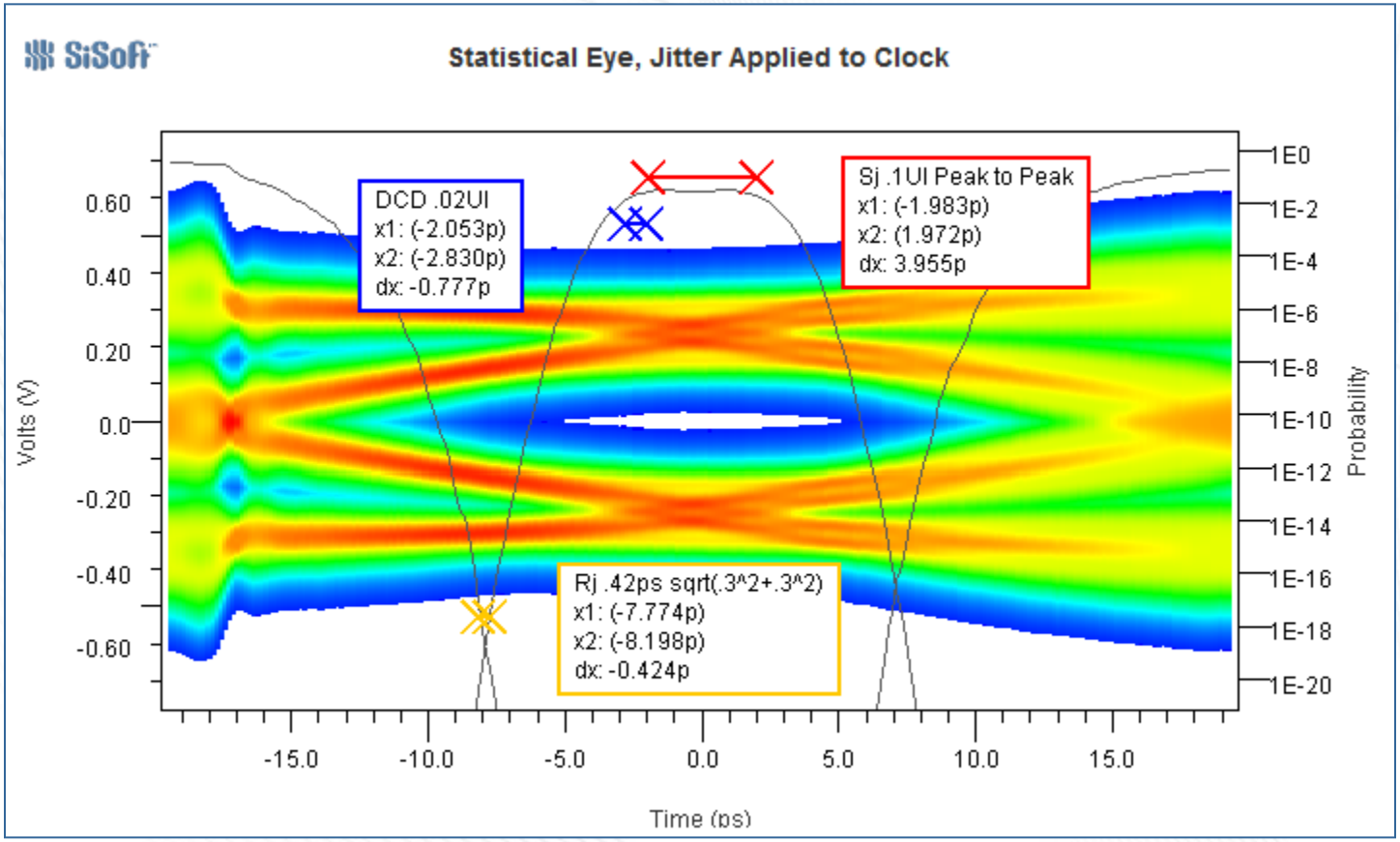
# Statistical Eye, Jitter Applied to Clock



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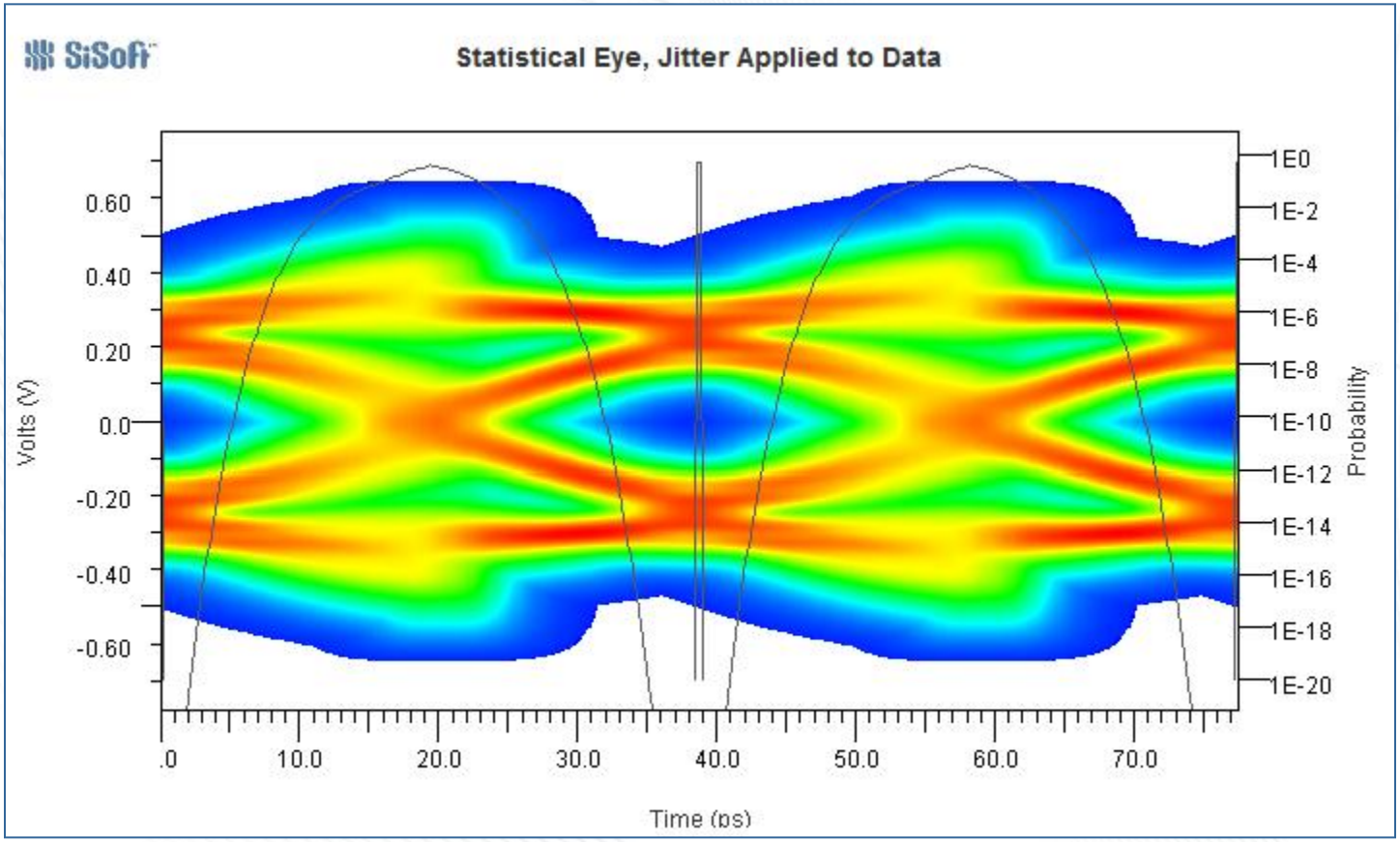
# Statistical Eye, Jitter Applied to Data



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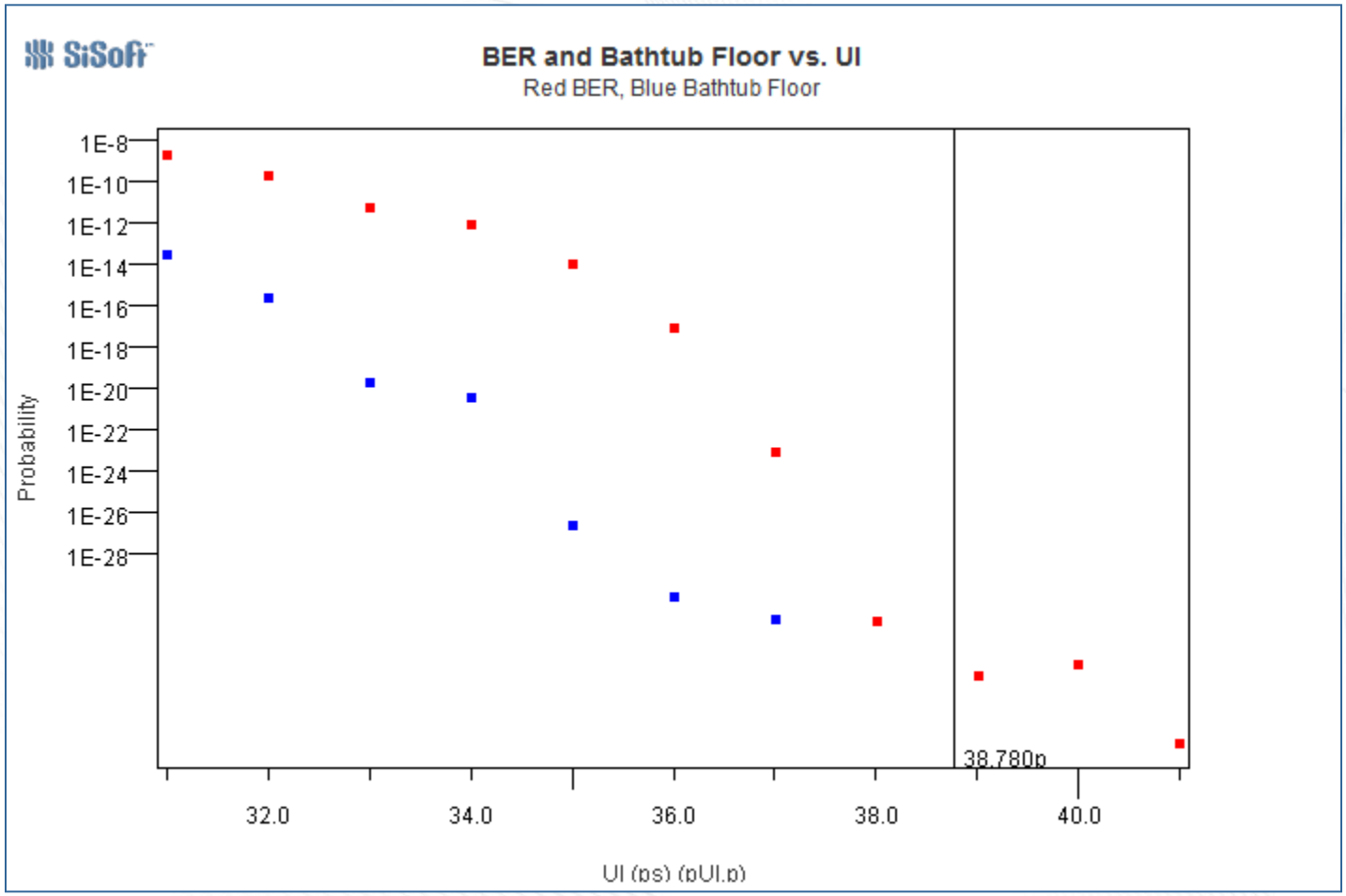
# BER as Function of UI

- Swept UI using Statistical Simulation
- FEC may require smaller UI
- Next slide can be helpful to evaluate various Channel, FEC and DFE strategies.

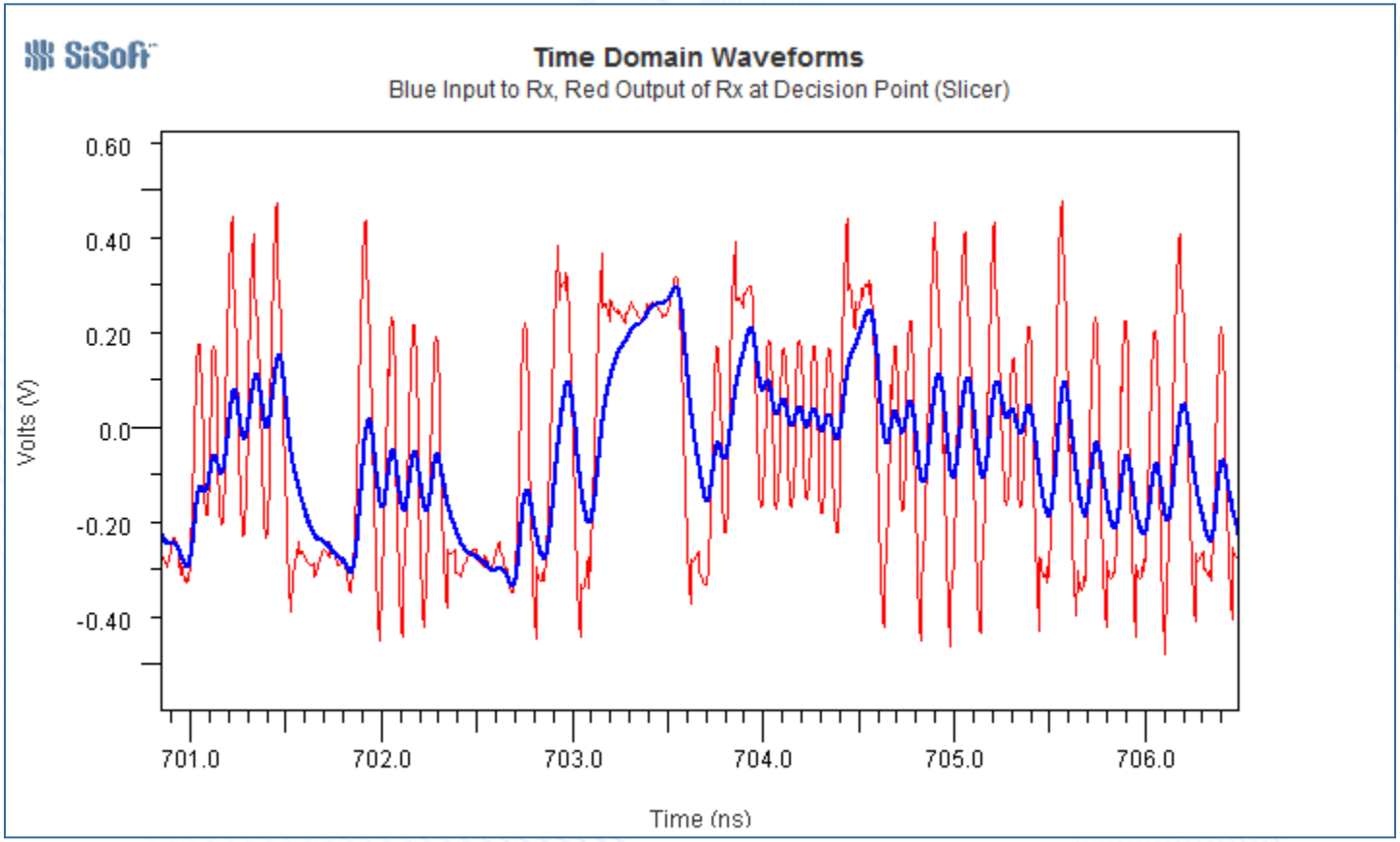
# BER and Bathtub Floor vs. UI



# Time Domain Simulations

- Input to AMI models
  - Impulse Response of Channel
  - Stimulus Pattern
- Output of AMI models
  - Waveform at input to Rx
  - Waveform at Rx Decision Point (Slicer)
  - Waveform Eye
  - Persistent Eye
    - Includes convolution with Tx and Rx Jitter and Rx Noise

# Time Domain Waveforms



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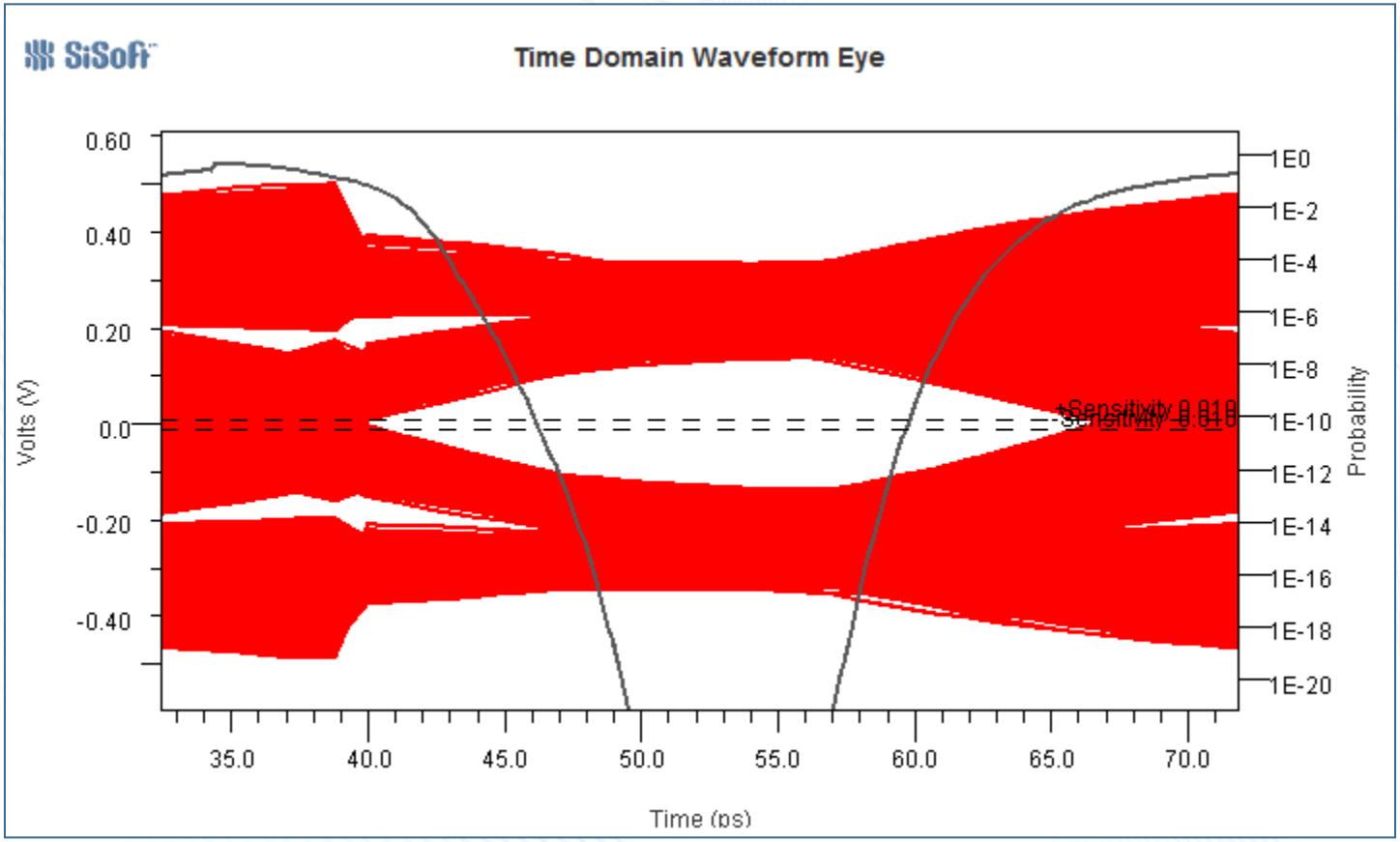
# Time Domain Waveform Eye



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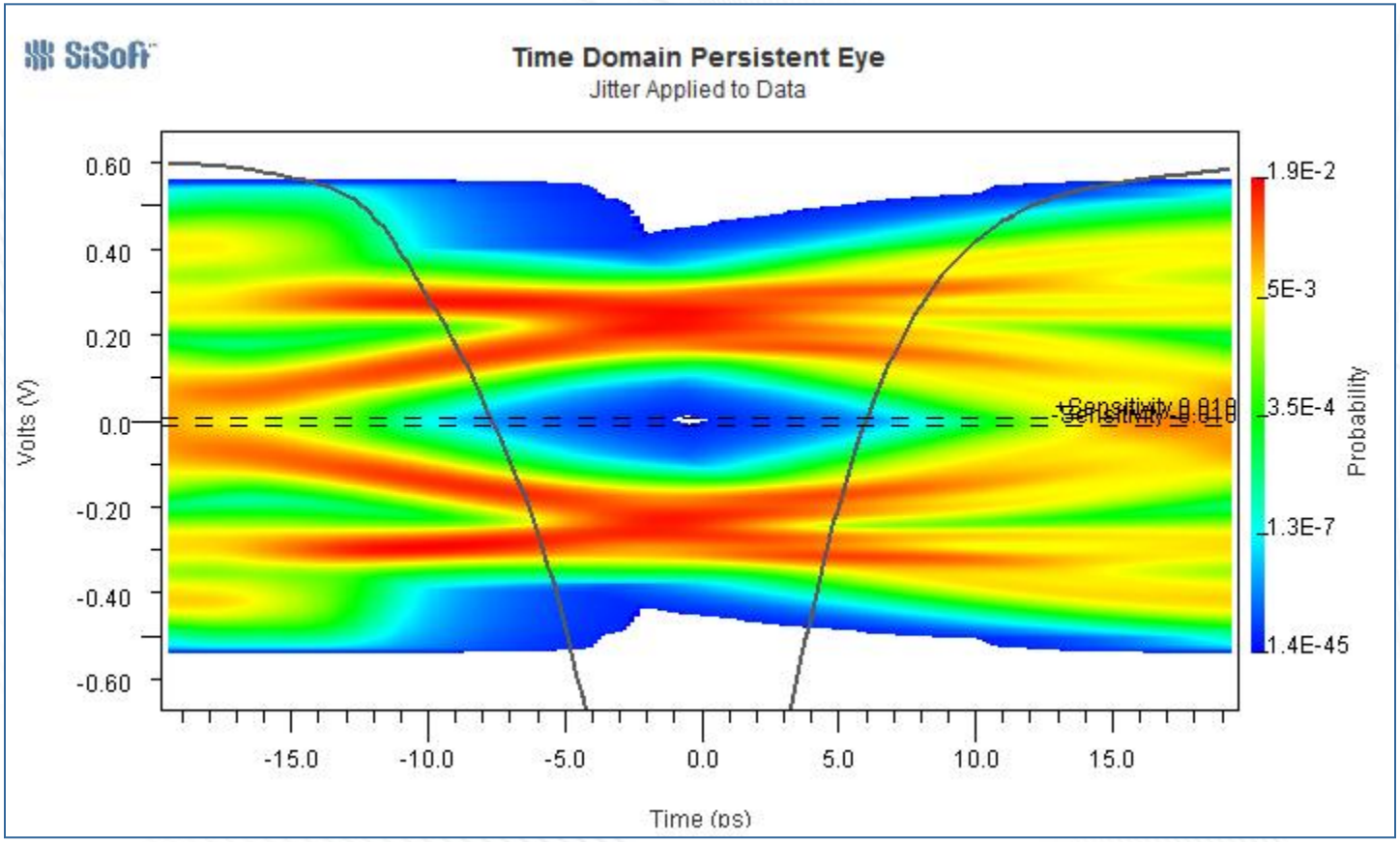
# Time Domain Persistent Eye



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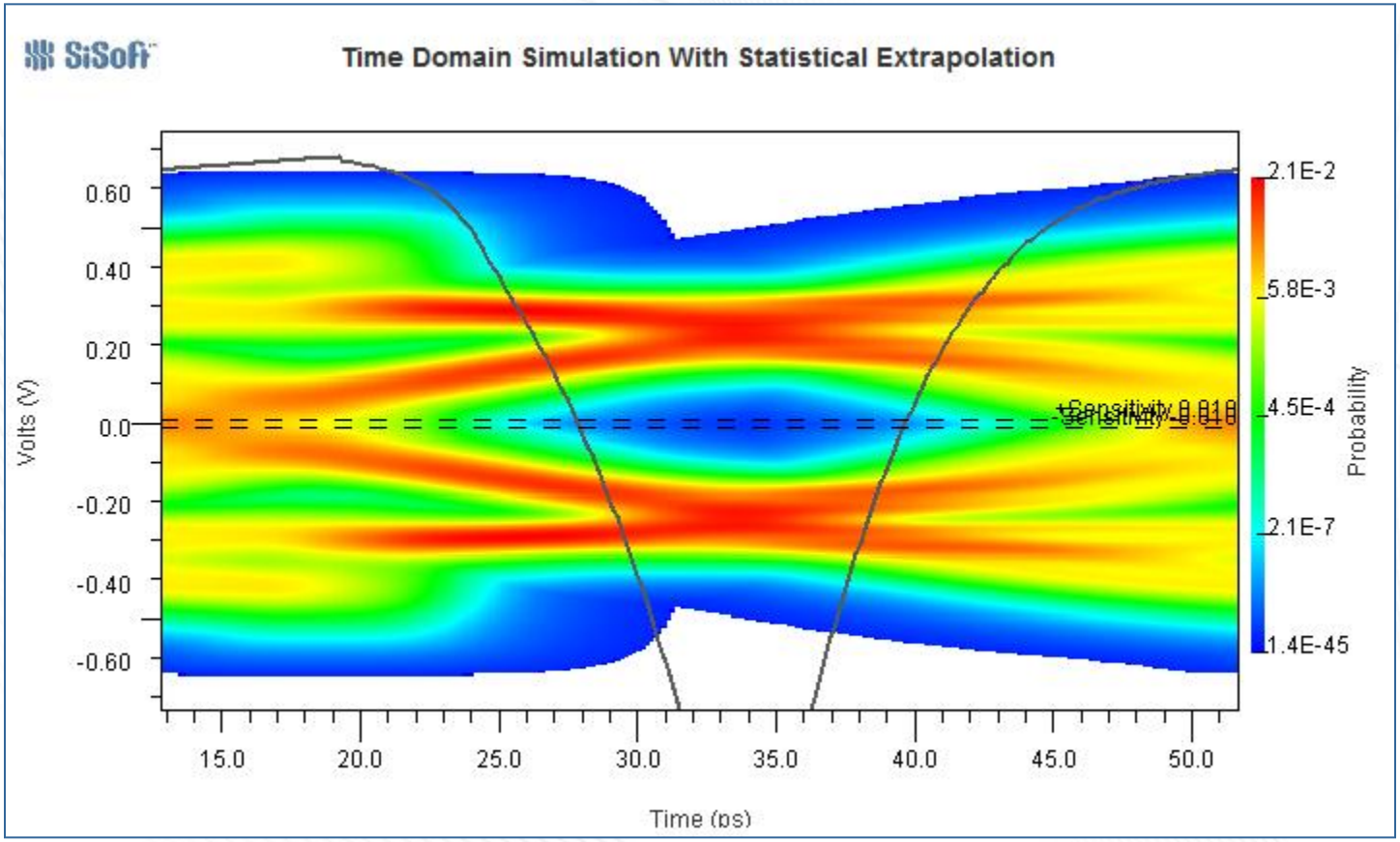
# Time Domain Statistical Extrapolation

- 1 Million bit simulations cannot directly predict events that occur with probabilities < 1.e-6, and therefore cannot directly determine the bathtub floor if < 1e-6.
- The method used to do statistical extrapolation is tool dependent.
- Following slides show time domain persistent eye with statistical extrapolation, and overlay of bathtub curves from statistical simulation, time domain simulation, and time domain simulation with statistical extrapolation

# Time Domain Simulation with Statistical Extrapolation



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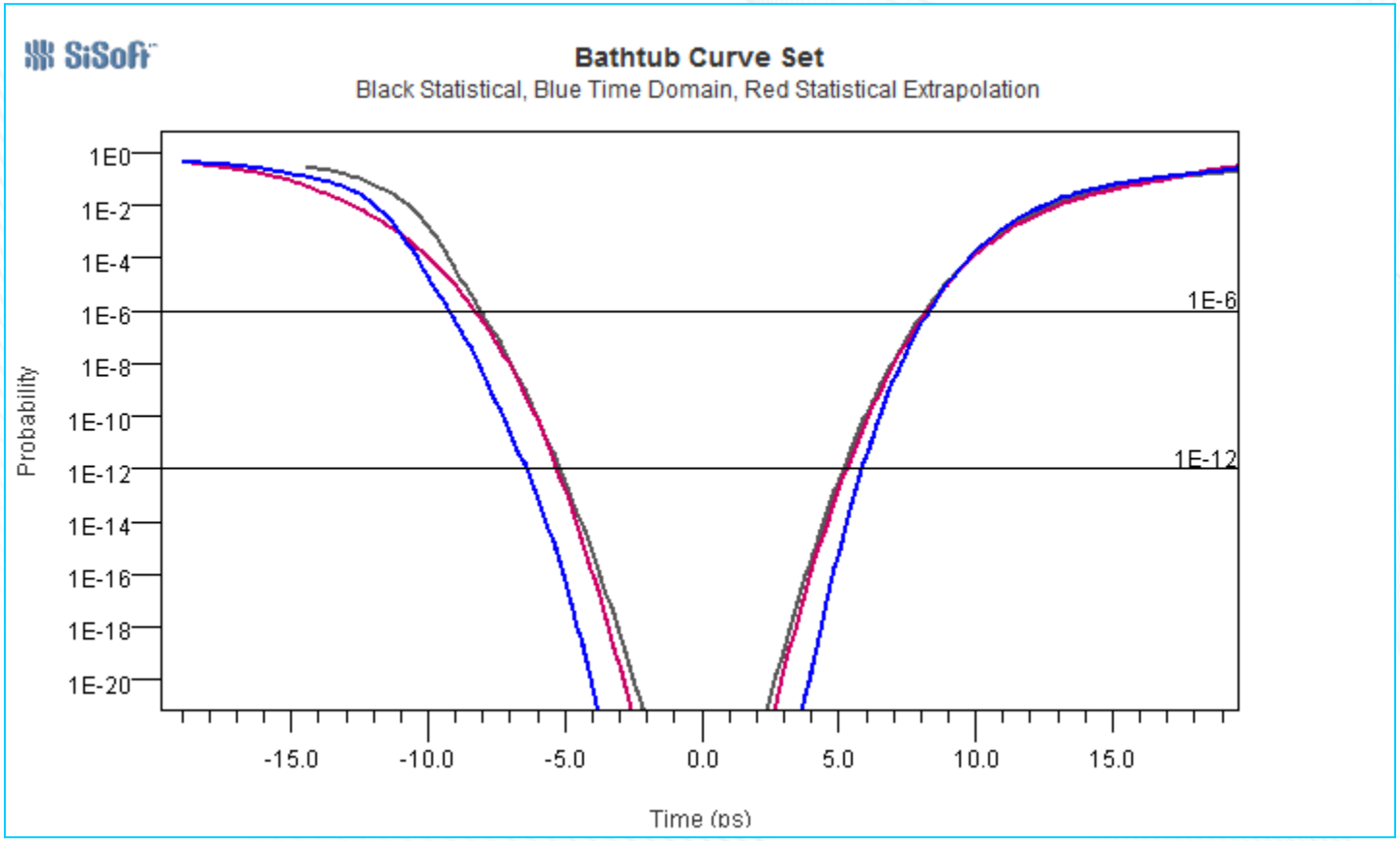
# Comparing Bathtub Curves from Statistical Analysis, Raw Time Domain Waveforms, and Time Domain with Statistical Extrapolation



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# Statistical Simulation vs. Time Domain Simulation

- Statistical Simulation is very fast, allowing exploration of large solution spaces.
- Time Domain Simulation accurately represents the detailed behavior of the Rx CDR, DFE and convergence of the Rx equalization. Besides being orders of magnitude slower than Statistical Simulation, it requires extrapolation of bathtub curves to correctly predict channel performance.

# Summary

- 30dB channel will meet 1e-12 BER requirements without FEC
- Need More Representative Models
  - Touchstone files should contain data to at least 30GHz
  - Broadband Tx and Rx analog buffer models
  - Rx models with enhanced equalization
- Analysis methodology of simulations needs to be clearly defined to compare results from different simulators