IBIS-AMI and Jitter

Mike LaBonte
SiSoft

SPI 2018 IBIS Summit
May 25, 2018
Brest, France

SiSoft™
We Are Signal Integrity

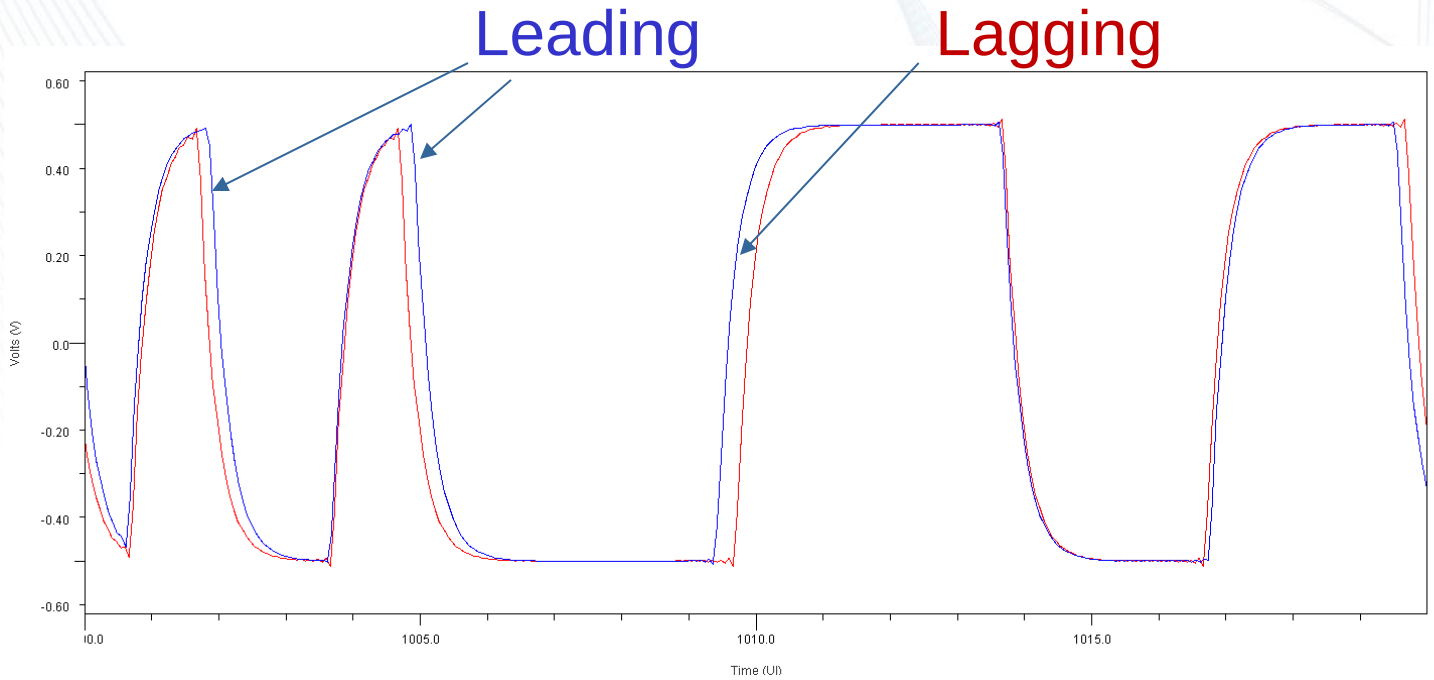
Agenda

- Overview of Jitter and Noise Concepts
- IBIS-AMI Jitter and Noise Reserved_Parameters
- IBIS-AMI Jitter and Noise Flows
- Examples of IBIS-AMI Jitter and Noise Effects
- Recommendations

© SiSoft, 2018

SiSoft™
We Are Signal Integrity

Time Domain Jitter



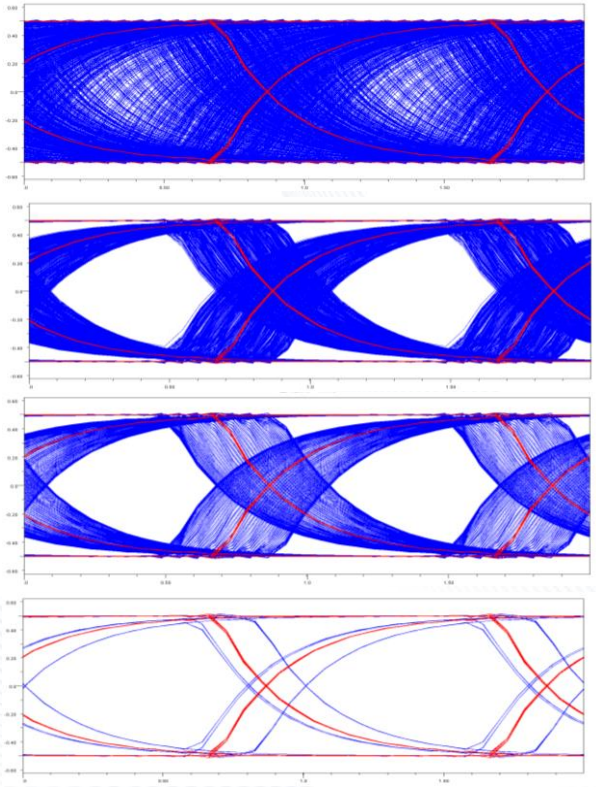
Red = no jitter

© SiSoft, 2018

SiSoft™
We Are Signal Integrity

Jitter Probability Characteristics

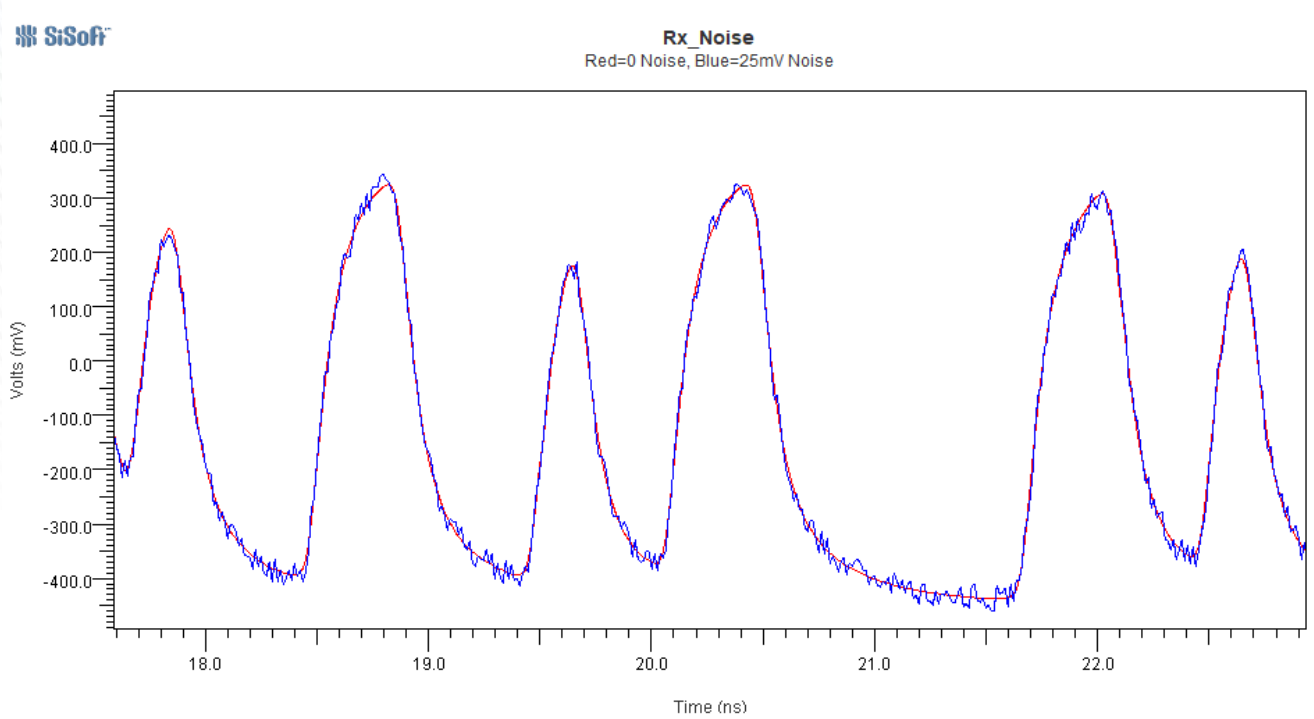
- Random (Rj)
  - Unbounded
  - Gaussian
- Deterministic (Dj)
  - Bounded
  - Uniform
- Sinusoidal (Sj)
  - Bounded
  - Example: Power Supply
- Duty Cycle Distortion (DCD)
  - Bounded
  - Unequal Pu/Pd



© SiSoft, 2018

SiSoft™
We Are Signal Integrity

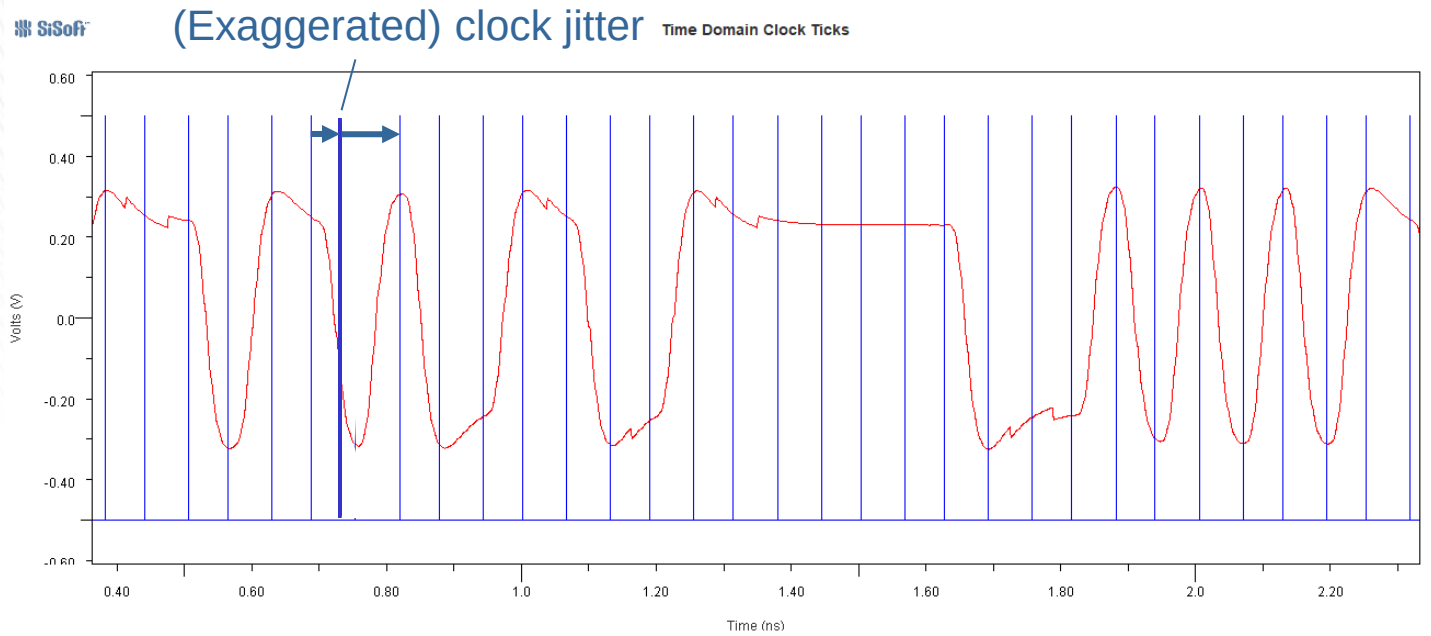
Voltage Domain Noise



© SiSoft, 2018

SiSoft™
We Are Signal Integrity

Clock Recovery Jitter

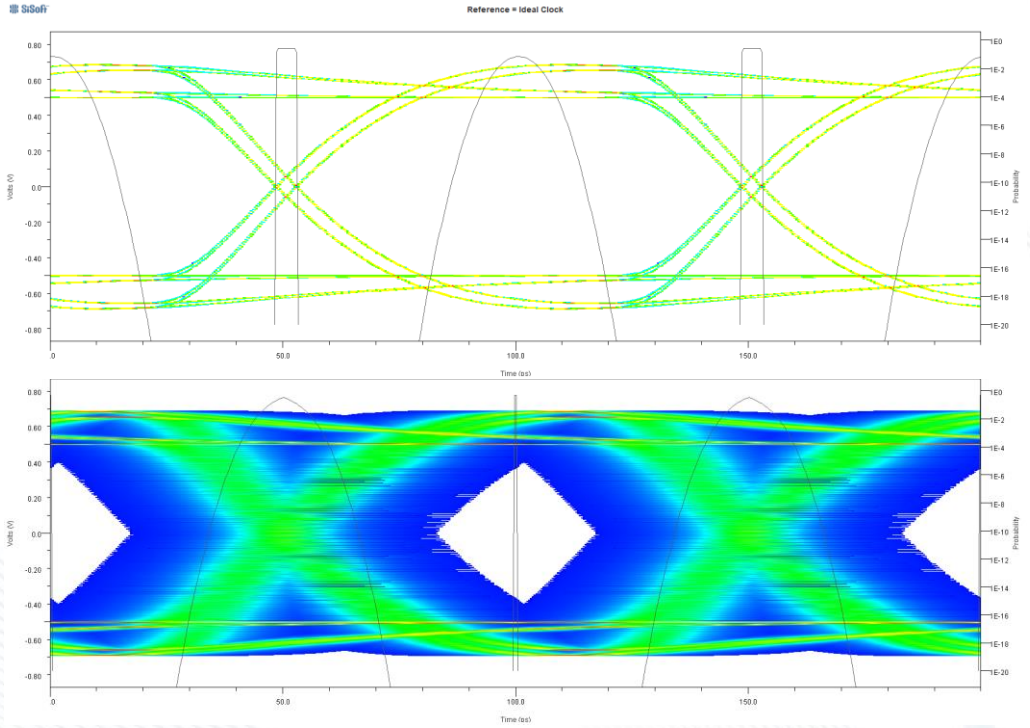


© SiSoft, 2018

SiSoft™
We Are Signal Integrity

Clock Jitter Viewed Different Ways

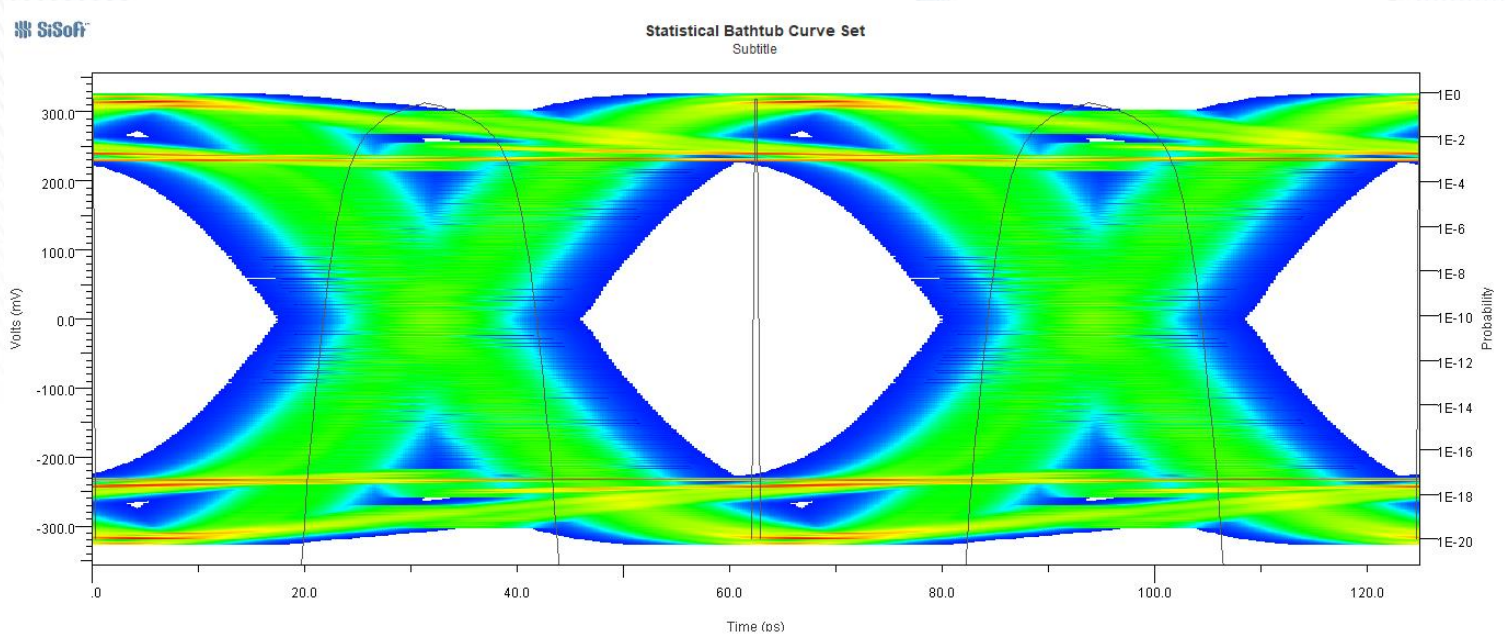
- Clock time probabilities plotted against an ideal 1 UI clock
- Waveform plotted against actual jittered clock times



© SiSoft, 2018

SiSoft™
We Are Signal Integrity

There is No Time Domain Clock in Statistical Analysis



Tools apply jitter and noise statistically

© SiSoft, 2018

SiSoft™
We Are Signal Integrity

AMI_GetWave Outputs Clock Time Values

```
long AMI_GetWave(
  double *wave_in,
  long wave_size,
  double *clock_times,
  char **AMI_parameters_out,
  void *AMI_memory );
```

Clock_times might not be perfectly regular

UI#	clock_times	period
997,510	62,344,398.5 ps	62.5 ps
997,511	62,344,461.0 ps	62.5 ps
997,512	62,344,523.5 ps	62.5 ps
997,513	62,344,586.0 ps	62.5 ps
997,514	62,344,648.5 ps	62.5 ps
997,515	62,344,711.0 ps	62.5 ps
997,516	62,344,773.5 ps	62.5 ps
997,517	62,344,836.5 ps	63.0 ps
997,518	62,344,899.0 ps	62.5 ps
997,519	62,344,961.5 ps	62.5 ps
997,520	62,345,024.0 ps	62.5 ps

© SiSoft, 2018

SiSoft™ We Are Signal Integrity

IBIS-AMI Jitter and Noise Reserved_Parameters

- Rx Jitter and Noise

Rx_Clock_PDF	5.0
Rx_Clock_Recovery_DCD	6.0
Rx_Clock_Recovery_Dj	6.0
Rx_Clock_Recovery_Mean	6.0
Rx_Clock_Recovery_Rj	6.0
Rx_Clock_Recovery_Sj	6.0
Rx_DCD	6.0
Rx_Dj	6.0
Rx_Noise, Rx_Gaussian_Noise	6.0, 7.0
Rx_Uniform_Noise	7.0
Rx_Receiver_Sensitivity	5.0
Rx_Rj	6.0
Rx_Sj	6.0

- Tx Jitter

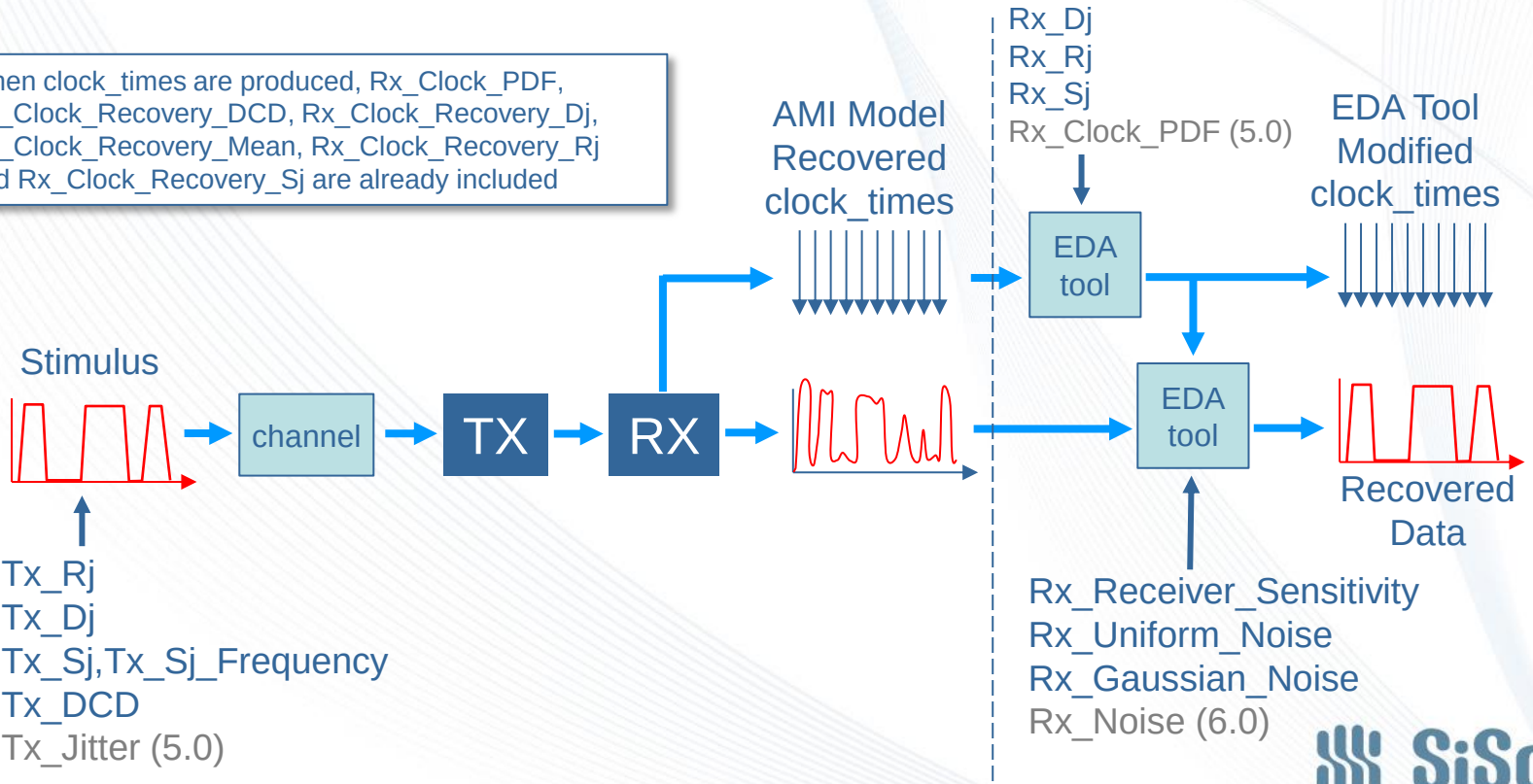
Tx_Jitter (Dj, Rj)	5.0
Tx_DCD	5.0
Tx_Dj	6.0
Tx_Rj	6.0
Tx_Sj	6.0
Tx_Sj_Frequency	6.0

© SiSoft, 2018

SiSoft™ We Are Signal Integrity

IBIS-AMI Time Domain Jitter and Noise Modeling When Rx AMI_GetWave Returns clock_times

When clock_times are produced, Rx_Clock_PDF, Rx_Clock_Recovery_DCD, Rx_Clock_Recovery_Dj, Rx_Clock_Recovery_Mean, Rx_Clock_Recovery_Rj and Rx_Clock_Recovery_Sj are already included

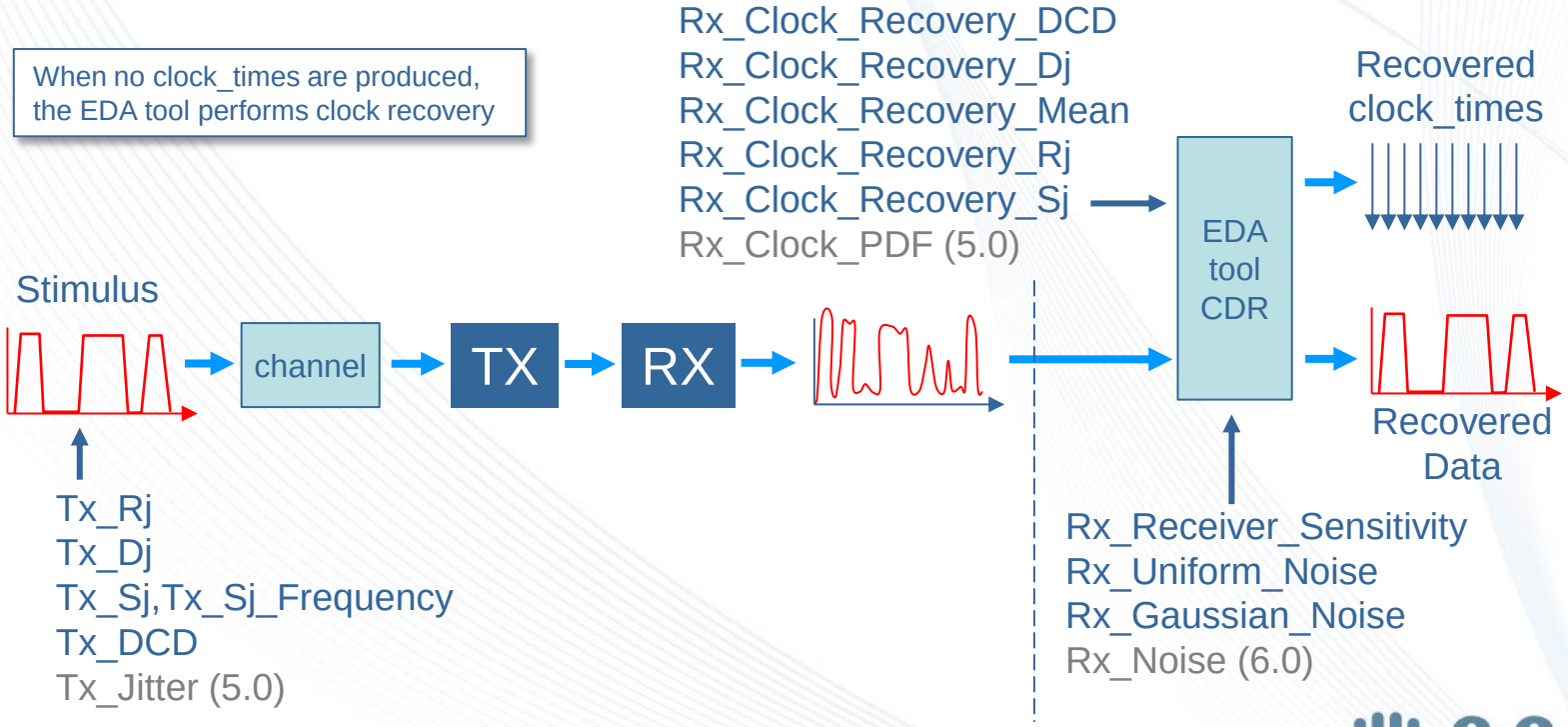


© SiSoft, 2018

SiSoft™
We Are Signal Integrity

IBIS-AMI Time Domain Jitter and Noise Modeling When Rx AMI_GetWave Does Not Return clock_times

When no clock_times are produced, the EDA tool performs clock recovery



© SiSoft, 2018

SiSoft™
We Are Signal Integrity

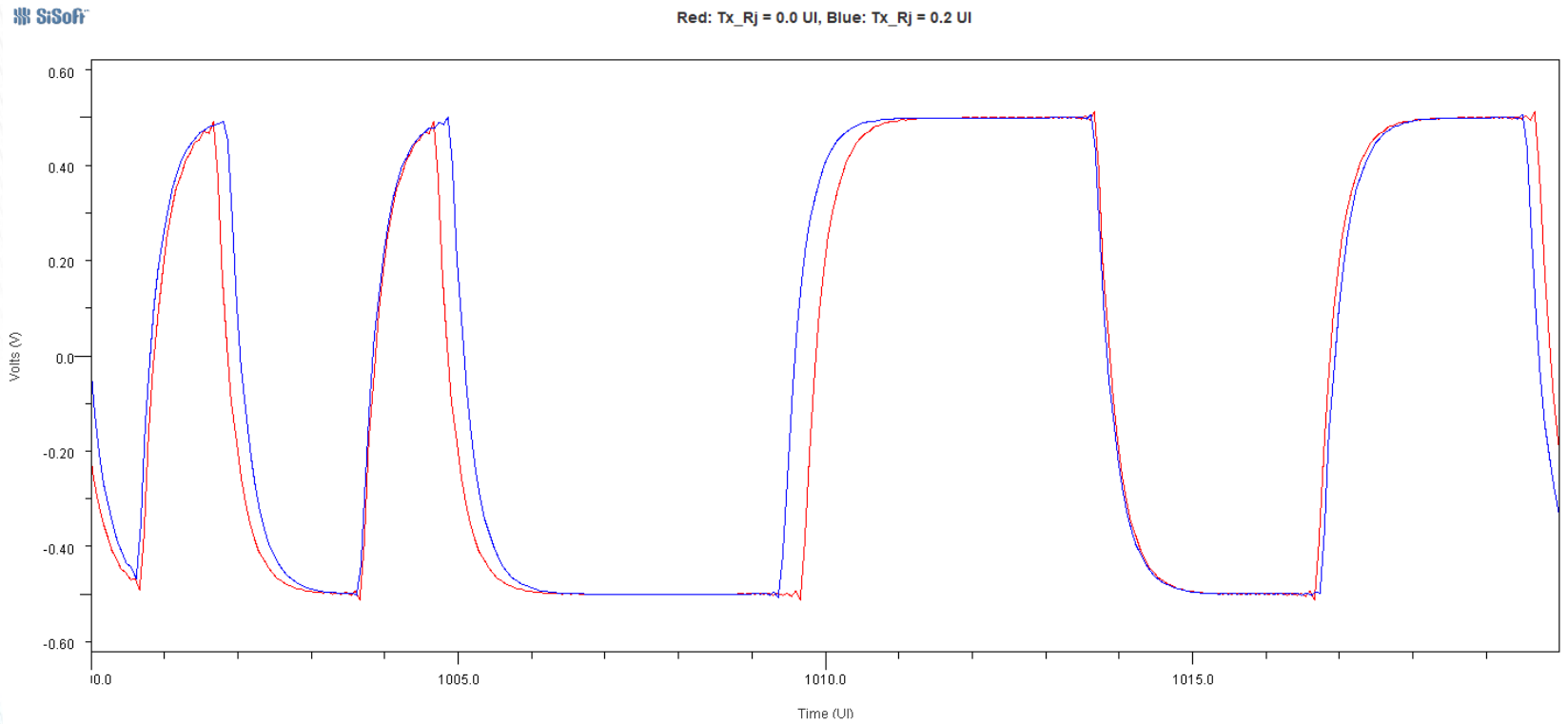
IBIS-AMI Statistical Jitter and Noise Modeling

Tx_Rj
Tx_Dj
Tx_Sj
Tx_DCD
Rx_Gaussian_Noise
Rx_Uniform_Noise
Rx_Clock_Recovery_DCD
Rx_Clock_Recovery_Dj
Rx_Clock_Recovery_Mean
Rx_Clock_Recovery_Rj
Rx_Clock_Recovery_Sj
Rx_Noise (6.0)
Tx_Jitter (5.0)
Rx_Clock_PDF (5.0)

© SiSoft, 2018

SiSoft™
We Are Signal Integrity

Tx_Rj Jitter Modulating the Tx Output

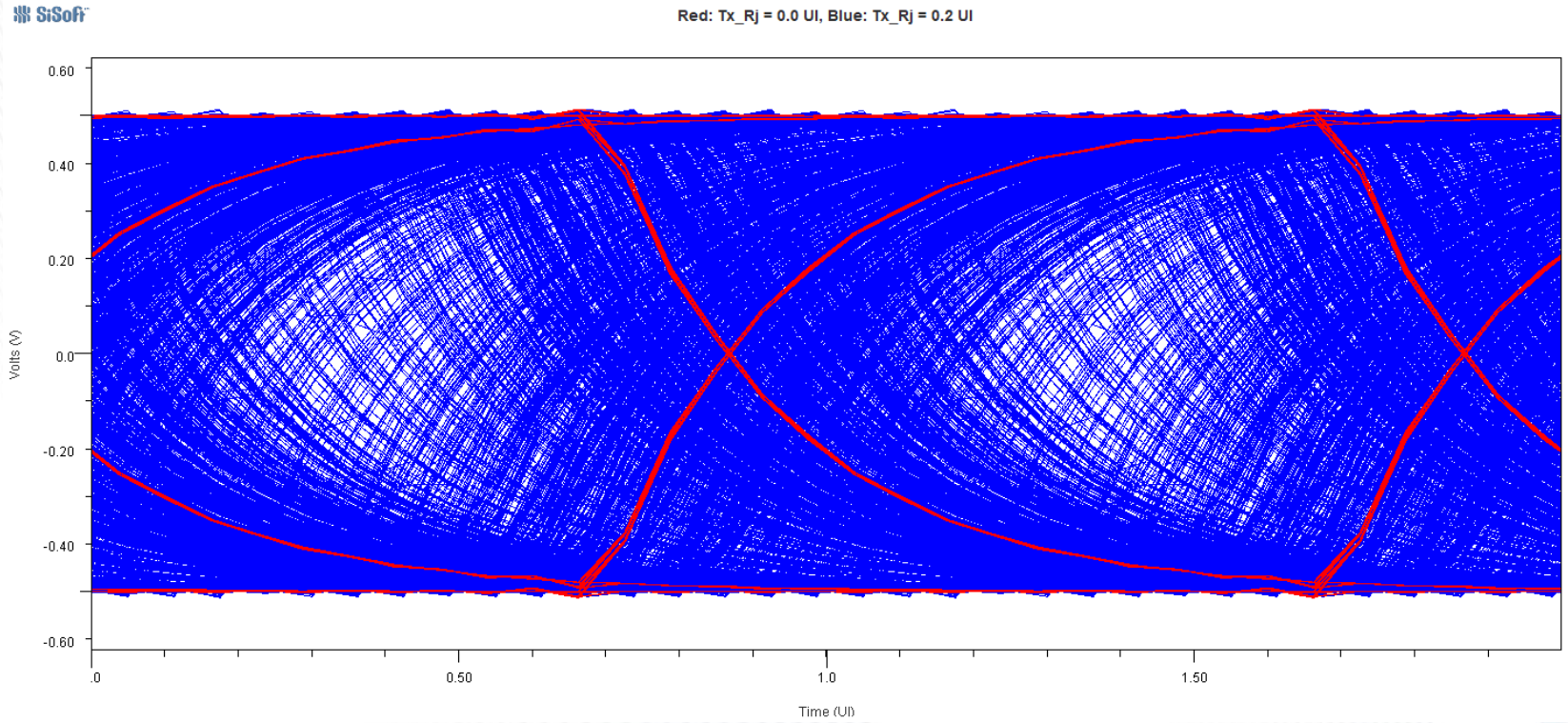


Time(n) = n * bit_time + Tx_Rj * gaussian_rand()

© SiSoft, 2018

SiSoft™
We Are Signal Integrity

Tx_Rj Jitter Modulating the Tx Output

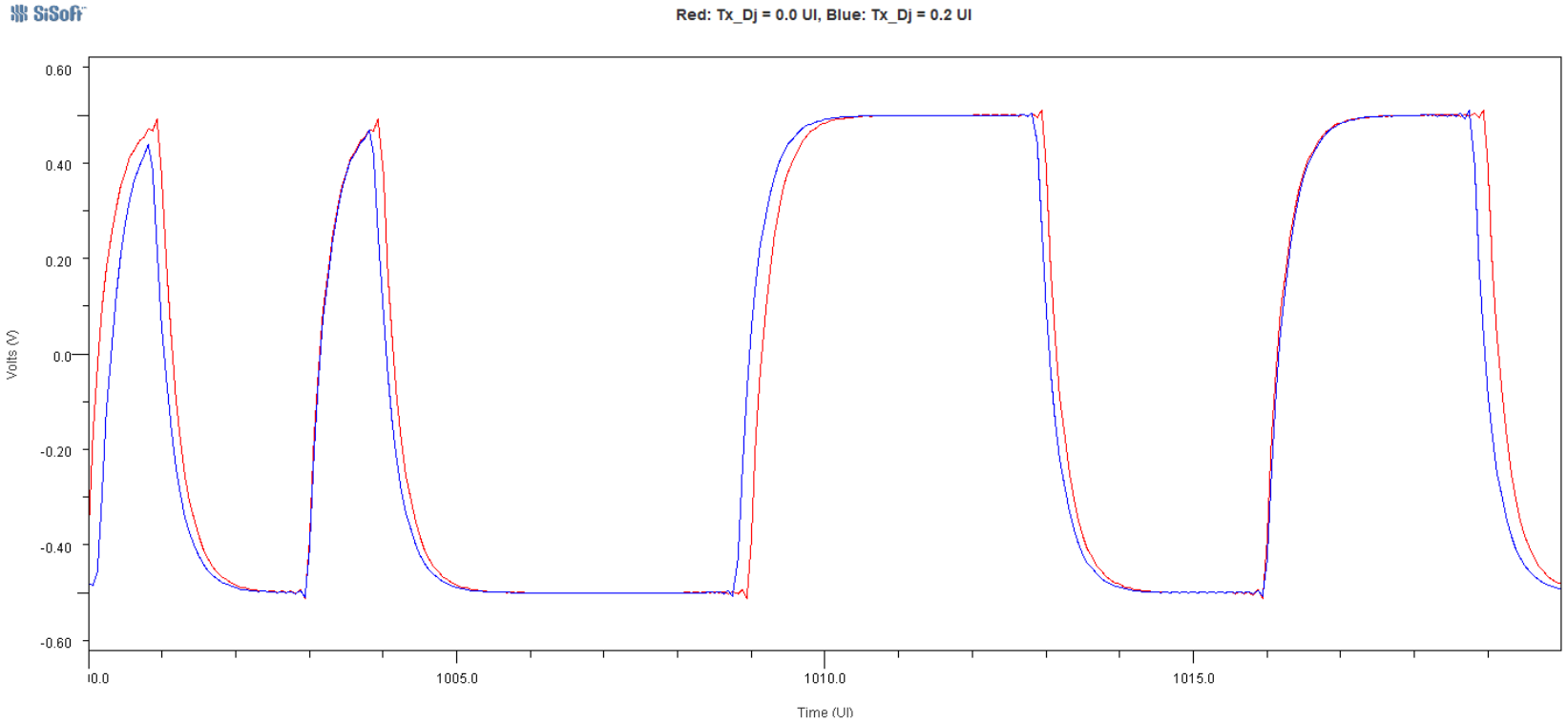


Rj = 0.2 UI at 1 sigma

© SiSoft, 2018

SiSoft™
We Are Signal Integrity

Tx_Dj Jitter Modulating the Tx Output

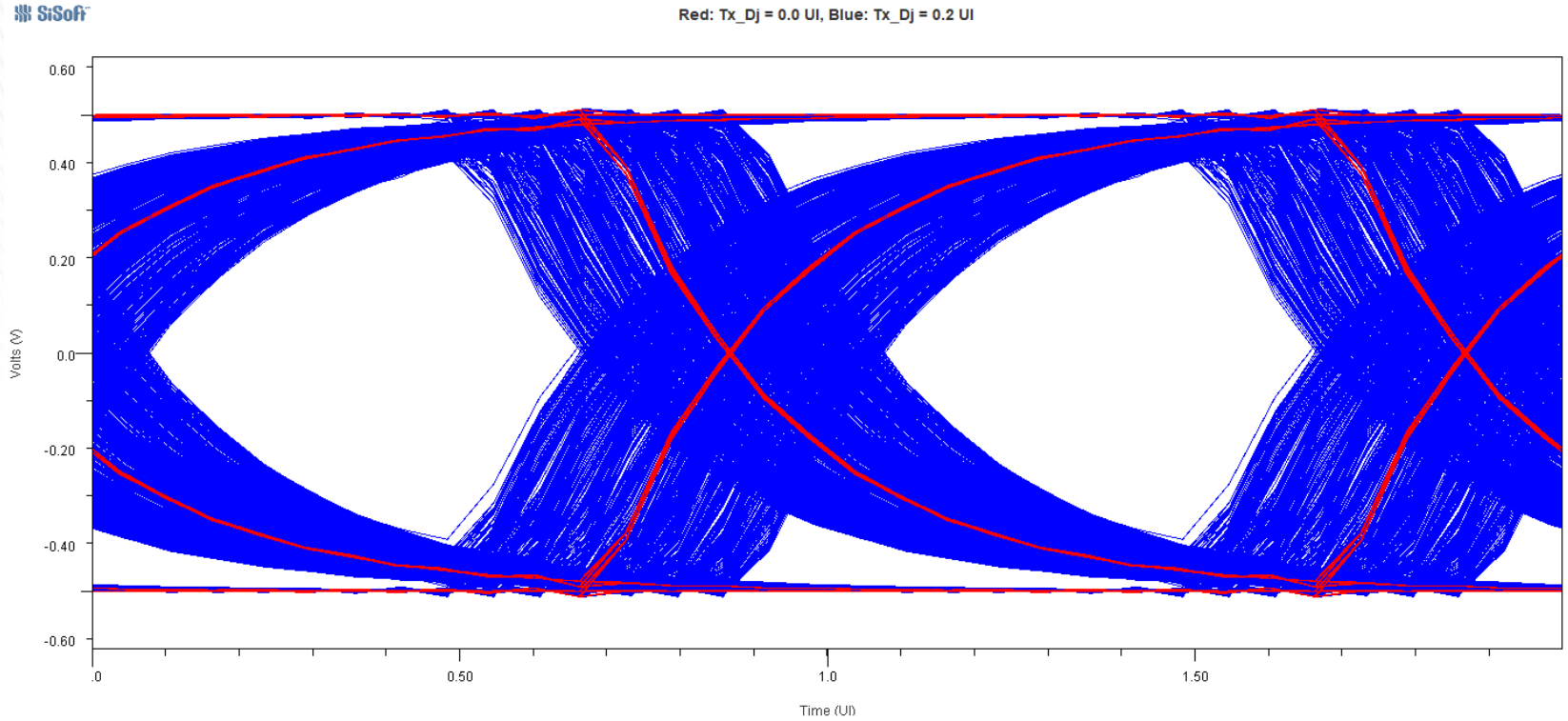


$$Time(n) = n * bit\_time + 2.0 * Tx\_Dj * rand()$$

© SiSoft, 2018

SiSoft™
We Are Signal Integrity

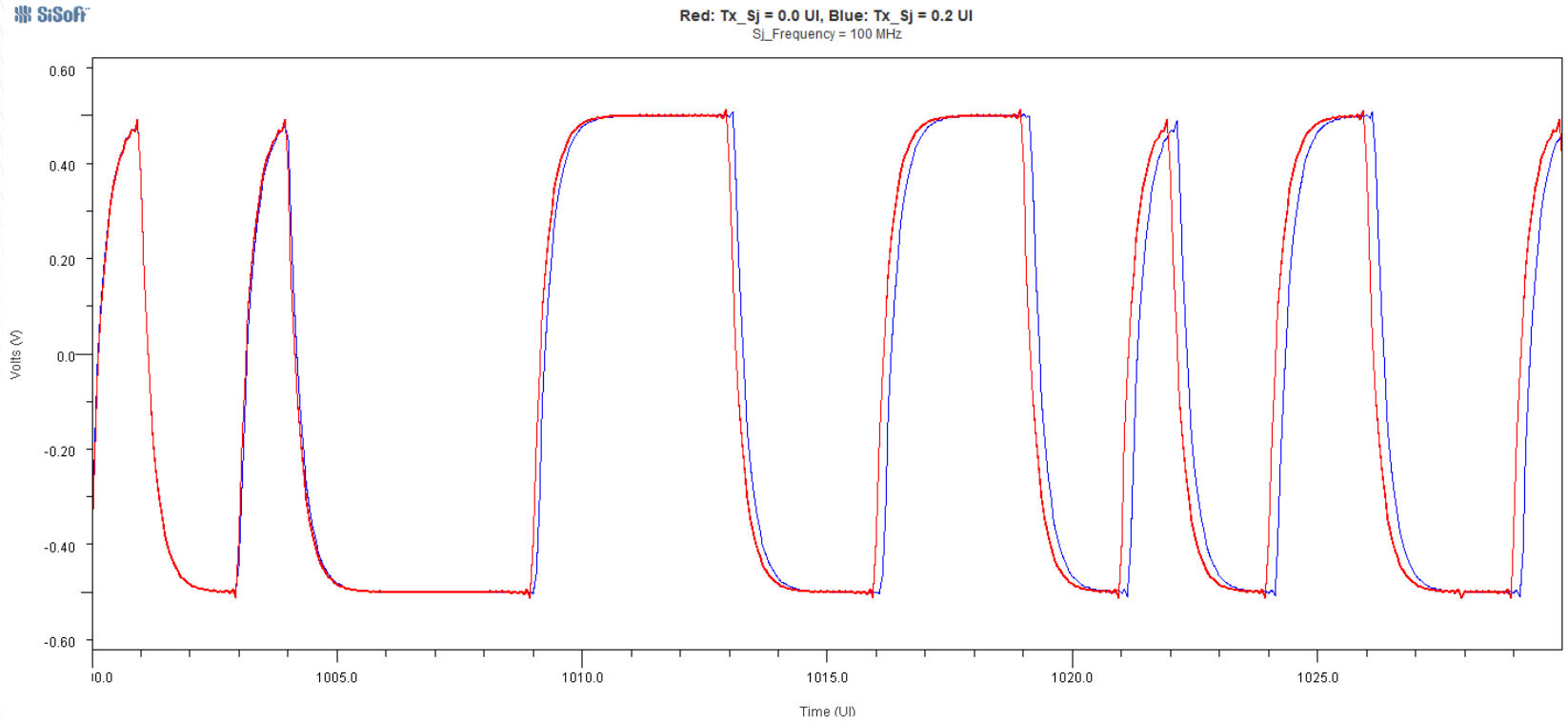
Tx_Dj Jitter Modulating the Tx Output



© SiSoft, 2018

SiSoft™
We Are Signal Integrity

Tx_Sj Jitter Modulating the Tx Output

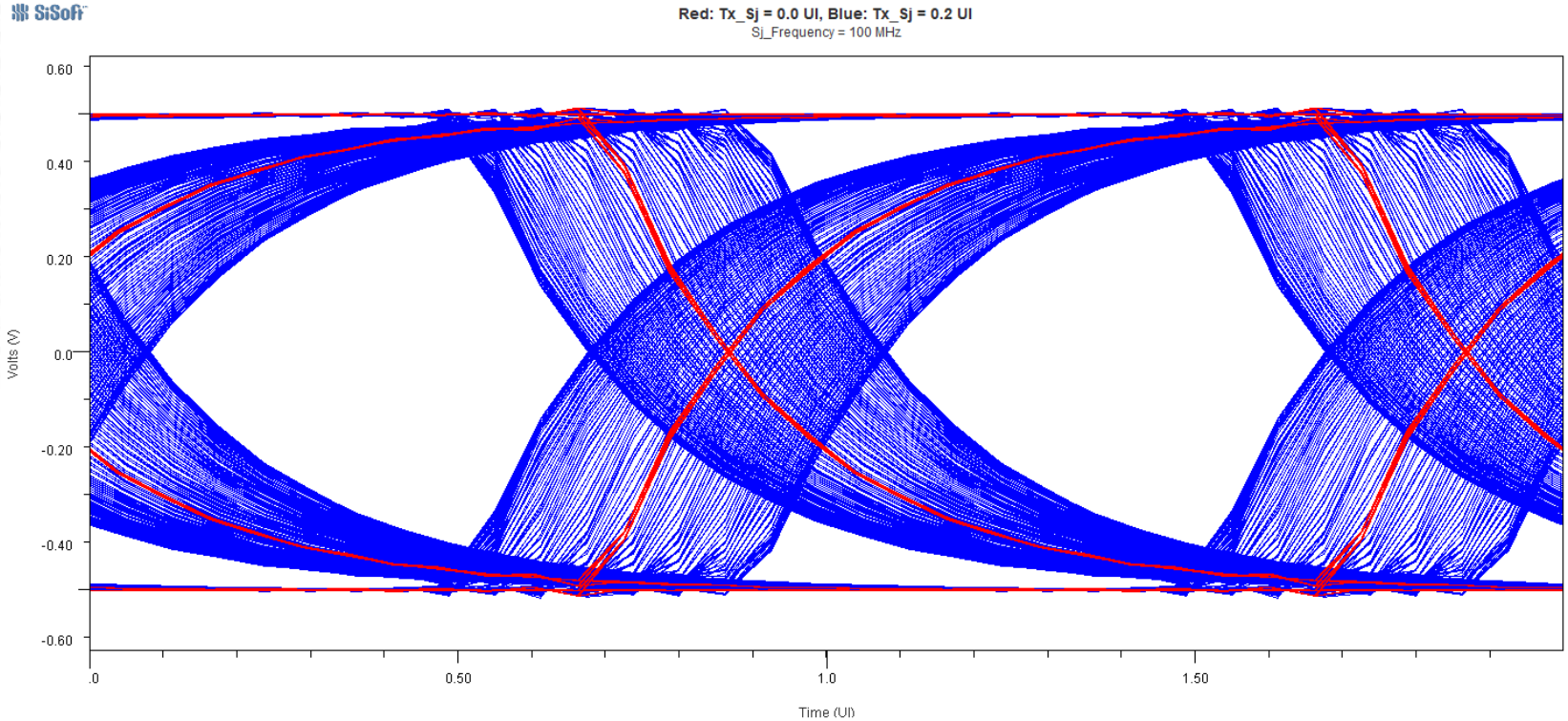


$$Time(n) = n * bit\_time + Tx\_Sj * \sin((n * bit\_time * 2.0 * Pi) * Tx\_Sj\_Frequency)$$

© SiSoft, 2018

SiSoft™
We Are Signal Integrity

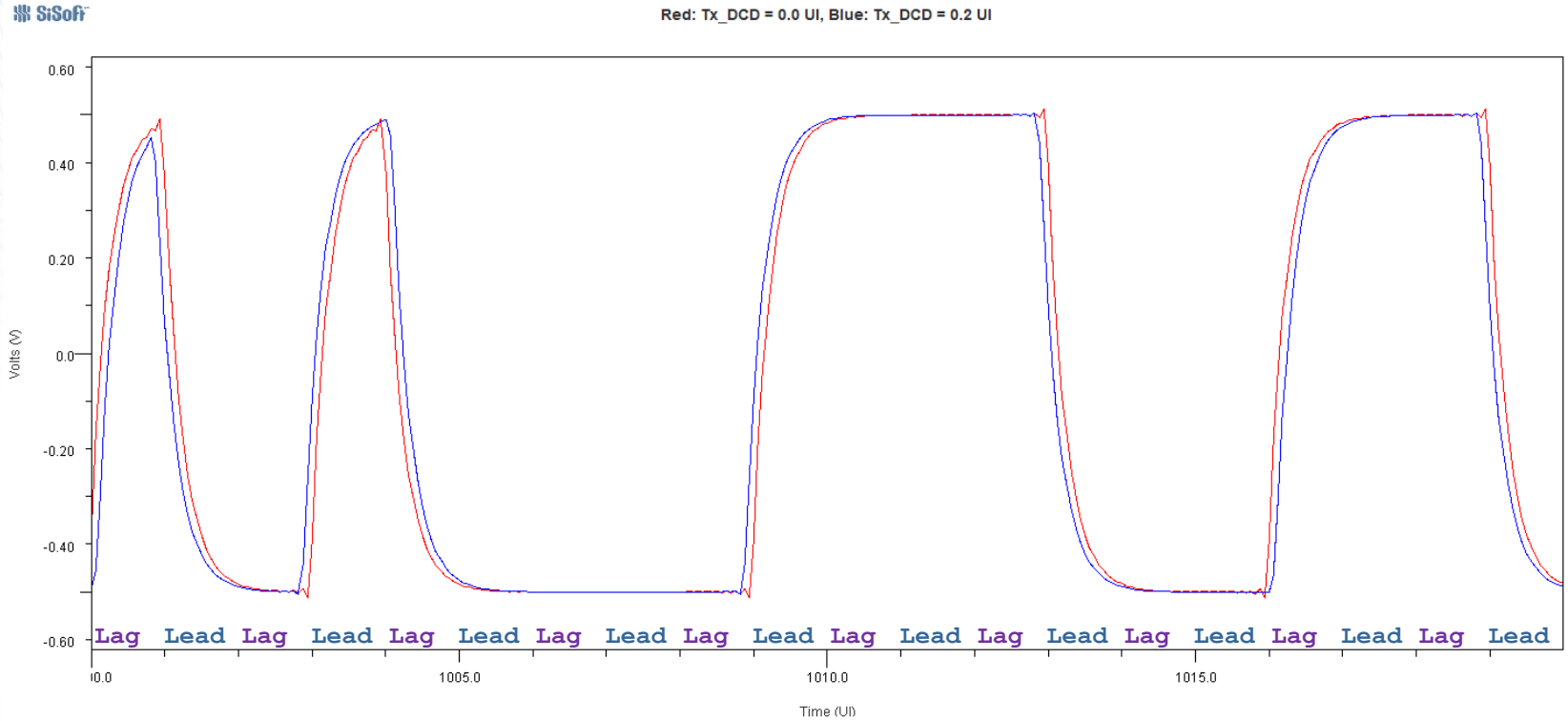
Tx_Sj Jitter Modulating the Tx Output



© SiSoft, 2018

SiSoft™
We Are Signal Integrity

Tx_DCD Jitter Modulating the Tx Output

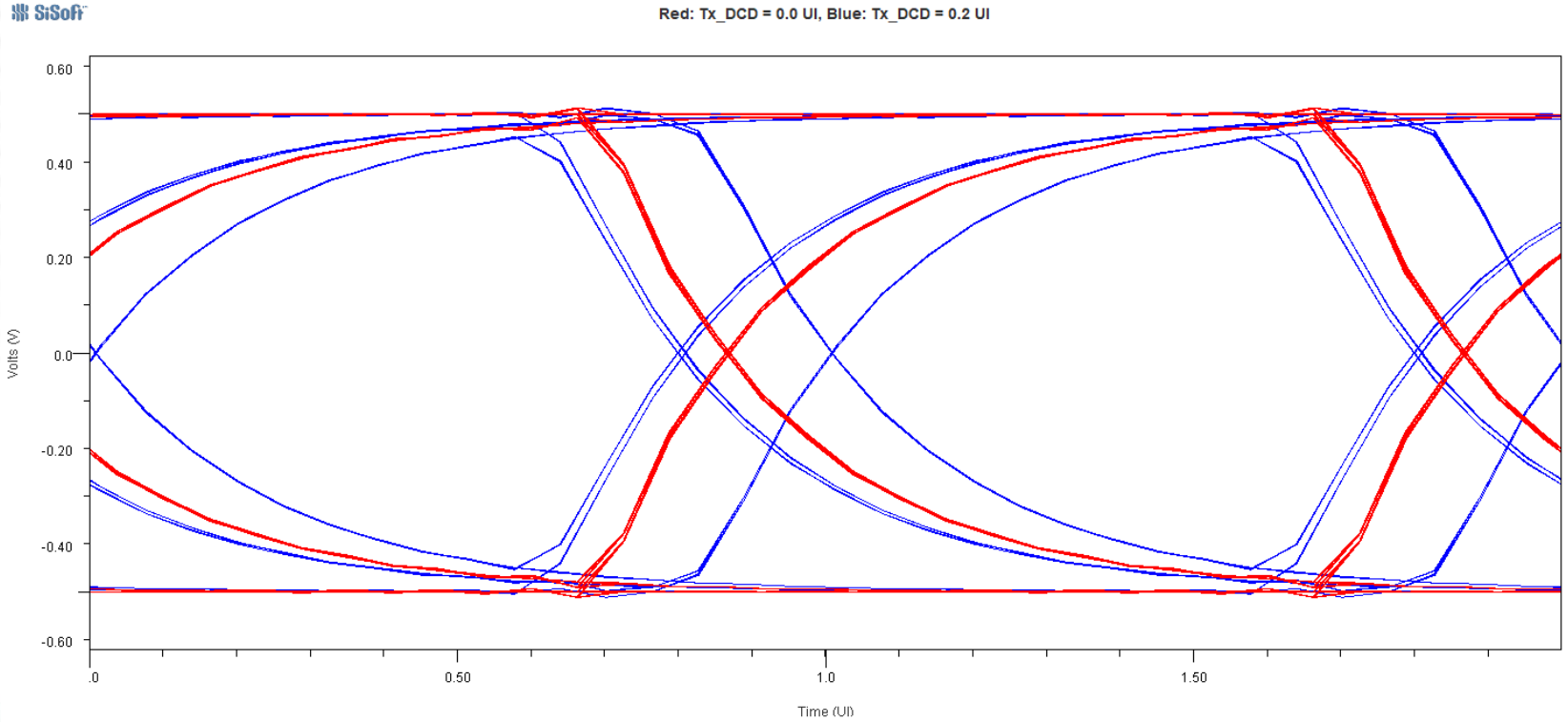


$$Time(n) = n * bit\_time + Tx\_DCD * (-1.0)^n$$

© SiSoft, 2018

SiSoft™
We Are Signal Integrity

Tx_DCD Jitter Modulating the Tx Output

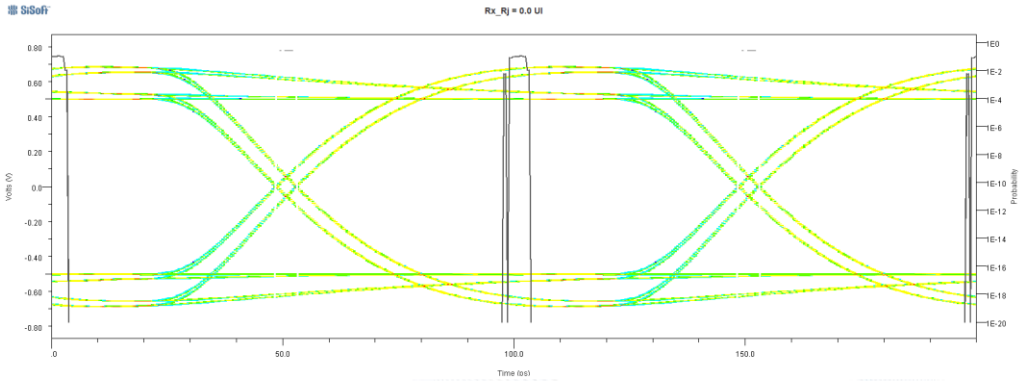


© SiSoft, 2018

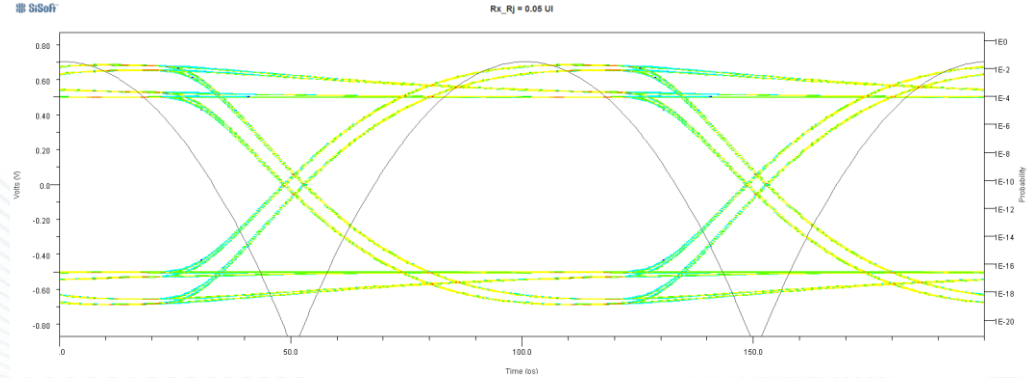
SiSoft™
We Are Signal Integrity

Rx_Rj Modulating the Sampling Clock

- Rx_Rj = 0.00 UI



- Rx_Rj = 0.05 UI

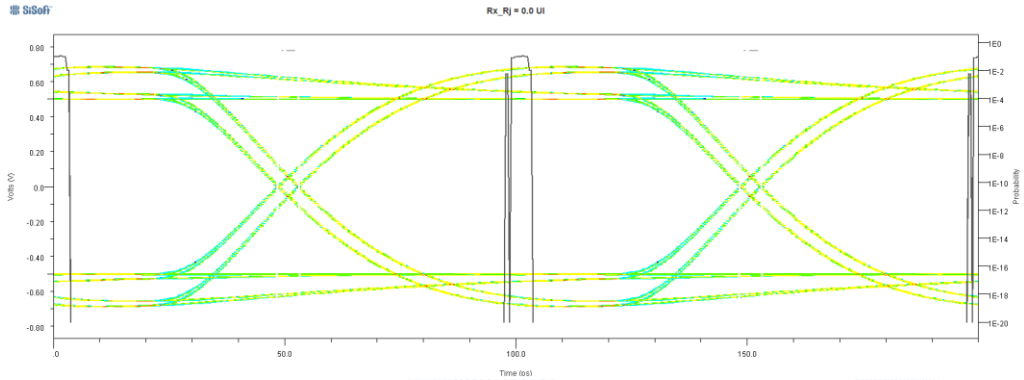


© SiSoft, 2018

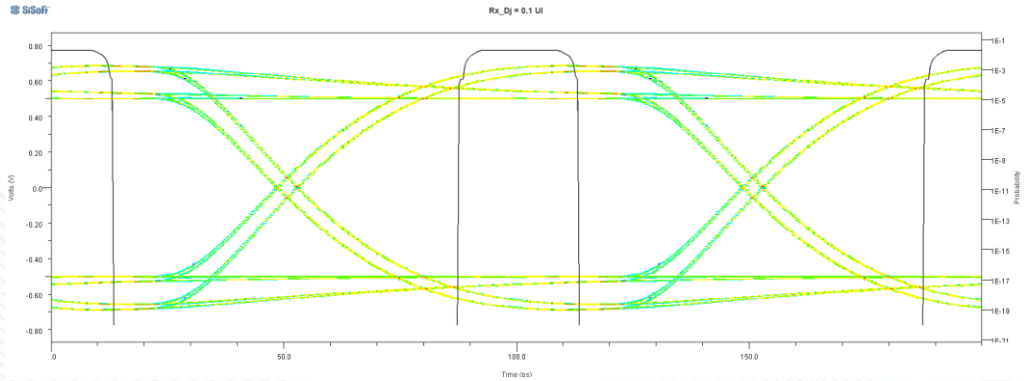
SiSoft™
We Are Signal Integrity

Rx_Dj Modulating the Sampling Clock

- Rx_Dj = 0.00 UI



- Rx_Dj = 0.10 UI

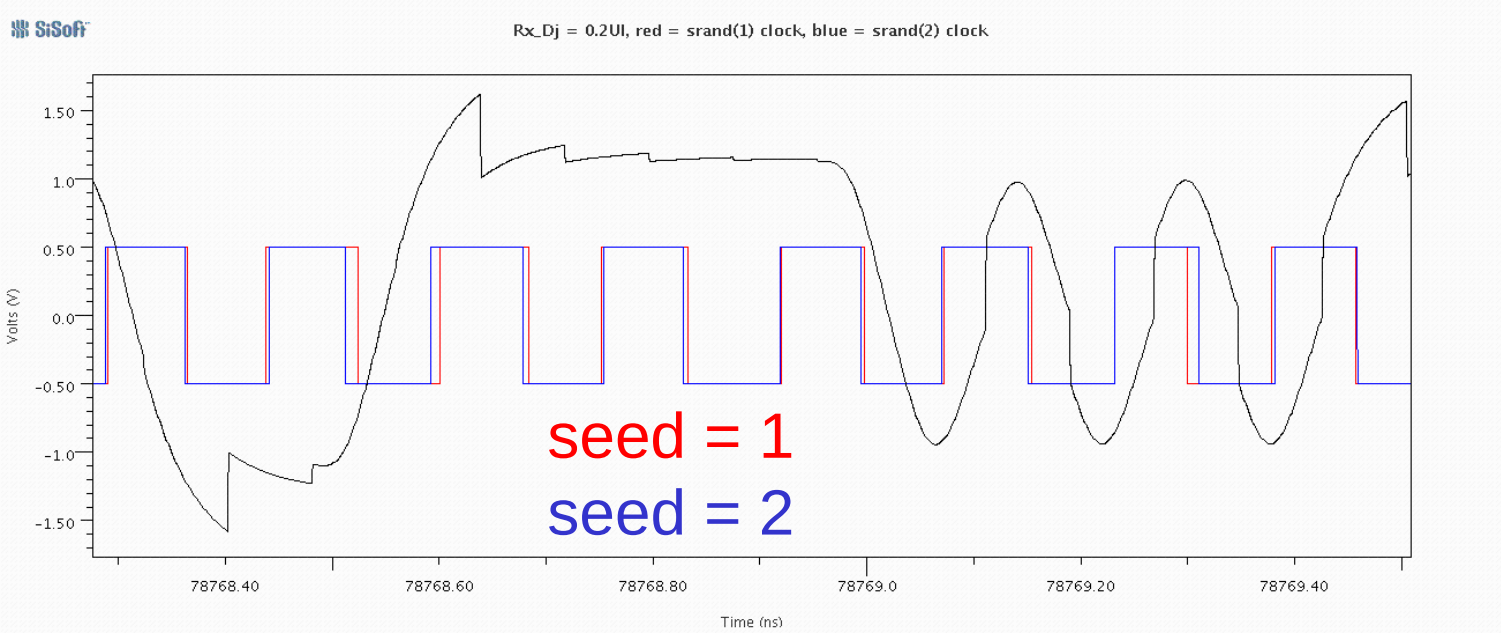


© SiSoft, 2018

SiSoft™
We Are Signal Integrity

Same Rx_Dj, Different Start Points

*actual_time = time + 2.0 * Rx_Dj * rand()* ⟸ Seed value?

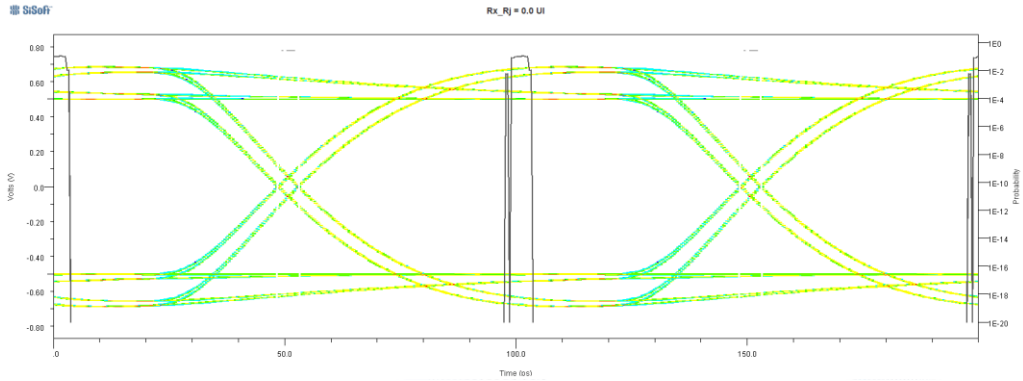


© SiSoft, 2018

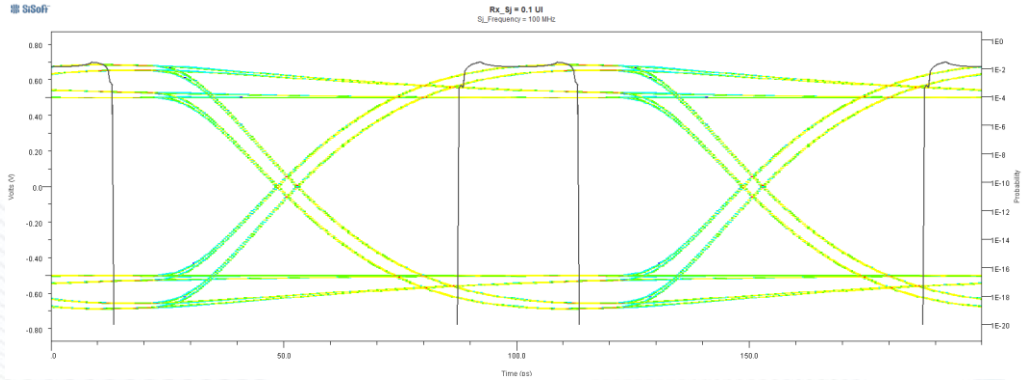
SiSoft™
We Are Signal Integrity

Rx_Sj Modulating the Sampling Clock

- Rx_Sj = 0.00 UI



- Rx_Sj = 0.10 UI

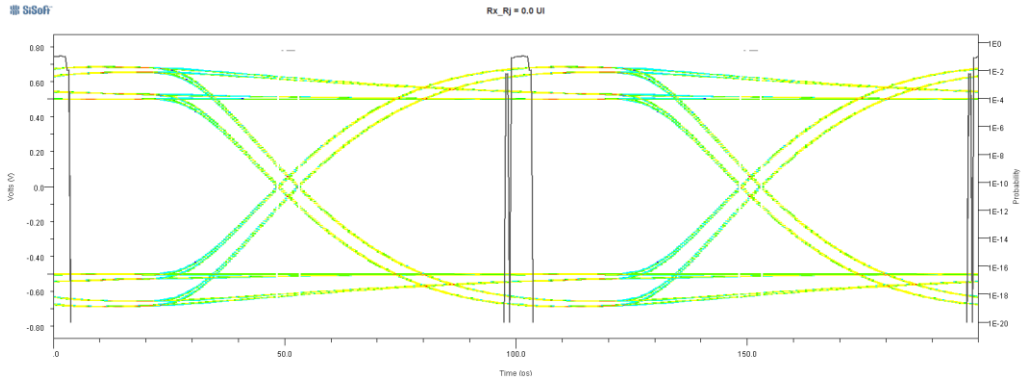


© SiSoft, 2018

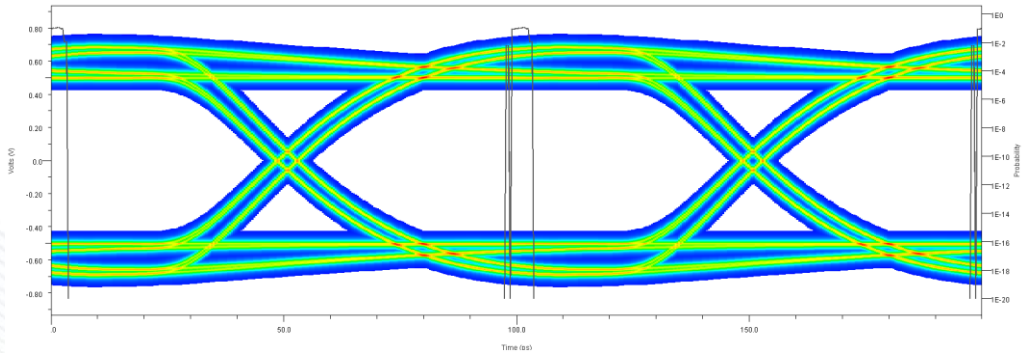
SiSoft™
We Are Signal Integrity

Rx_Noise Modulates the Sampling Latch Input

- Rx_Noise = 0.000 V



- Rx_Noise = 0.005 V

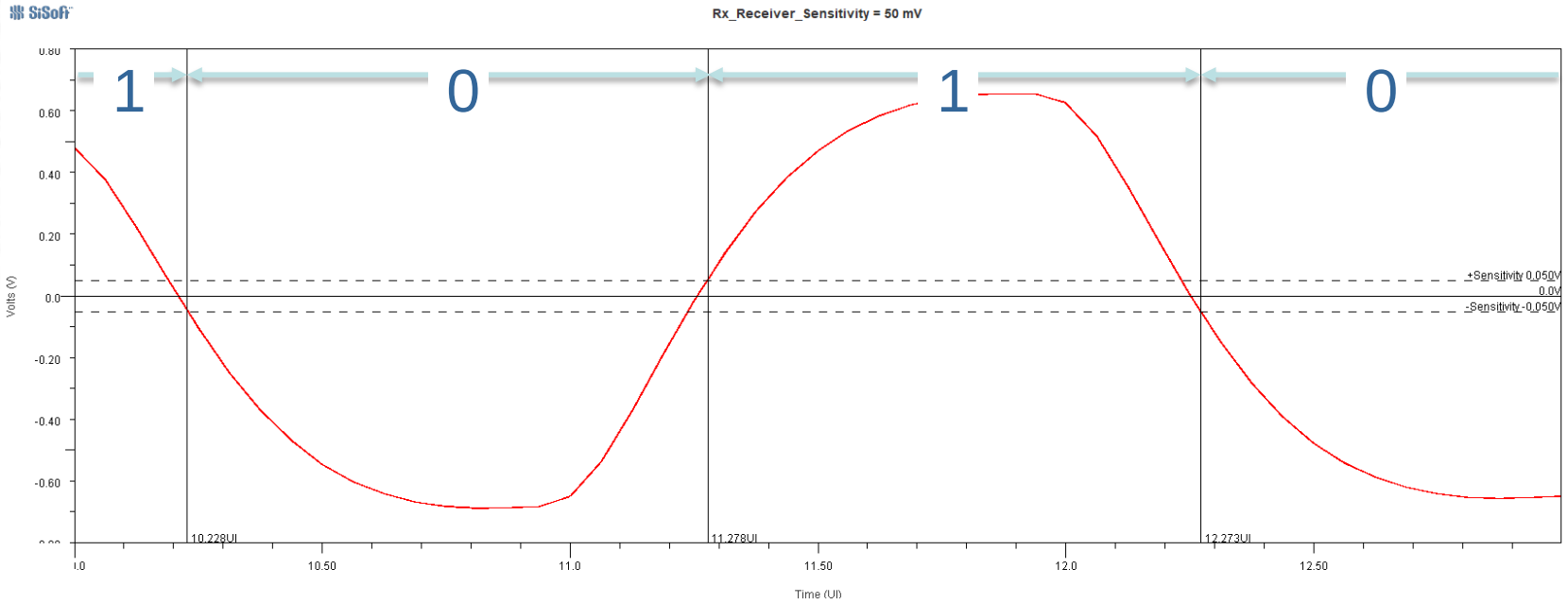


IBIS 7.0 will have Rx_Gaussian_Noise and Rx_Uniform_Noise (BIRD188.1)

© SiSoft, 2018

SiSoft™
We Are Signal Integrity

Rx_Receiver_Sensitivity Models Hysteresis



Voltage at sample latch

SiSoft™ We Are Signal Integrity

The Only IBIS 5.0 Tx Jitter Parameter: Tx_Jitter

```
(Tx_Jitter      (Usage Info) (Type Float)
                (Gaussian 0.2e-12 0.03e-12))
(Tx_Jitter      (Usage Info) (Type Float)
                (Dual-Dirac 3e-12 6e-12 0.5e-12))
(Tx_Jitter      (Usage Info) (Type Float)
                (DjRj 0 6E-12 1.3E-12))
(Tx_Jitter      (Usage Info) (Type Integer Float Float)
                (Table
                (Labels "Row_No" "Time" "Probability")
                        (-4 -4e-12 3e-7)
                        (-3 -3e-12 1e-4)
                        (-2 -2e-12 1e-2)
                        (-1 -1e-12 0.29)
                        (0 0 0.4)
                        (1 1e-12 0.29)
                        (2 2e-12 1e-2)
                        (3 3e-12 1e-4)
                        (4 4e-12 3e-7)))
```

Replaced by:
Tx_Dj,
Tx_Rj,
Tx_Sj,
Tx_DCD

© SiSoft, 2018

SiSoft™
We Are Signal Integrity

The Only IBIS 5.0 Rx Jitter Parameter: Rx_Clock_PDF

```
(Rx_Clock_PDF  (Usage Info) (Type Float)
               (Gaussian 0.2e-12 0.03e-12))
(Rx_Clock_PDF  (Usage Info) (Type Float)
               (Dual-Dirac 3e-12 6e-12 0.5e-12))
(Rx_Clock_PDF  (Usage Info) (Type Float)
               (DjRj 0 6E-12 1.3E-12))
(Rx_Clock_PDF  (Usage Info) (Type Integer Float Float)
               (Table
               (Labels "Row_No" "Time" "Probability")
                       (-4 -4e-12 3e-7)
                       (-3 -3e-12 1e-4)
                       (-2 -2e-12 1e-2)
                       (-1 -1e-12 0.29)
                       (0 0 0.4)
                       (1 1e-12 0.29)
                       (2 2e-12 1e-2)
                       (3 3e-12 1e-4)
                       (4 4e-12 3e-7)))
```

Replaced by:
Rx_Clock_Recovery_Dj,
Rx_Clock_Recovery_Rj,
Rx_Clock_Recovery_Sj,
Rx_Clock_Recovery_DCD

© SiSoft, 2018

SiSoft™
We Are Signal Integrity

Recommendations

- Be cautious using IBIS-AMI models using Rx_Clock_PDF or Tx_Jitter
- Be suspicious of IBIS-AMI models with no jitter parameters at all!
- When viewing eye diagrams, be aware of what your tool is showing you (clock PDF vs. eye smearing)
- Experiment by changing model jitter and noise values, see if the results are expected

© SiSoft, 2018

SiSoft™
We Are Signal Integrity