Advanced Analysis
for High Speed Serial Data Stream

"Advanced Measurements …not only Signal Integrity " *- July2009*

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Agenda

- **BER Contours mapping (Iso-BER)**
  - Concepts
  - Benefits
- **Advanced Signal Integrity Measurements Methods:**
  - **High Speed Serial Data Challenge**
  - **What Bandwidth for Serial Data Signal ?**
  - **Improve accuracy and add precision to measurements :**
    - **De-embedding methods**
    - **Emulating methods**
  - **Equalization** :
    - **Equalized System and Measurement Challenges**
    - **Transmitter emphasis**
    - **Receiver equalization**
  - **Equalization methods combined with jitter measurements**

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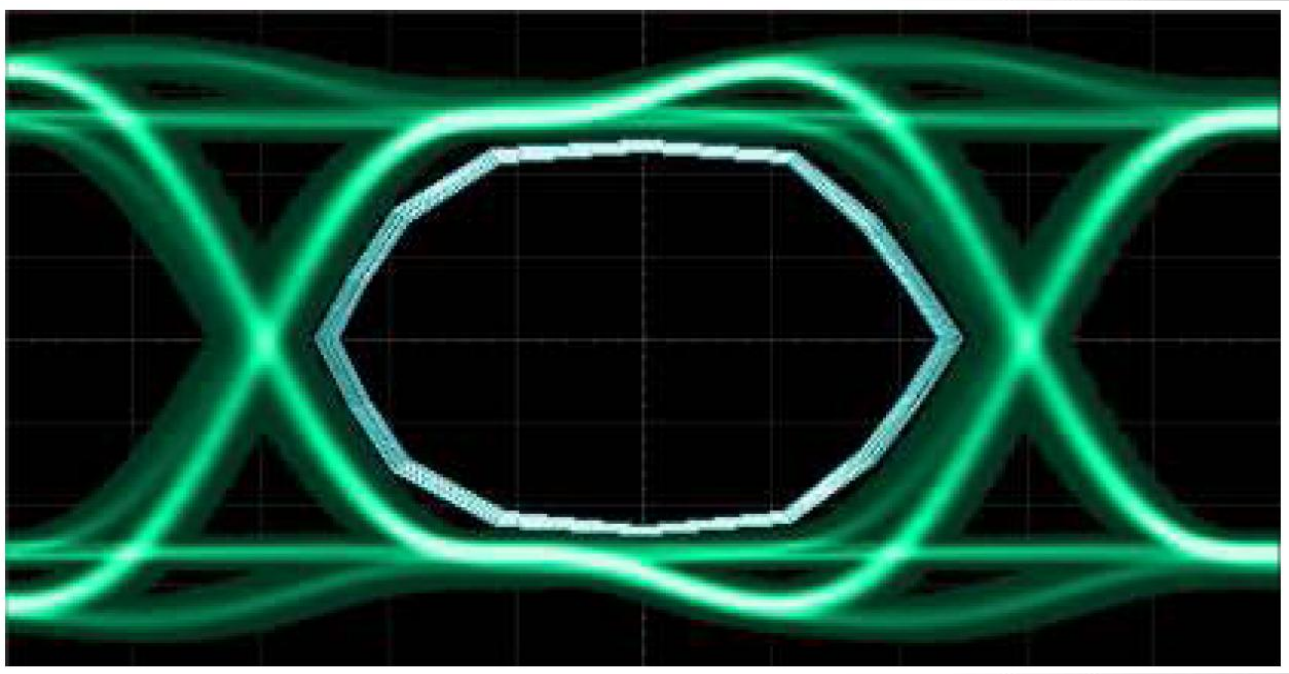
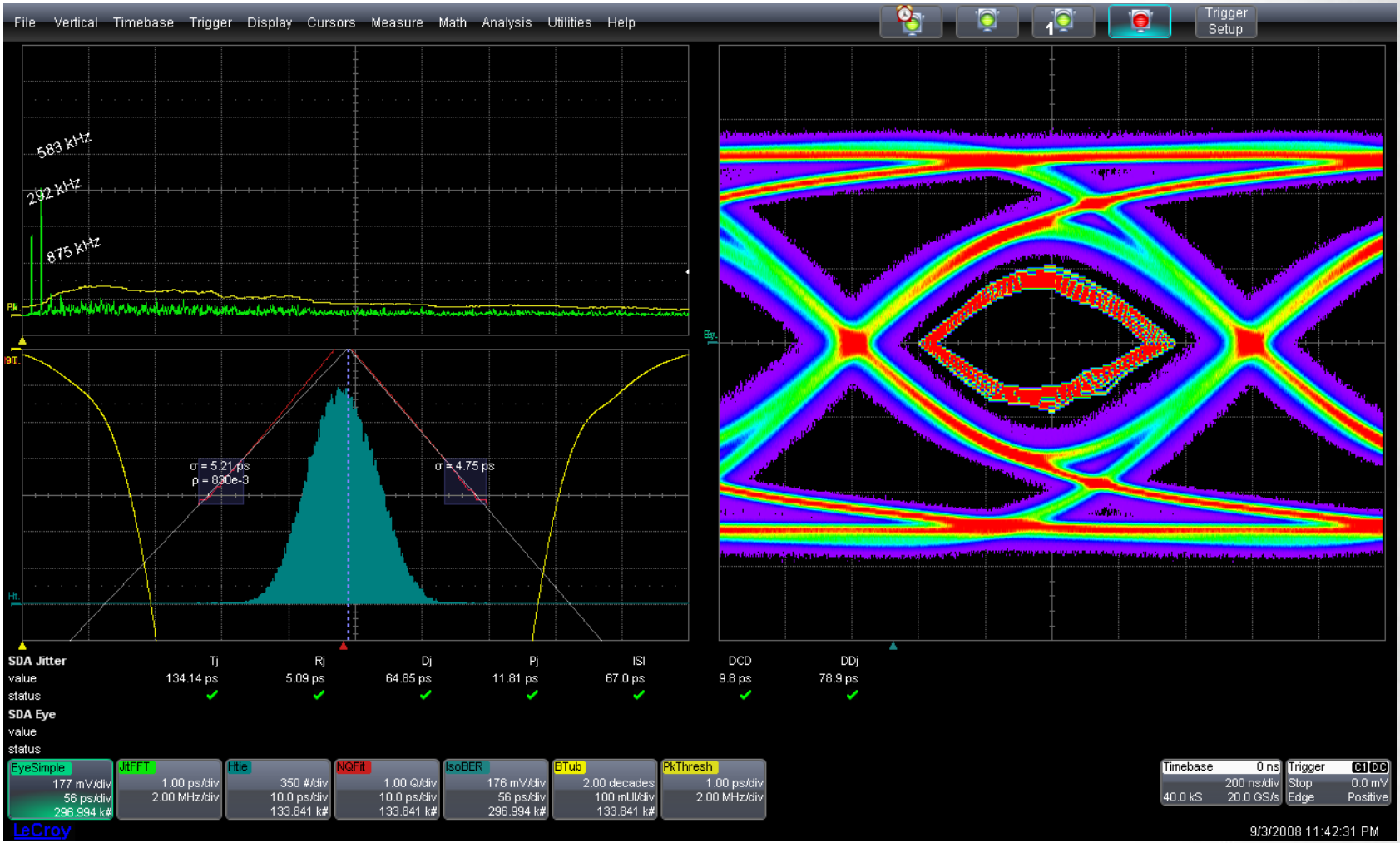
BER Contours mapping (Iso-BER)

- ✓ ***Show the estimated eye closure of the eye pattern after collecting a certain number of UI in the eye pattern (UI=BER^{-1})***
- ✓ ***Allows the ability to measure noise impact on amplitude as well as on jitter***
- ✓ ***Identify always crosstalk design issues:***
  - ✓ *Also in case aggressor transitions are not incident with signal victim transitions and therefore jitter data are not impacted.*



BER Contours displayed from 10^{-6} to 10^{-12}

BER Contours – No Crosstalk



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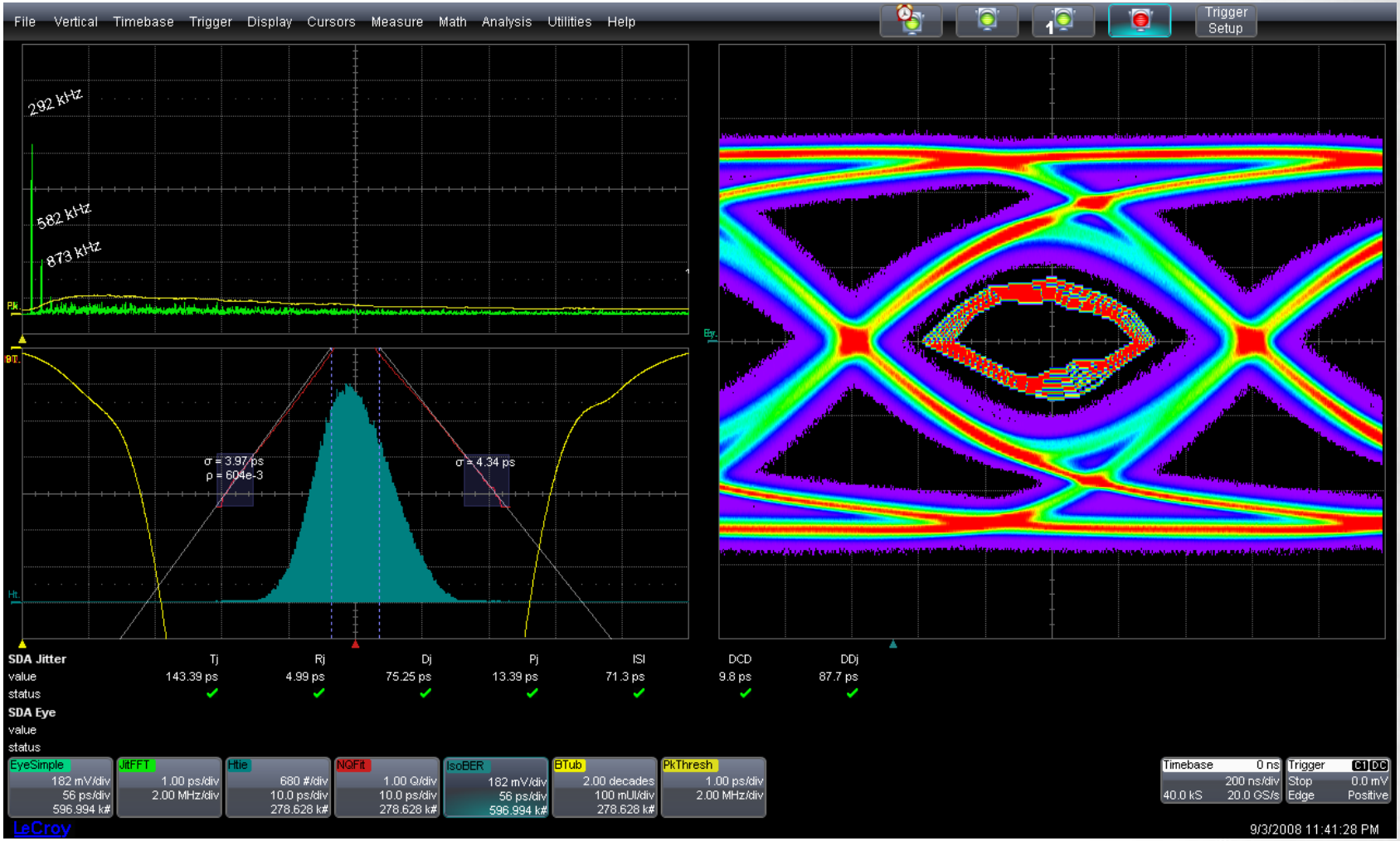
BER Contour With Crosstalk



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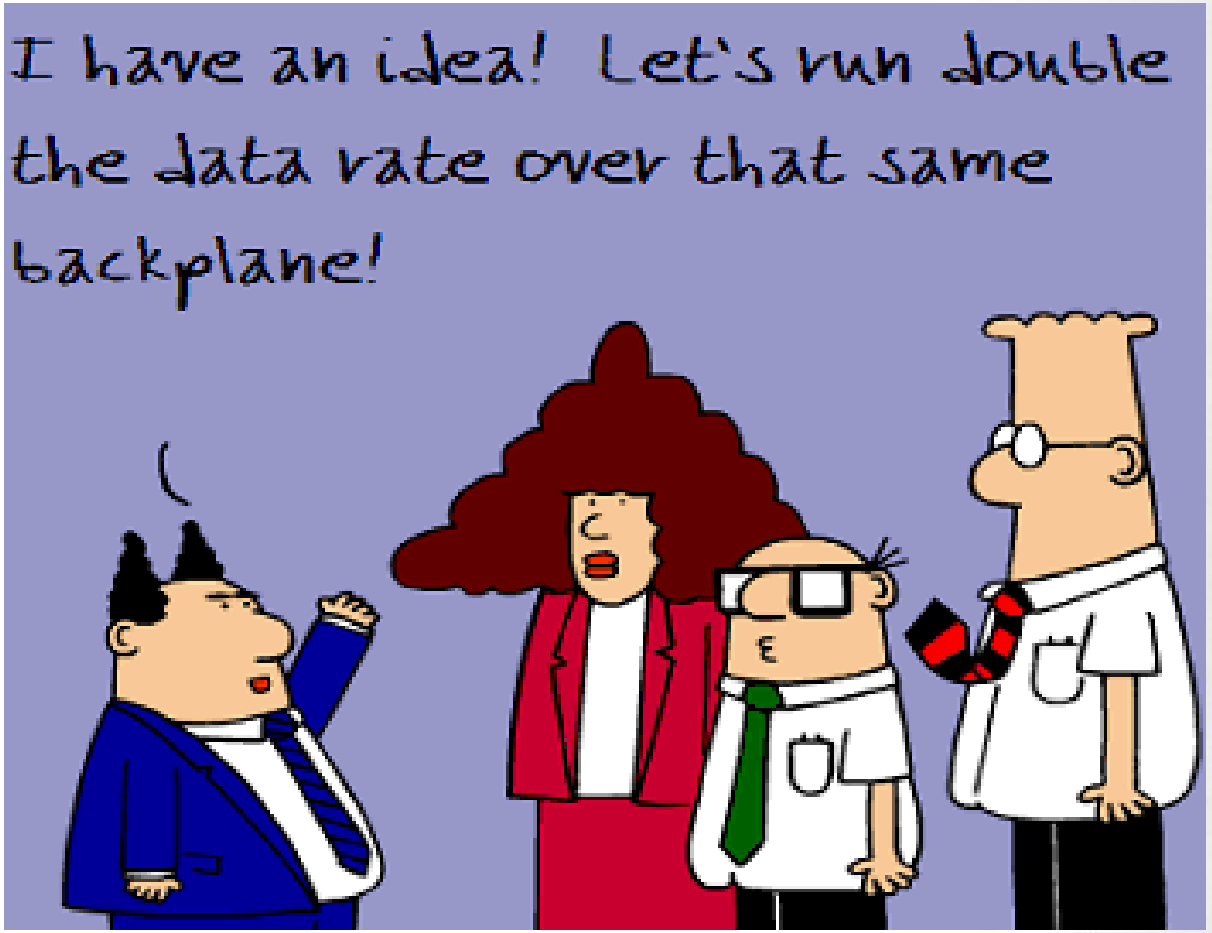
High Speed Serial Data Stream



Signal speeds and data rates have increased into the frequency range while propagation mediums remained unchanged !

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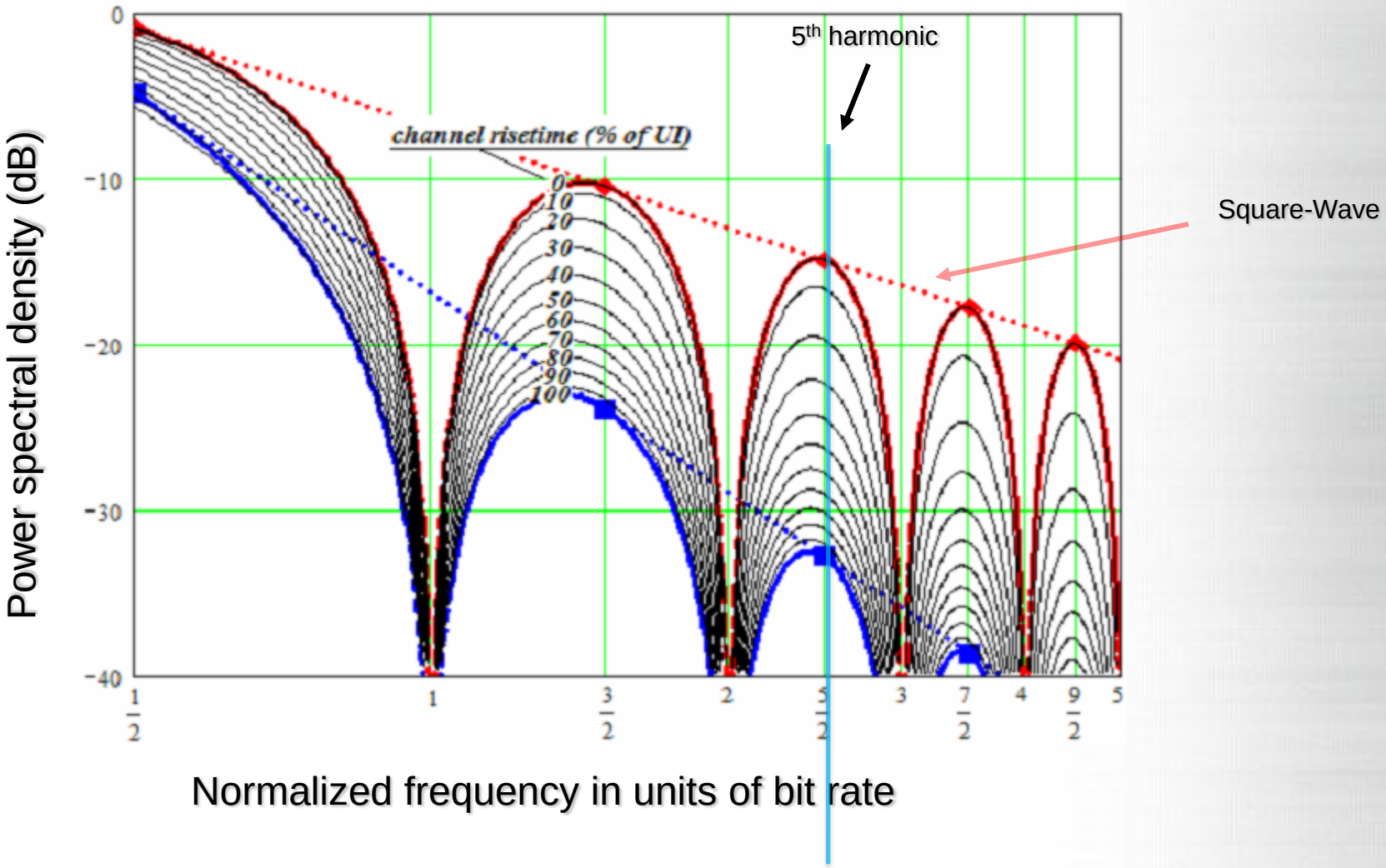
Serial Data Signal Frequency Content
depends on bit rate and rise time



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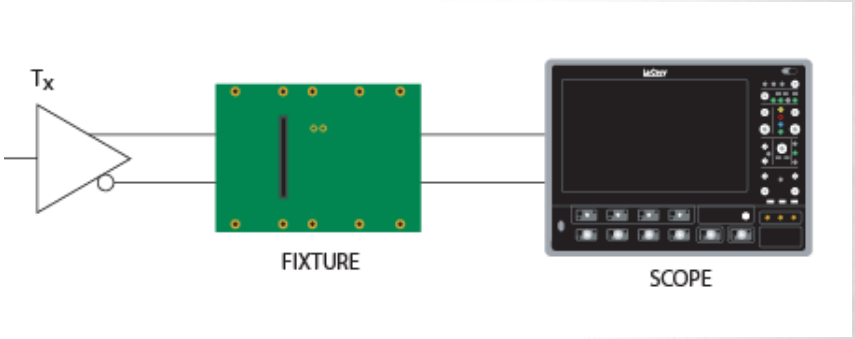
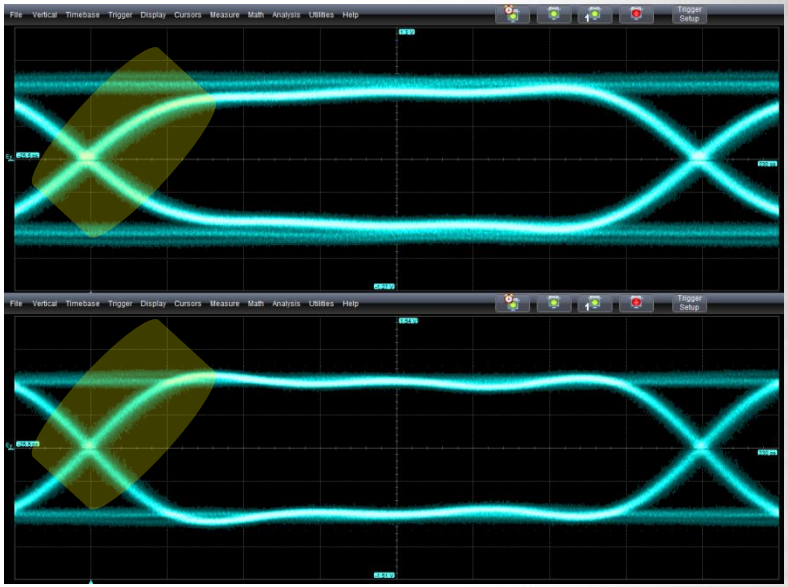
Cable/Fixture/Serial Data Channel
De-embedding

- ***De-embedding gives the user the ability to view their waveforms as if the cable/fixture/serial data channel was not present.***



- ***Cable/fixture/serial data channel effect is defined by user-supplied S-parameter file.***

- ***Should be always done when frequency content is increasing into the microwave range***



Cables and fixture de-embedding effects on a PCIs Gen 2 signal

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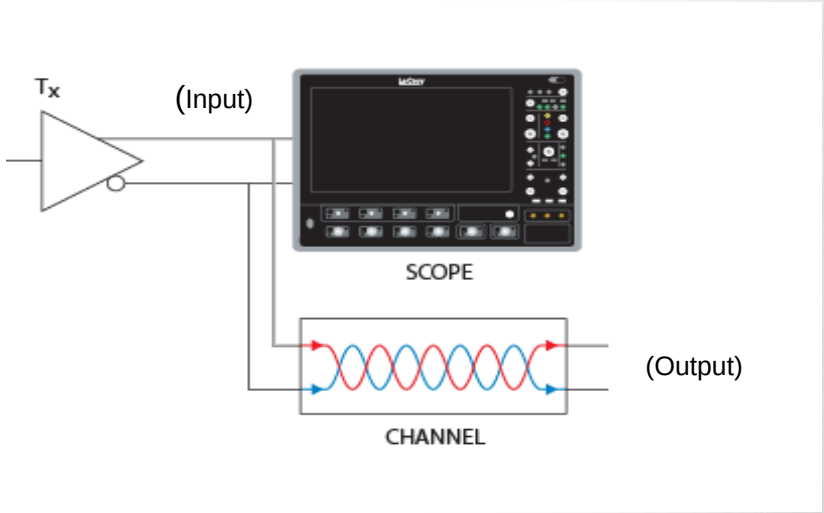
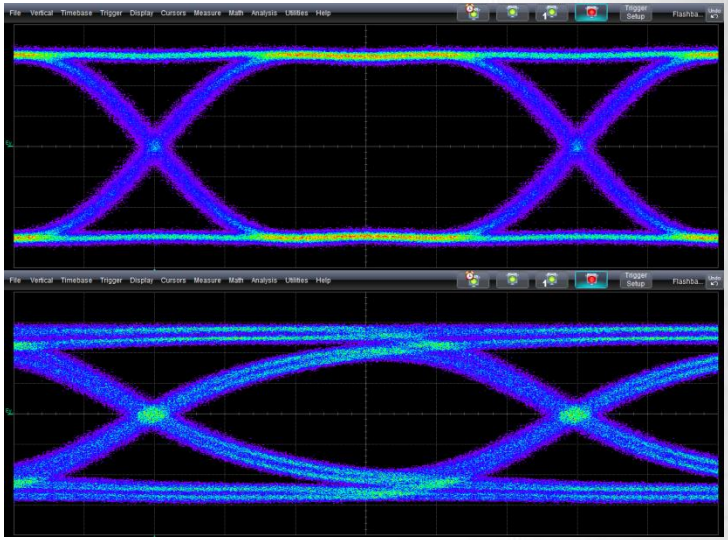
Serial Data Channel Response
Emulation

- ***Channel emulation gives the user the ability to view their waveform as if it were passing through a serial data channel that isn't present.***
- ***The channel effect is defined by a user-supplied s-parameter file.***
- ***Useful to model worst-case scenarios and understand how design margins are maintained in those situations***





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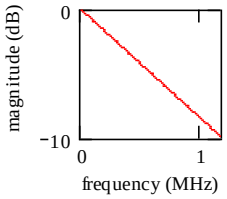
Equalization (simplistic view)

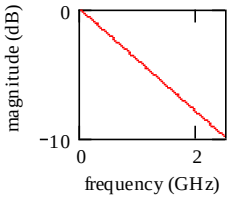
$$Q = \left[\frac{loss}{length \cdot frequency} \right]^{-1}$$

$$speed \cdot length = loss_{acceptable} \cdot Q$$

- ✓ ***For a given frequency, loss is proportional to length***
- ✓ ***For a given length, loss is proportional to frequency.***
- ✓ ***Channel quality depends on loss characteristics vs. frequency and length***

$$2.5 \cdot GHz \cdot 30 \cdot in \approx 1 \cdot MHz \cdot 1 \cdot mi$$





- ✓ ***Serial Data Equalization is using same methods used previously in the telecommunication at longer distance :***
  - ✓ *2.5 GHz over 30 in. is equivalent as 1 MHz over 1 mi. (1.6 Km)*

Equalization increases the acceptable loss number, thereby increasing either speed or length or both,

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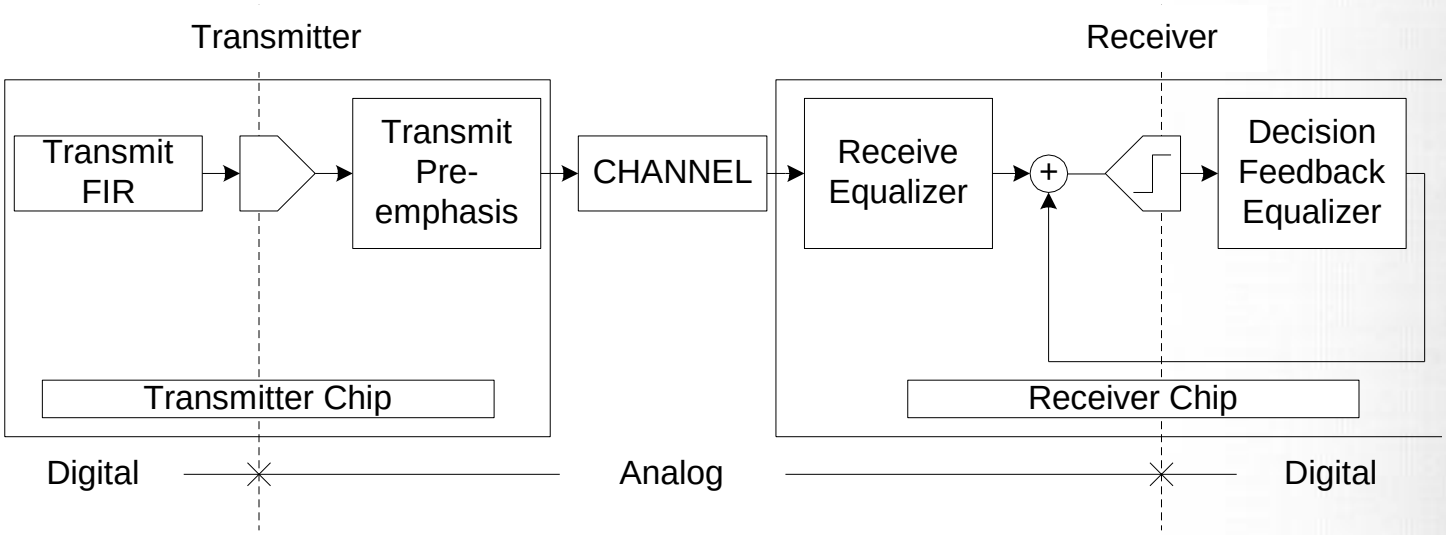
Equalized System



- ✓ **Transmit pre-emphasis pre-distorts TX signal in order to compensate in anticipation the channel degradation**
- ✓ **Linear receive equalization (FFE or CTLE) compensates channel degradation at the receiver**
- ✓ **Decision feedback equalization (DFE) change dynamically the ideal threshold level based on previous decoded data**

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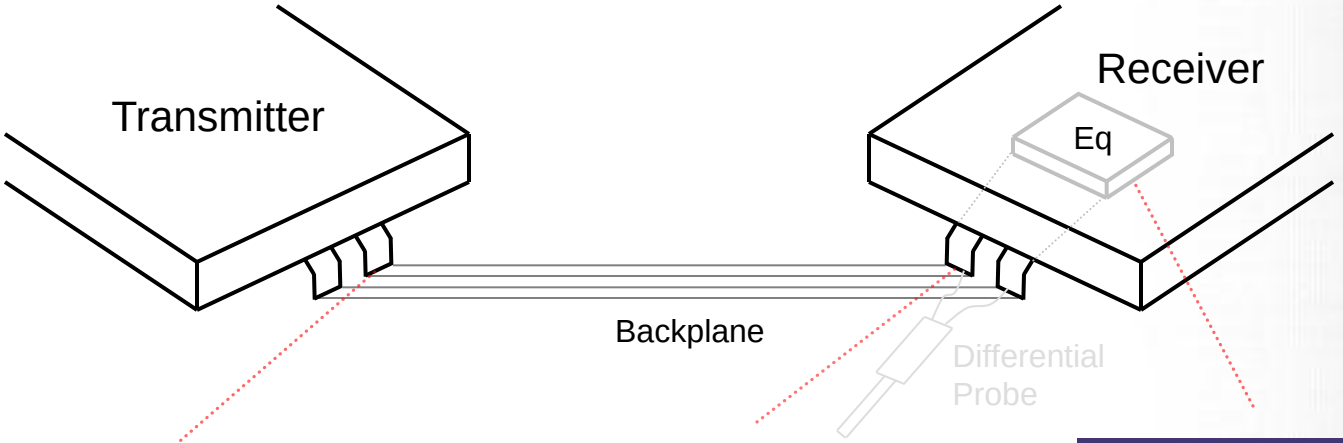
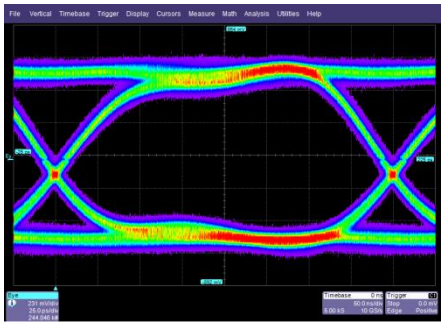
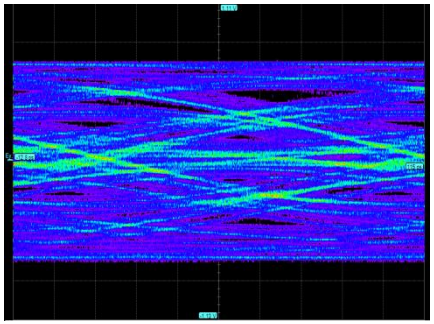
Equalized System Measurements Challenge

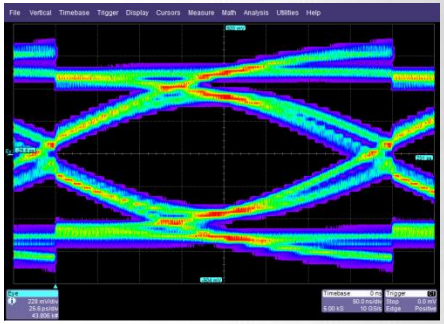




For very fast data rates (>5 Gb/s), the transmitter signal typically has very good signal integrity. However, after propagating through the backplane, this signal will become severely degraded.



At the far end of the channel, the eye is closed. The signal at the receiver pins (which can be probed) is not the signal of interest. The equalized signal inside of the receiver chip (which cannot be probed) is the signal of interest.



The equalized signal within the receiver chip cannot be probed. How can this signal be validated to ensure low jitter, a clean eye pattern, and good signal integrity?

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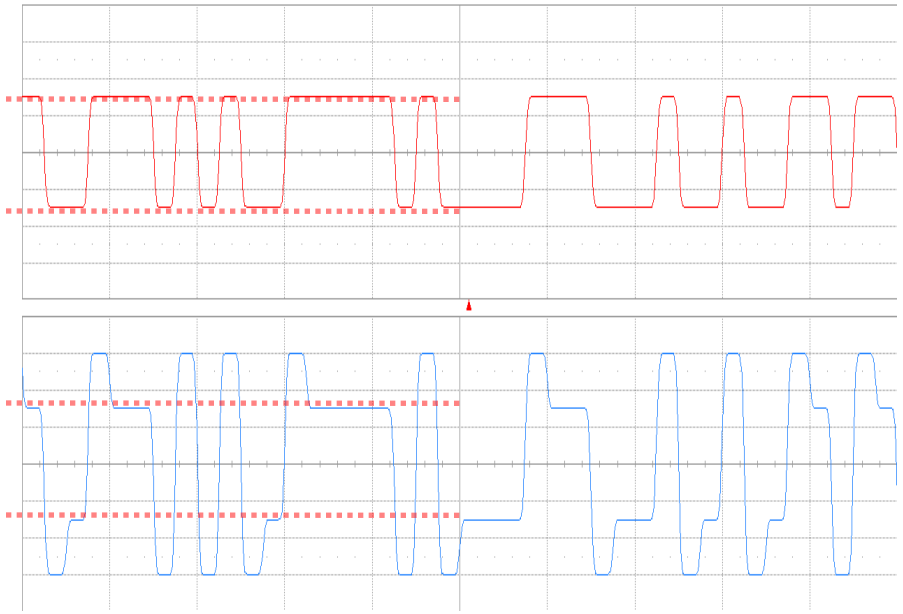
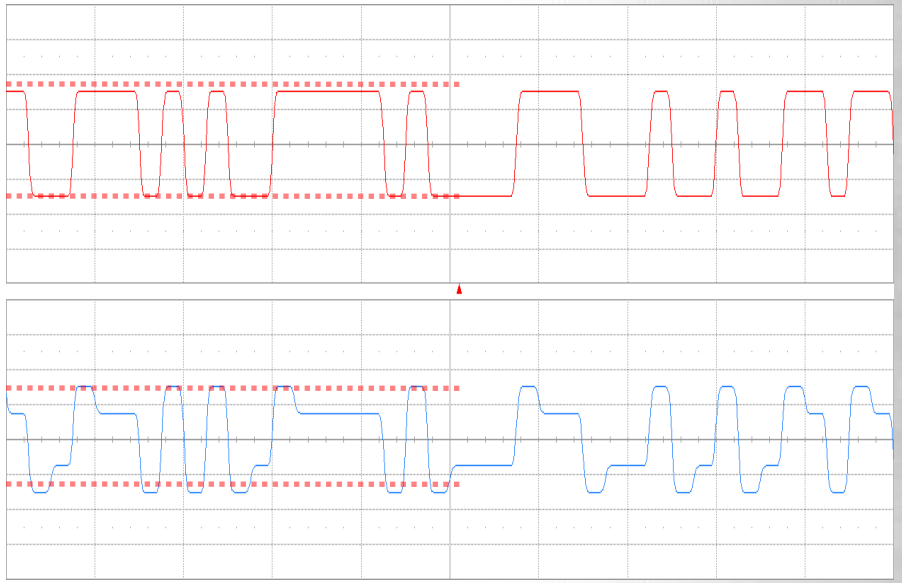
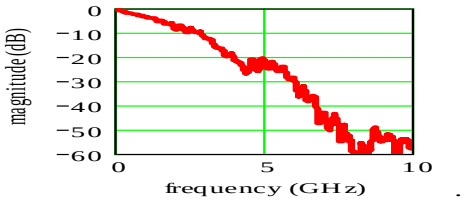
Transmitter Emphasis



***Pre-Emphasis** boosts the high frequency components while leaving the low frequency components unchanged*

***De-Emphasis** attenuates the low frequency components while leaving the high frequency components unchanged*





Transmitter designers employ the use of emphasis to pre-compensate the disproportionate impact on the high frequency content of the serial data channel

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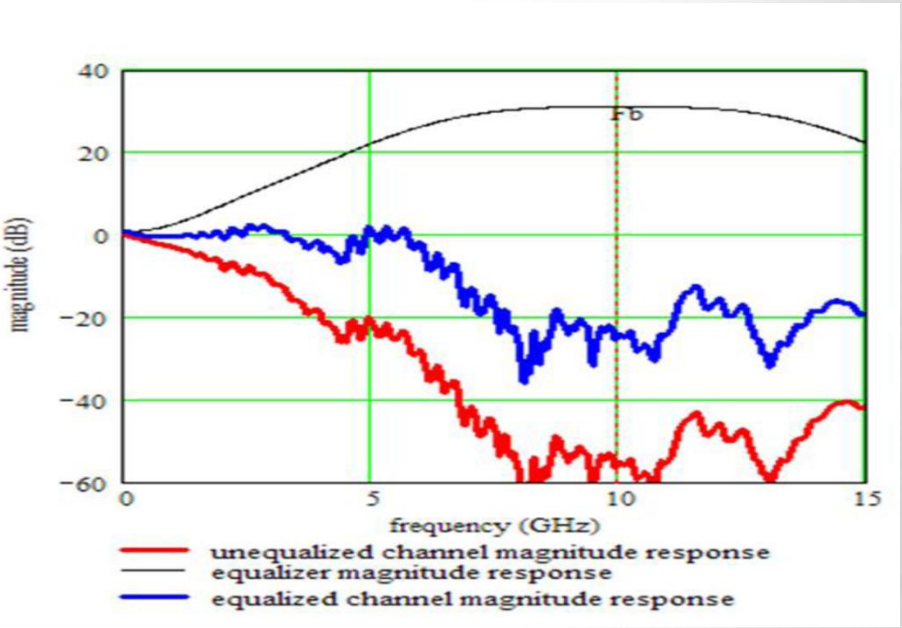
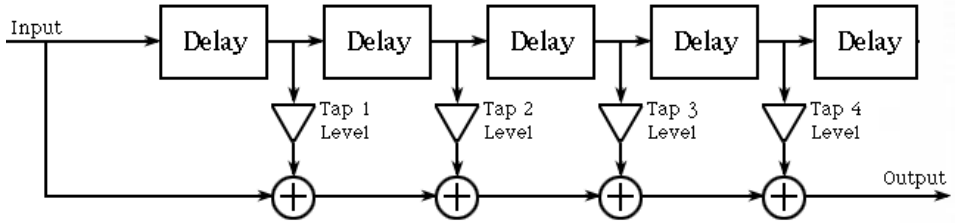
Feed Forward Equalization (FFE)

Receiver Equalization

- ✓ *Hinted at , from the frequency response , compensate frequency loss of the serial data channel*
- ✓ *Corrects the received waveform voltage value using previous values and not decoded data (DFE).*
- ✓ *Delay is usually 1 UI*
- ✓ *Tap value is the gain of the amplifier in that stage*
- ✓ *Each stage is then added together to create the output waveform*





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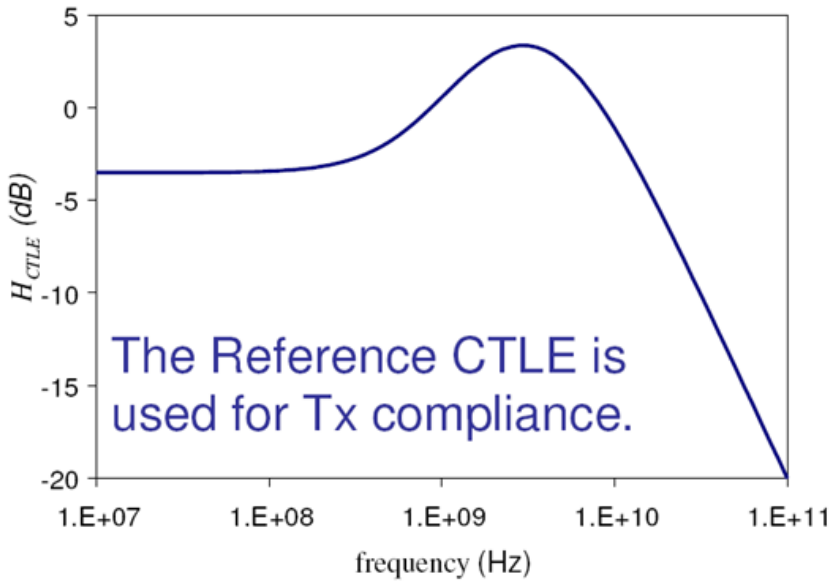
Continuous Time Linear Equalization (CTLE)

- ✓ *Emphasize the high frequency content on the receiver side*
- ✓ *CTLE Auto Mode allows the user to specify the amount of boost in dB*
- ✓ *CTLE Custom mode allows the user to define DC Gain, Zero, Pole 1 and Pole 2 Frequencies*



Ref CTLE Parameters

DC Gain	-3.5dB
AC-DC Gain	6.9dB
Gain BW	10 GHz
f_{zero}	650 MHz
f_{p1}	1.95 GHz
f_{p2}	5 GHz

**Image source USB-IF*

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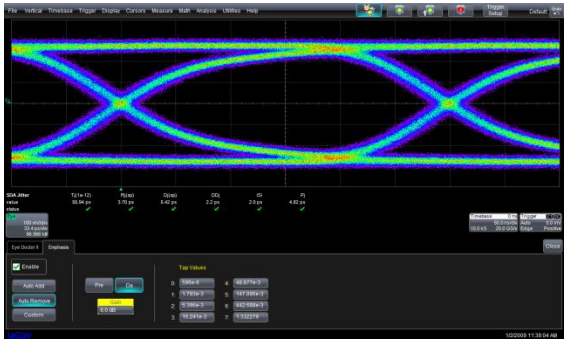
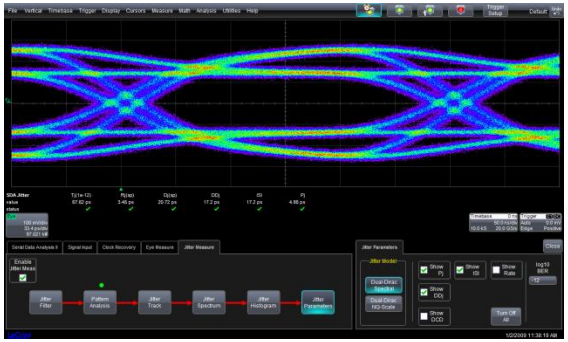
Equalization
and Jitter Measurements

- Extend Jitter and Eye pattern analysis to equalized systems
- Allows full signal integrity measurements made from a “receiver eye view” :
  - Jitter and Eye measurements representative of actual system performance
  - Accurate Performance Margin measurements on the receiver signal
- Tell you what the jitter looks like under various equalized situations
- How much equalization is required for how much ISI reduction ?
- How much equalization is increasing Rj (Noise) ?
- What the transmitter jitter looks like without pre or de-emphasis ?





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