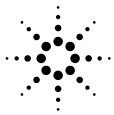

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2004 High-Speed Digital Design Seminar

Presentation 3

Characterizing Jitter in High Speed Buses

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Characterizing Jitter in High-Speed Digital Buses

Why Jitter?

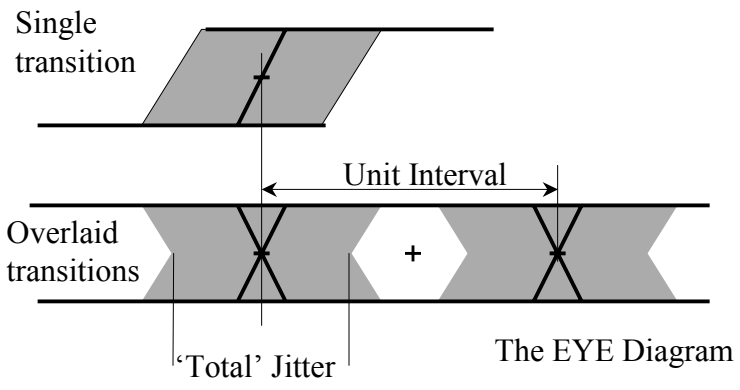
- Digital Data Transport = high speed serial
- Timing Margins are Thin
- Functional --> Parametric
- Ensure Bit Error Ratio
- Need Actionable Insight

Agenda

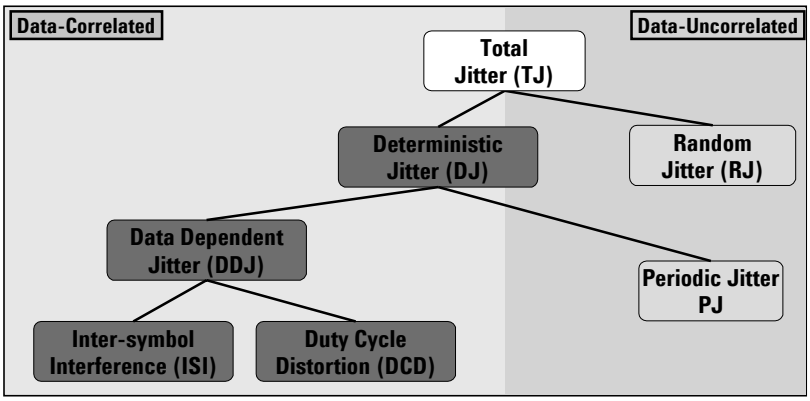
- Quick Review of Jitter
- Creating a Jitter Transmitter
- What's driving Jitter specs?
- New RJ/DJ measurement tools
- Measurement examples
- Summary/Q&A

Jitter

- A Measure of the time variation of the significant instances of a digital signal from their ideal positions in time.



A Jitter Taxonomy



Page 5

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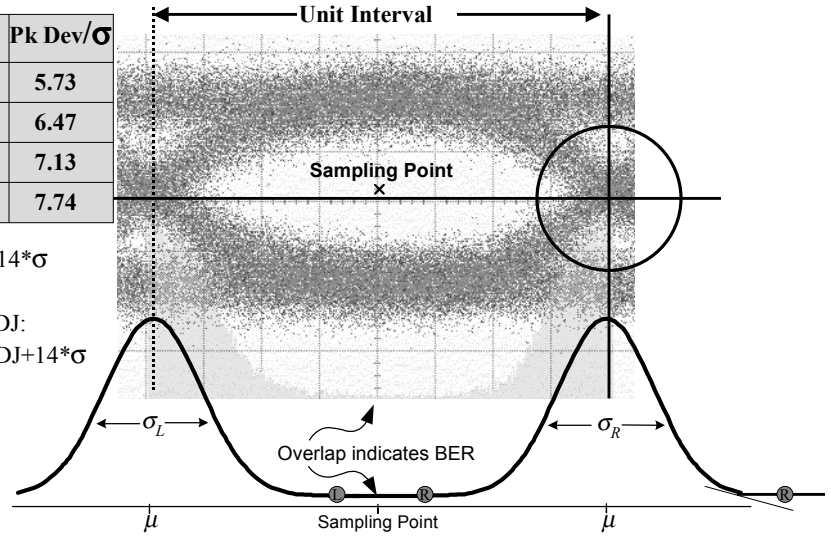
Jitter and BER

BER	Pk Dev/σ
$1x10^{-8}$	5.73
$1x10^{-10}$	6.47
$1x10^{-12}$	7.13
$1x10^{-14}$	7.74

$TJ_{est}=14*\sigma$

With DJ:
$TJ_{est}=DJ+14*\sigma$



Page 6

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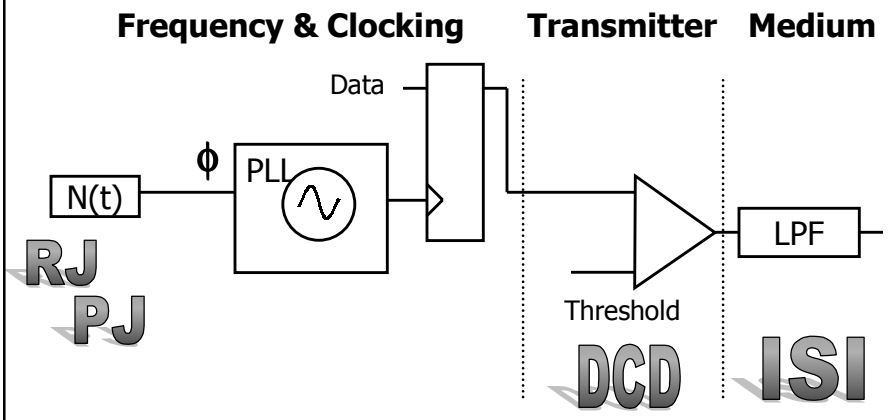
Jitter in a System: a Model



Page 7

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Agenda

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Page 8

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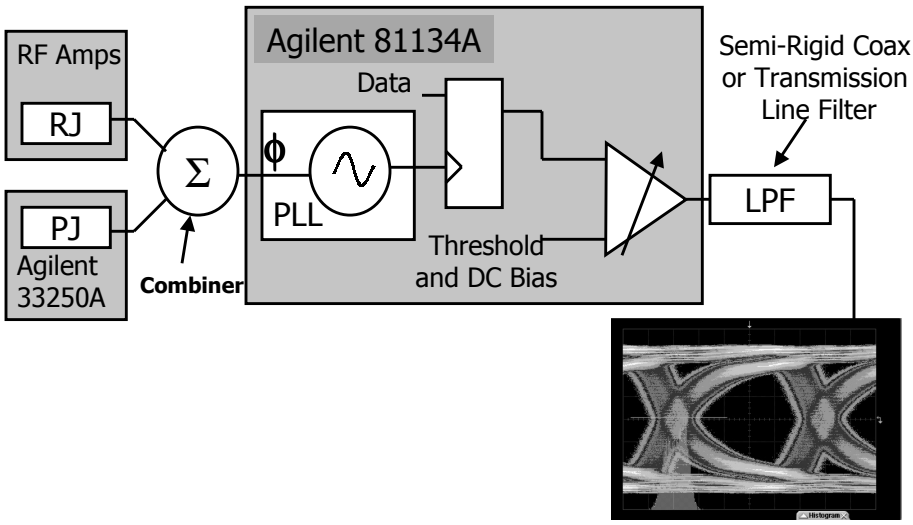
A Jitter Source



Page 9

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Key Question

- **How do you know what you have??**

  - **Answer #1: Use Agilent Timing Interval and Jitter Analysis Software**

  - **Answer #2: Use fundamental Measurements and own statistical analysis**

Page 10

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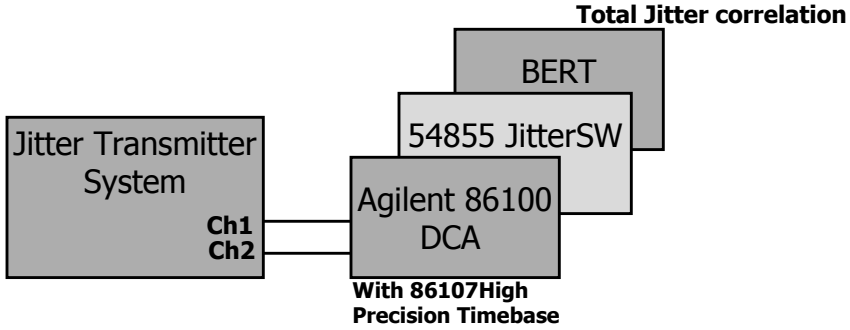
Jitter Transmitter Cal and Performance

- What is the Accuracy of RJ and DJ in any given state?
  - What is the Intrinsic or Residual Jitter?
  - How much contribution to RJ do you get from DJ sources?
  - How much DJ do you get from RJ source?
  - What is the interaction of the DJ sources?



Page 11 Agilent Technologies

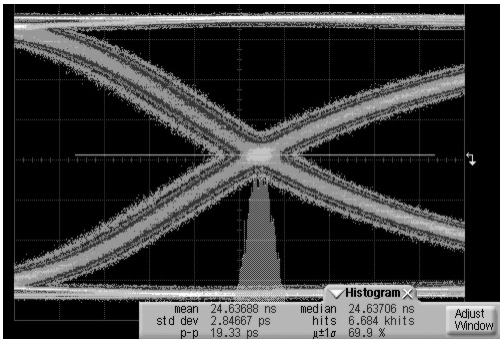
Calibration Process

1. Quantify Jitter Transmitter Residuals
   a. RJ
   b. DJ
2. Evaluate RJ only source
   a. Multiple values of RJ
   b. Evaluate Histogram Shape
      1. Evaluate sigma (σ)
      2. Evaluate Undesired DJ
3. Evaluate Deterministic each Jitter Source
   a. Multiple values of DJ
   b. Consider Potential for interaction with other sources
   c. Evaluate Histogram Shape
      1. Change in Baseline sigma
      2. DJ Evaluation

Page 12 Agilent Technologies

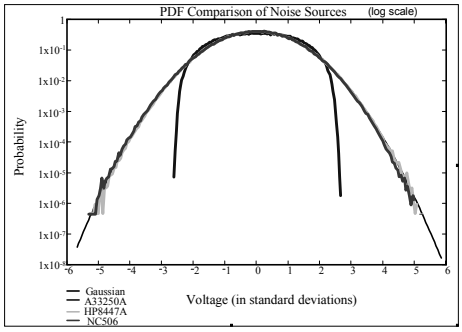
Process Example: all jitter sources

- Baseline
  - σ = 2.7 ps
  - DJ = 4.8 ps



Process Example

- RJ Source
  - Must choose source carefully



Low Level: σ = 4.1 ps
DJ = 4.8 ps

High Level: σ = 10.6 ps
DJ = 4.8 ps

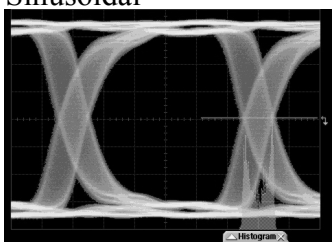
Process Example

- Periodic Source

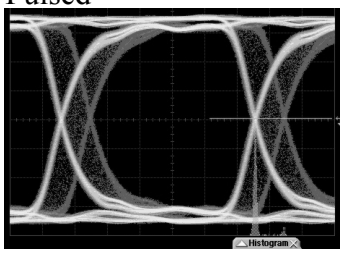
  Low Level
  - σ = 2.7 ps
  - DJ =17.5 ps

  High Level
  - σ = 2.7 ps
  - DJ = 63.5 ps

Sinusoidal



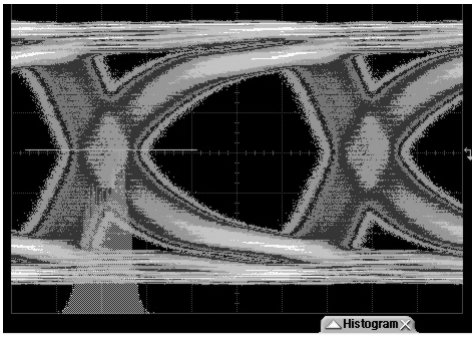
Pulsed



Process Example

- All combined

  PJ=63.5
  DDJ=28.2
  DCD=35.1
  - σ = 10.6 ps
  - DJ = 154 ps



- Total Jitter:
  - TJ_{BERT}= 253 ps
  - TJ_{EST} = 302 ps !

Agenda

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Real-Time Oscilloscope Measurements

- MJSQ[1] standards recommendations on jitter measurement test equipment
- Real-time oscilloscope vs. BERT
  - Capture of V vs. t data
  - Capture of threshold time-tags only
  - Statistical differences in wall-clock time
  - Jitter debug with additional views

[1] "Fibre Channel Methodologies for Jitter and Signal Quality Specification", T11.2 / Project 1316-DT/ Rev 12.0
ftp://ftp.t11.org/t11/pub/fc/mjsq/03-042v3.pdf

Real-Time Oscilloscope Measurements

- Bottom-line is accurate estimate of TJ at specified BER level
- Acquiring enough data to measure a 10^{-12} BER would take a lot of time
- What if we could estimate RJ/DJ accurately to predict TJ?
- Extracting RJ and DJ
  - Curve fit of histogram
  - Spectrum analysis

Real-Time Oscilloscope Example

2.5Gbps PRBS Pattern 31-bits (2^5-1)

- Capture 1Mpts of data at 20GSa/s
- 50μs/400ps = 125,000 UI~1000 patterns
- Calculate confidence level:
  - For no errors, acquire 3.84/BER UI for 95%
  - Example: 125,000 UI per acquisition
    - 3.84^{12} / 125,000 = 30,072,000 acquisitions
    - This would take over 3 days!

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Amherst Systems Associates

M1 Time Interval and Jitter Analysis

- Patent license agreement with Agilent Technologies
- Offered as Agilent Time Interval and Jitter Analysis Software
- Leveraging 20+ years of ASA's clock, timing and data jitter measurement expertise

Amherst Systems Associates

M1 Time Interval and Jitter Analysis

- Comprehensive suite of RJ/DJ extraction methods in compliance with MJSQ recommendations
- Additional analysis tools for decomposing jitter signature during functional debug and system characterization

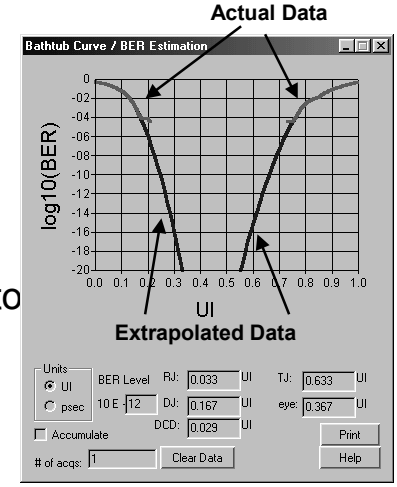
Rj/Dj Methods

- Pattern-Marker based
  - one method
- Best Fit/Equivalent Jitter based
  - two methods based on Edge Jitter/TIE
  - two methods based on Pulsewidth Jitter
  - five methods based on TIA-Style sampling
- Duty-Cycle Distortion
  - Calculated independently of RJ/DJ

All Non-Pattern Methods

Combination of BERT-scan and Curve Fit

- Individual event data is combined to form a Bathtub Curve
- The tails are fitted to extract RJ/DJ values
- The RJ/DJ values are used to extrapolate down to lower BERs



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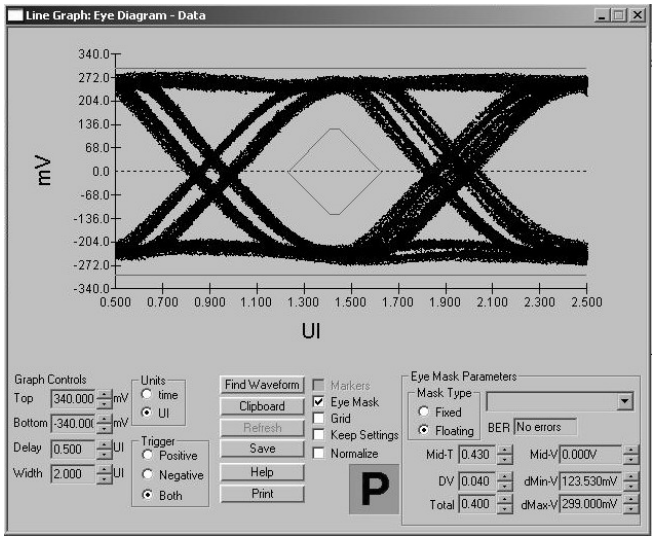
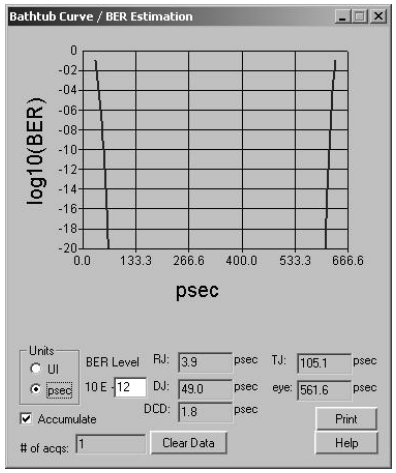
SATA 1.5Gbps Example

- Eye-diagram view allows alignment of entire data acquisition vs. recovered clock
- Mask testing for measuring data-valid window



SATA 1.5Gbps Example

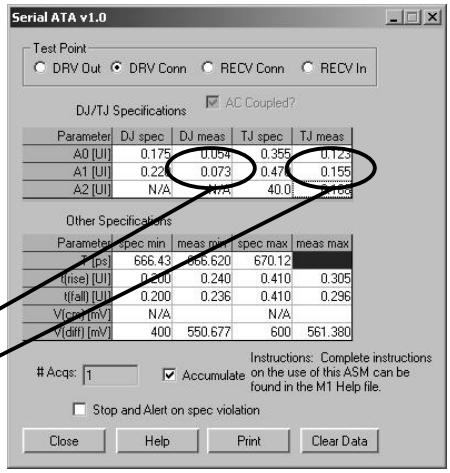
- Bathtub curve shows extrapolated data for estimating TJ and eye opening at lower BERs
- Accumulate mode allows longer time captures to identify random occurrences and converge toward more accurate TJ estimates



SATA 1.5Gbps Example

Application Specific Measurement Window

- Provides critical measurements vs. the specified values
- Accumulate mode and stop on failure allow test to run hands-free
- DJ appears to contribute as much toward TJ as RJ
  - DJ = 0.073 UI pk
  - TJ = 0.155 UI pk



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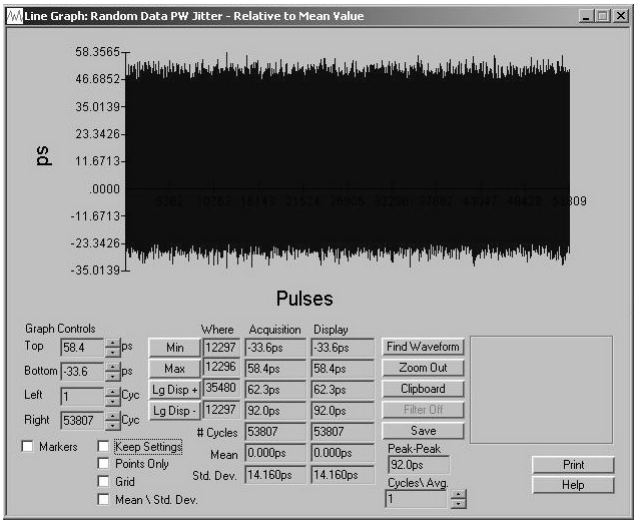
SATA 1.5Gbps Example

- Sometimes the measurement trend can identify RJ vs. PJ, but not in this case
- A histogram will better identify the distribution of measured pulsewidth values



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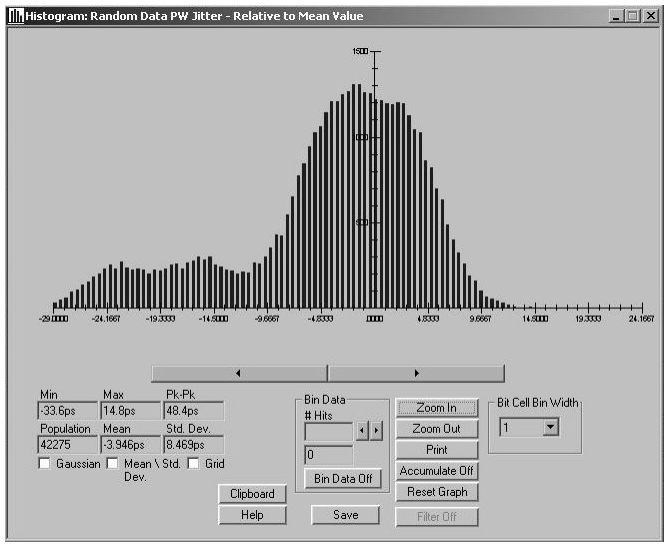
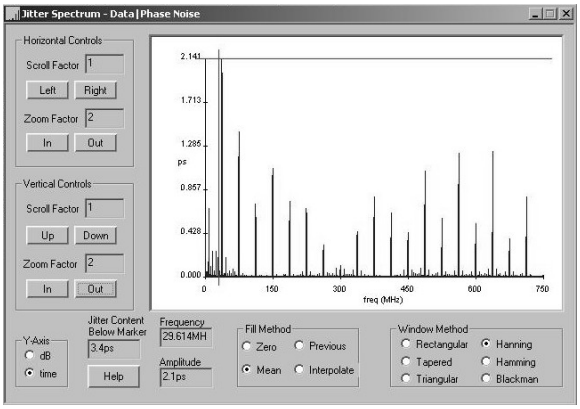
SATA 1.5Gbps Example

- Identify a major source of DJ as a side-tail to the RJ distribution



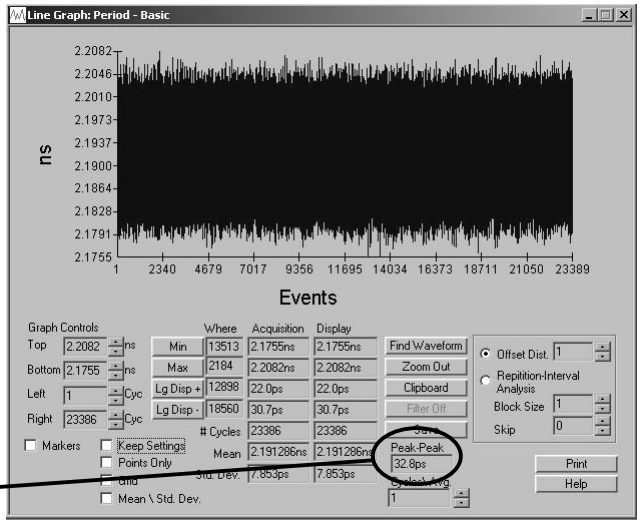
SATA 1.5Gbps Example



- Identify periodic and data dependent jitter frequencies
- Troubleshooting tool for eliminating accidental crosstalk jitter or identifying ISI

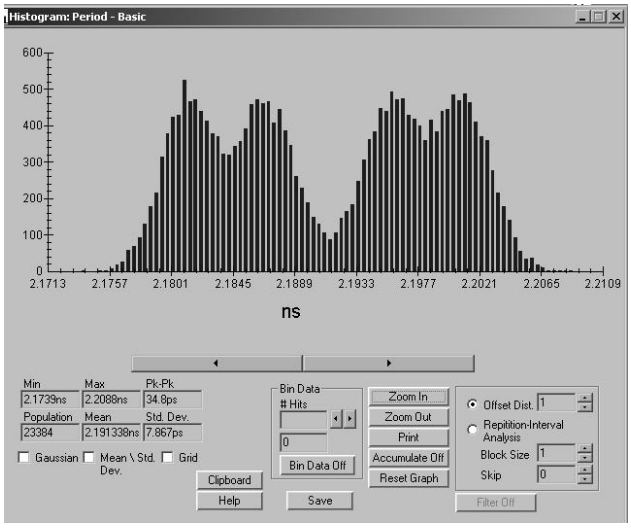
Clock PLL Example

- 456 MHz distributed clock signal
- Includes a PLL with divide-by-4 feedback loop between VCO and phase detector
- Only 32ps of p-p jitter



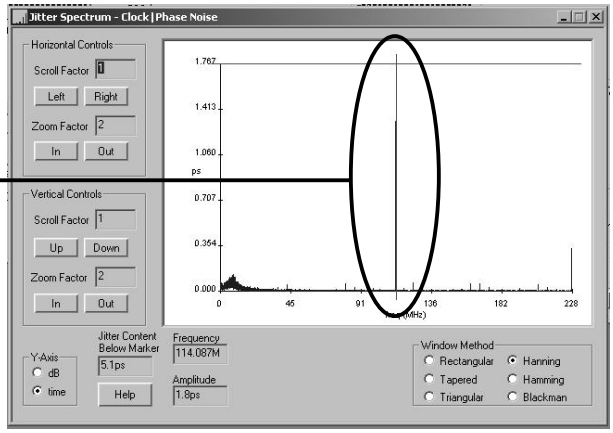
Clock PLL Example

- This isn't the kind of distribution we want for our perfect clock!



Clock PLL Example

- Isolated energy peak at 114 MHz suggests sub-harmonic coupling



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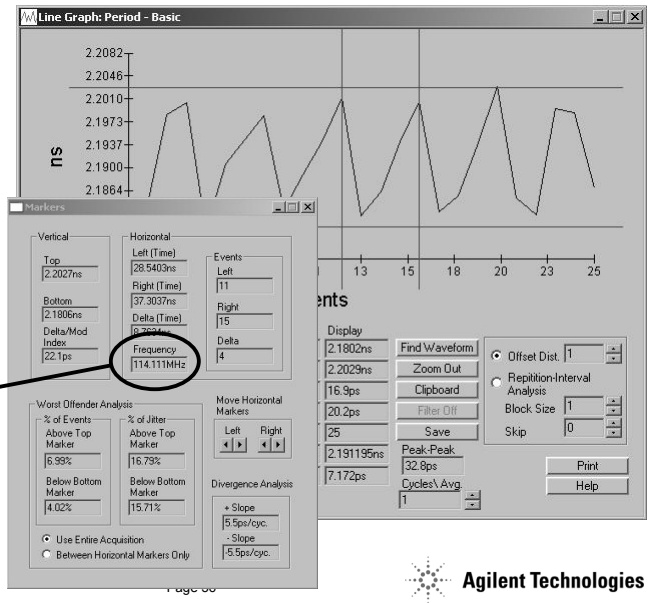
Clock PLL Example

- Revisit our measurement trend
- Zoom in to find that 114 MHz crystal output is finding its way into the VCO output



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- Quick Review of Jitter
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- New Jitter analysis and debug tools
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Summary

- Increasing signal bandwidths are creating jitter sources (ISI, dispersion, etc.)
  - Need a jitter transmitter for simulation and calibration of test equipment
  - Need RJ/DJ separation to speed analysis time and compliance testing
- Analysis tools provide much greater insight as to root cause, beyond RJ/DJ
- Resources:
  - Jitter www.agilent.com/find/jitter_info
  - Oscilloscopes www.agilent.com/find/infiniimax

Agilent 54850 Infiniium Performance Series

www.agilent.com/find/infiniimax

2.5GHz to 6GHz

- 4 channels
- Up to 32 MB deep memory
- Up to 20 GSa/s sample rate/channel
- MEGAZoom technology
- Infiniium award-winning usability
- Timing Interval & Jitter Analysis Software

Model	BW	Channels	Sample Rate Per Channel	Standard Mem/Ch	Optional Mem/Ch
54853A	2.5GHz	4	20GSa/s	256K	1M/32M
54854A	4 GHz	4	20 GSa/s	256K	1M/32M
54855A	6 GHz	4	20 GSa/s	256K	1M/32M

Page 39

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