

Building a Precision Jitter Source

June 1, 2004

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Presentation Topics

- 1. Requirements of a Jitter Source
- 2. Design of the Source
- 3. Metrology of the Source
- 4. Conclusions



Reasons for Building a Jitter Source

- 1. Compare Jitter Measurement Devices.
- 2. Characterize the Jitter Tolerance of a Receiver Circuit.

Note: This is an engineering study. This IS NOT a product!



First Effort at a Transmitter....

Noise Source Σ Ck Pattern Transmission Line Generator



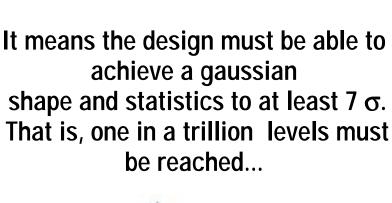
Requirements of a 'Golden' Jitter Source

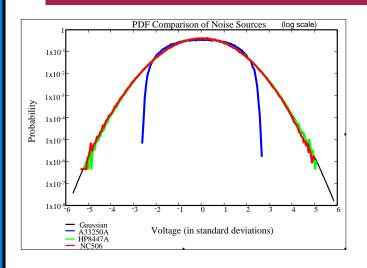
- 1. Must be semi-automated
- 2. It must be able to generate all types of jitter

3. All Jitter types must be settable and simultaneously operable. Total 4. It must be accurate! Jitter (TJ) Random **Deterministic** Jitter (RJ) Jitter (DJ) **Data Dependent Periodic Jitter (DDJ) Jitter PJ Bounded Inter-symbol Duty Cycle Uncorrelated** Interference (ISI) **Distortion (DCD) Agilent Technologies** 5

Considerations for the Random Jitter Source

- 1. Settability
- 2. No Drift
- 3. Low Source Residuals
- 4. Gaussian Distribution to support 10⁻¹² Bit Error Ratios







Random Jitter Source

How to Verify Gaussian distribution to 10⁻¹² BER?

An easy way is to measure BER and convert to 'Q' Scale as a visual aid.

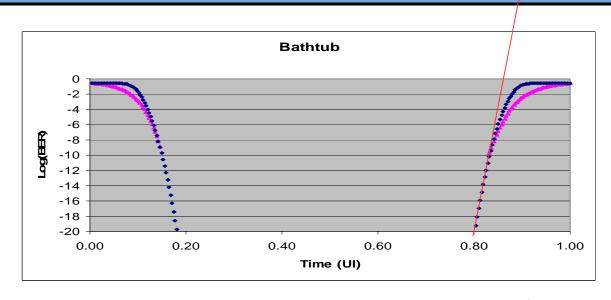
For Q<6
BER>10⁻⁹
$$BER = \frac{1 - erf}{2}$$

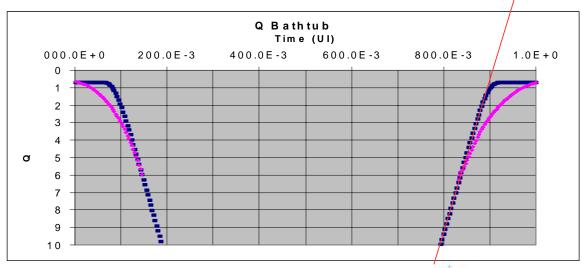
For Q>6
BER<10⁻⁹ BER =
$$\frac{e^{-\left(\frac{Q^{2}}{2}\right)}}{O\sqrt{2\pi}}$$

Q Scale Reference: CEI Implementation Draft document



Random Jitter Source (Q Scale)

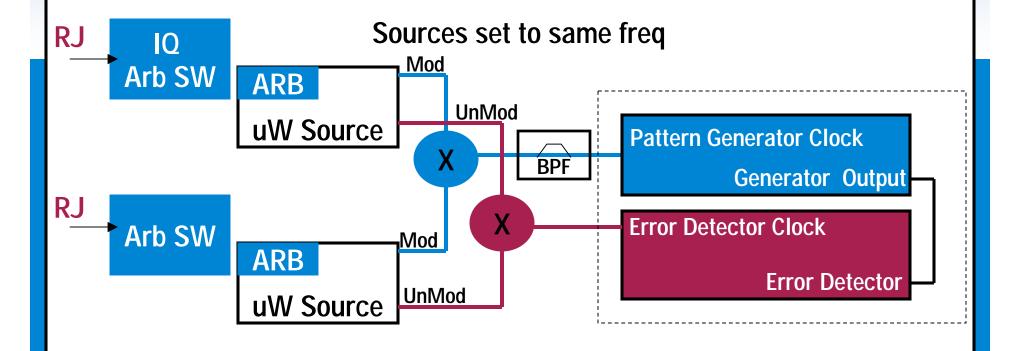




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Random Jitter Source Design

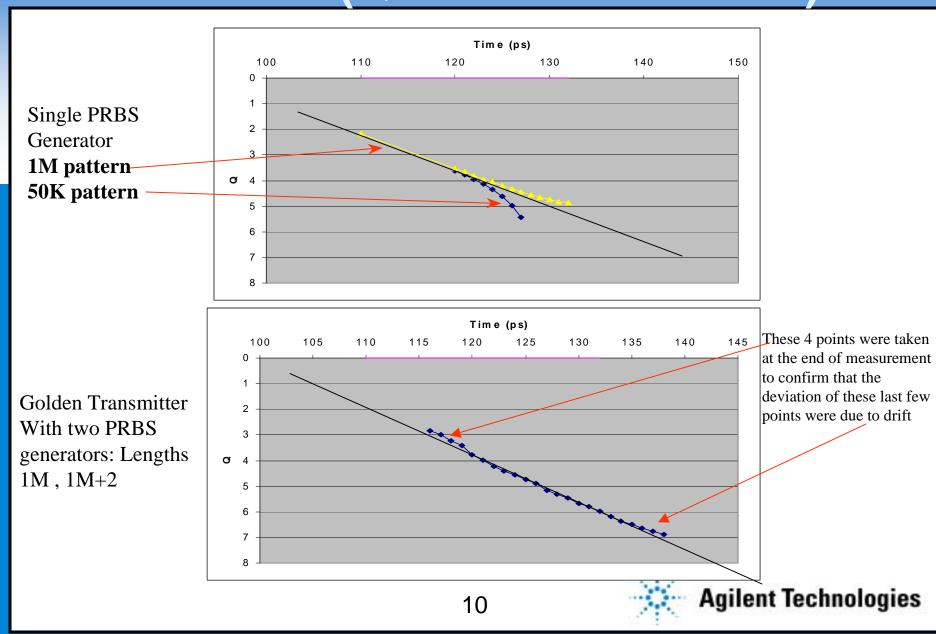
Different seeds, and different lengths. Pattern repeats every 3.5 hours!



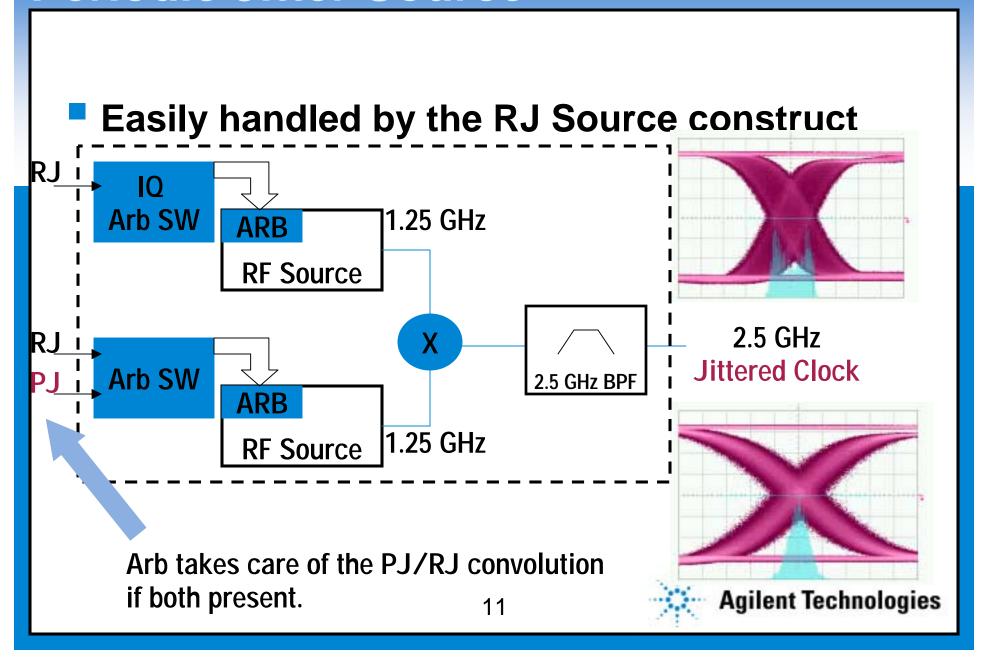
Solves settability, drift and 7 sigma problem!



Random Jitter (Q Scale Verification)

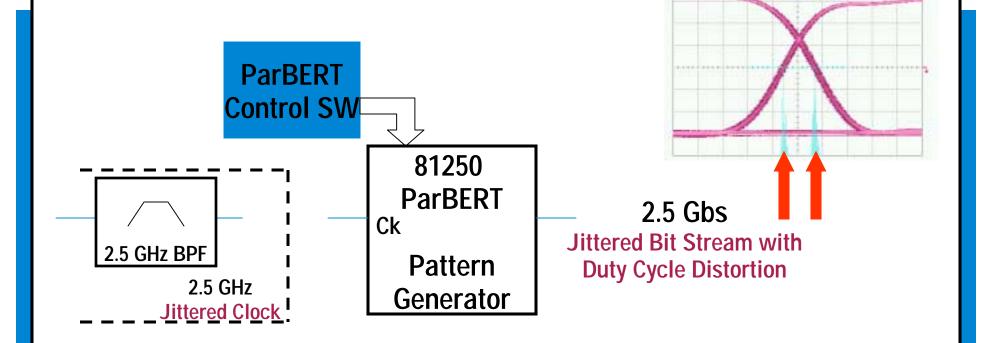


Periodic Jitter Source



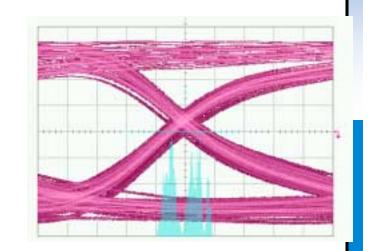
Duty Cycle Distortion Jitter Capability

DCD achieved with the <u>crossover point adjust</u> capability on the Agilent 13.5 Gb ParBERT



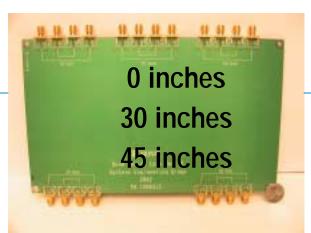
Inter Symbol Interference

- 1. Not possible in Sources today
- Different Types of ISI...
 filters, backplane.
 Not automated.
 Selection dependent on rate



81250 ParBERT

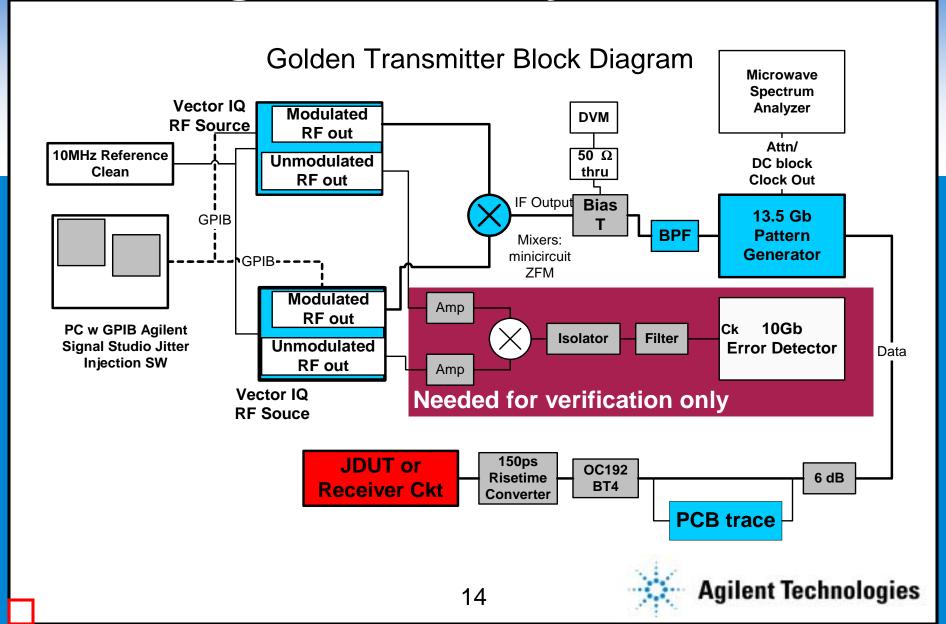
2.5 Gbs
Jittered Bit Stream
with DCD



To the Test Device



The Design in Summary



Now the Work Begins!

- We have the Block diagram to deliver capabilities desired.
- Now we need to <u>calibrate settings</u> and <u>determine accuracies</u>.

Need to Remember:

- 1. We want to set up conditions that are consistent with expected encounters by engineers with Enterprise serial digital designs.
- 2. One selected pattern length (2⁷-1) and at least one rate 2.5 Gbs



Jitter conditions and settings

Want to set up NO More than ~.6 UI so...

With 1 UI = 400 pseconds

Total Jitter_{MAX} = $14*\sigma_{HIGH} + DCD_{HIGH} + PJ_{HIGH} + ISI_{HIGH} < 240 ps$

 σ_{HIGH} ~ 6 pseconds

DCD_{HIGH} ~ 20 pseconds

PJ_{HIGH} ~ 30 pseconds

ISI_{HIGH} ~ 140 pseconds

(5 Levels: .7 to 6 ps)

(3 Levels: Off, Low, High)

(5 Levels, 2 Types)

(3 Levels: None, Low, High)

Total Possible Jitter Configurations: 5*3*5*2*3=450



Determining the Accuracies

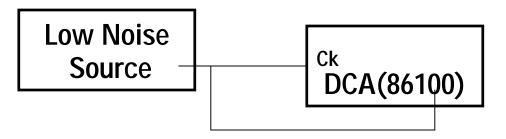
Process:

- 1. Evaluate the Baseline transmitter performance
- 2. Determine the RJ/PJ Sensitivity Factors
- 3. Evaluate DCD performance
- 4. Evaluate ISI performance
- 5. Theoretically calculate Total Jitter
- 6. Measure Total Jitter

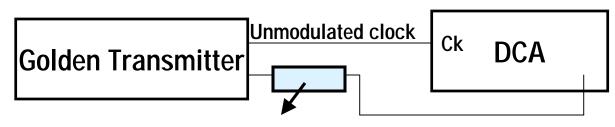


1a. Baseline Performance (RJ or σ)

The DCA Baseline:



.8 pseconds Gaussian



Path Elements

RJ

Alternating Pattern PRBS7 Pattern

1.1 pseconds 1.5 pseconds



Residual σ

.69 pseconds

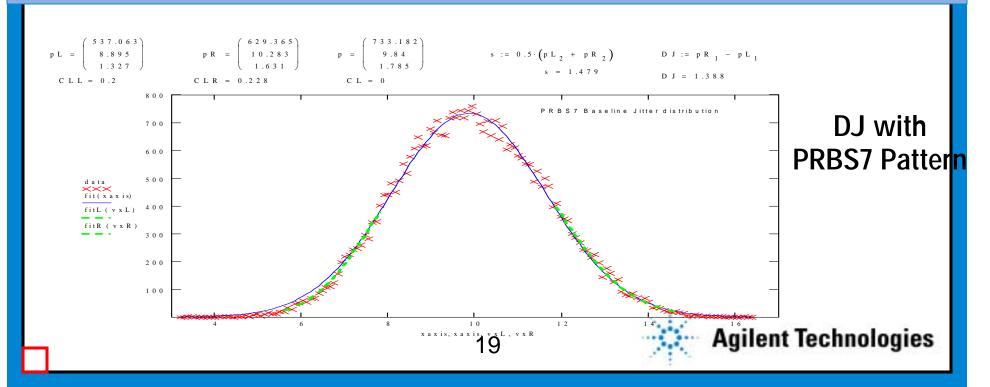
.53 pseconds unc



1b. Baseline Performance (DJ)

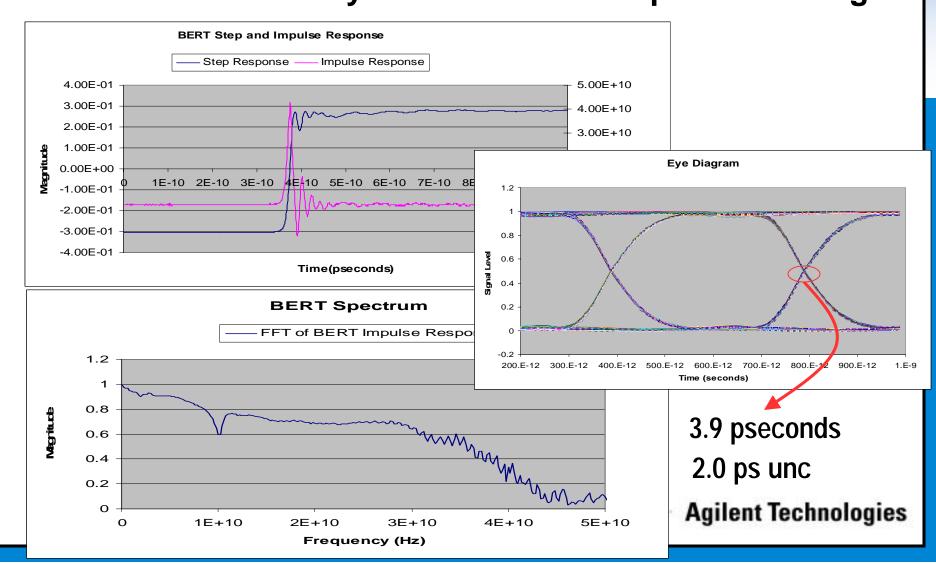
Two Step Approach:

- 1. Analyze Non Gaussian Nature of Waveform
- 2. Calculate theoretical DJ from calculated eye derived from step response of Pattern Generator, S-parameters of Passives (filters).



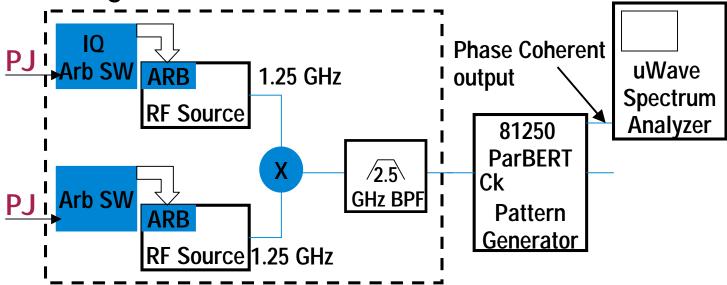
1b. Transmitter Baseline (DJ)

 Convolve Impulse Responses of PG, Attenuator, Filters, then mathematically transmit a PRBS7 pattern through...



2. RJ/PJ Sensitivity Factors...

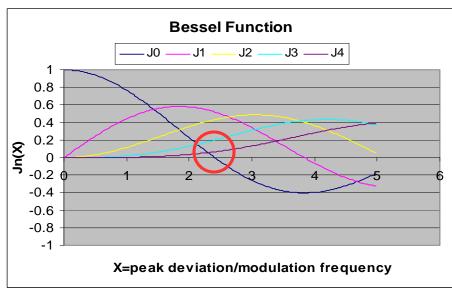
Block Diagram

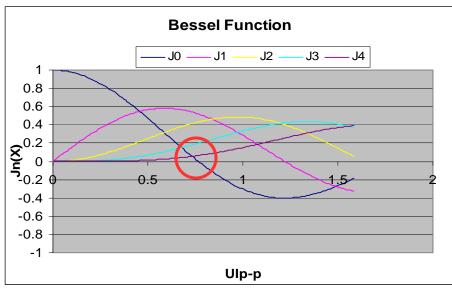


With Sinusoidal Modulation of Phase we can use <u>Bessel Nulls</u> as a calibration reference point!



2. RJ/PJ Factors: Bessel Null Calibration



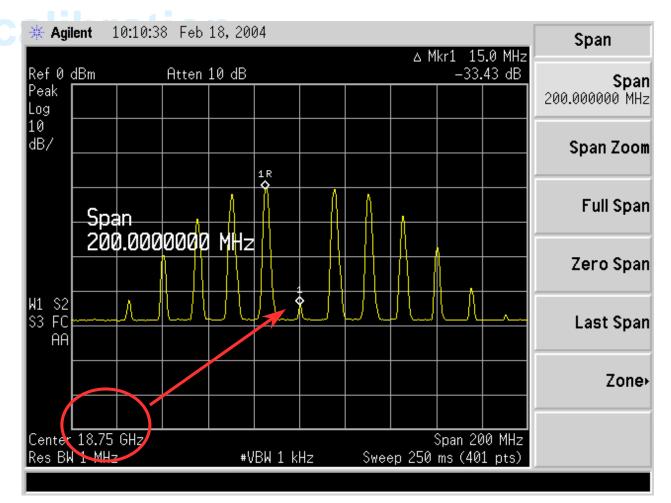


The First Bessel Null (the Carrier) occurs at .76 Ul.

If an alternating pattern is transmitted (1.25GHz clock) and is harmonic rich then we will see this Null at the 15th harmonic when we have precisely .102 UI set.



2. RJ/PJ Factors: Bessel Null for PJ



The Bessel Null when <-33dB assures us of a 1% deviation accuracy.

For RJ, path flatness decreases accuracy to 1.5%

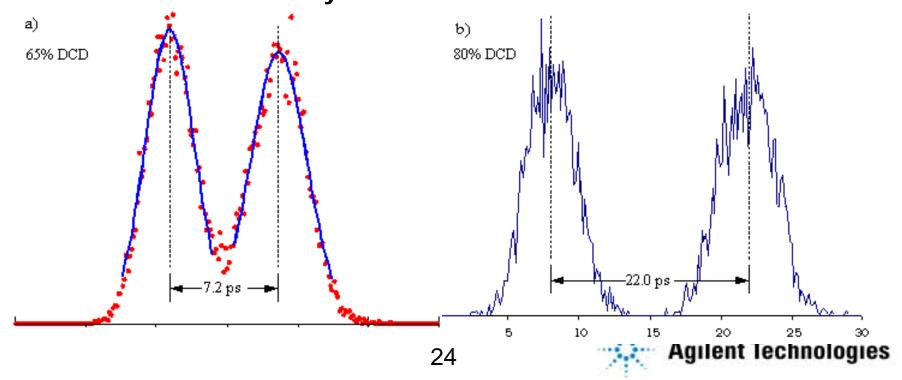
For RJ, many PJ frequencies are measured and path flatness is evaluated. For the RJ then, an extra error term arises Agilent Technologies

3. Evaluating DCD Performance

Pattern Generator Rise and Fall speeds limit the range of DCD we can apply.

Analyzed simply by analysis of transition histograms of Pattern Generator Output.

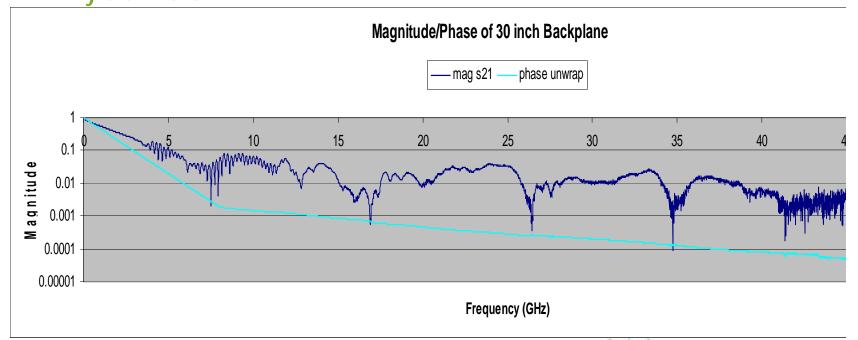
Uncertainties are <1 psecond and are related to bin separation and timebase uncertainty



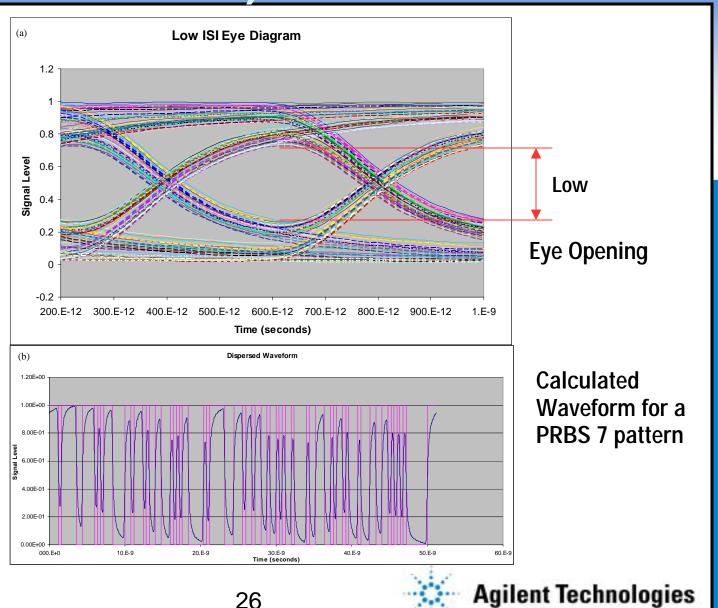
4. InterSymbol Interference

2 sections of serpentined pc traces: one 30 inches long, the other 15 inches long. Gives two ISI conditions, 30 and 45 inches.

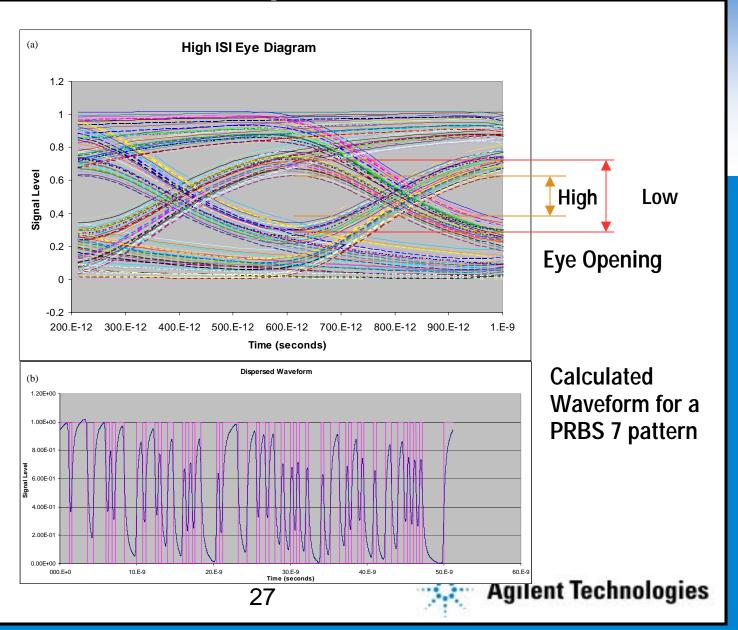
Convolve Impulse Responses of the PG, Attenuator, Filters, and the backplane then mathematically transmit a PRBS7 pattern through. Errors associated with VNA yield ~.5%



4a. ISI (30 inch trace)



4b. ISI (45 inch trace)



4c. ISI: Interaction between ISI and DCD

ISI and DCD interact and is a difficult condition to analyze

Requires each ISI/DCD state to be evaluated separately.

Depends on pattern symmetry, rise time vs. fall time.

Most significant issue is receiver circuit threshold setting process



Summary of Performance

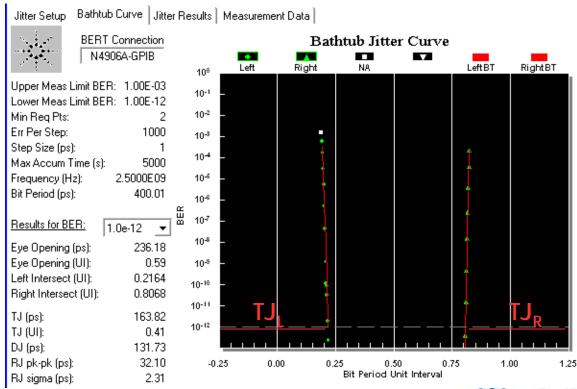
	(all values in ps)	(RJ) σ	δσ	J_{PP}	$\delta\! J_{PP}$
Transmitter baseline (prbs7)		0.685	0.53	3.90	2.00
RJ	1	1.39	0.02, 0.55*	0	0
	2 (Low)	2.79	0.04, 0.57*	0	0
	3	4.18	0.06, 0.59*	0	0
	4 (High)	5.57	0.08, 0.61*	0	0
Sinusoidal PJ	1	0	0	6.83	0.07
	2 (Low)	0	0	13.66	0.137
	3	0	0	20.49	0.20
	4 (High)	0	0	27.32	0.27
Triangular PJ	5 (Low)	0	0	13.26	0.13
	6 (High)	0	0	26.53	0.27
DCD	2 (Low), ~.03UI	0	0	7.71	1.14
	4 (High), ~.06UI	0	0	14.0	0.15
ISI	2 (Low), 30 in	0	0	70.5	0.35
	4 (High), 45 in	0	0	139.4	0.70
DCD * ISI	2 (Low) * 2 (Low)	0	0	72.5	1.11
	2 (Low) * 4 (High)	0	0	138.5	1.44
	4 (High) * 2 (Low)	0	0	77.1	1.14
	4 (High) * 4 (High)	0	0	140.5	1.45



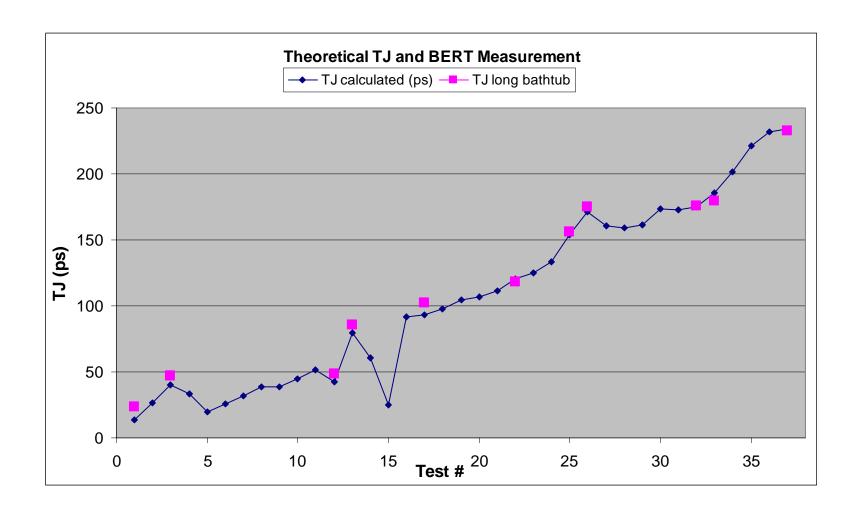
5. Total Jitter Estimation and Evaluation

Two Processes

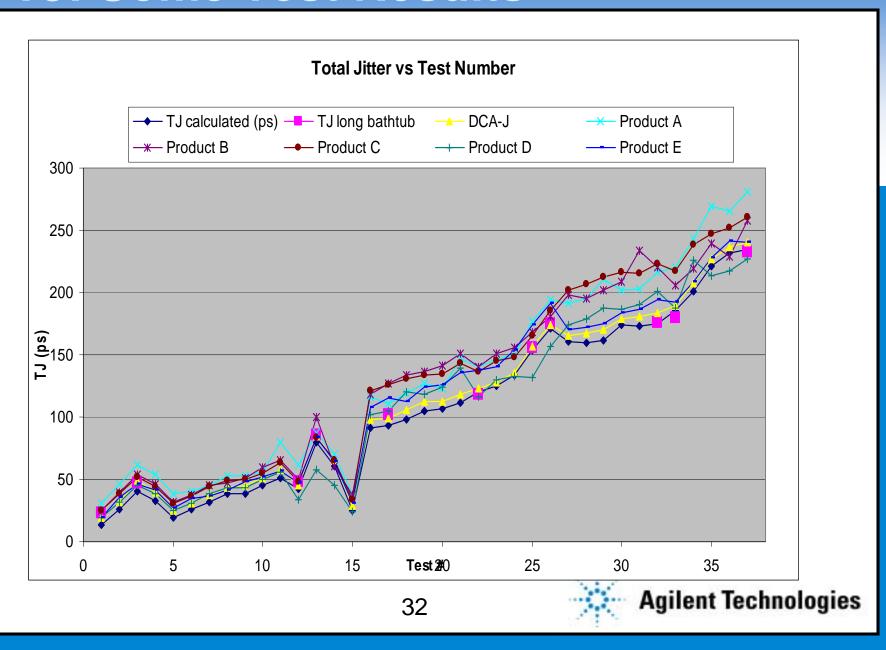
- 1. Total Jitter Measurement using BERT BathTub
- 2. Theoretical Analysis using jitter component convolution



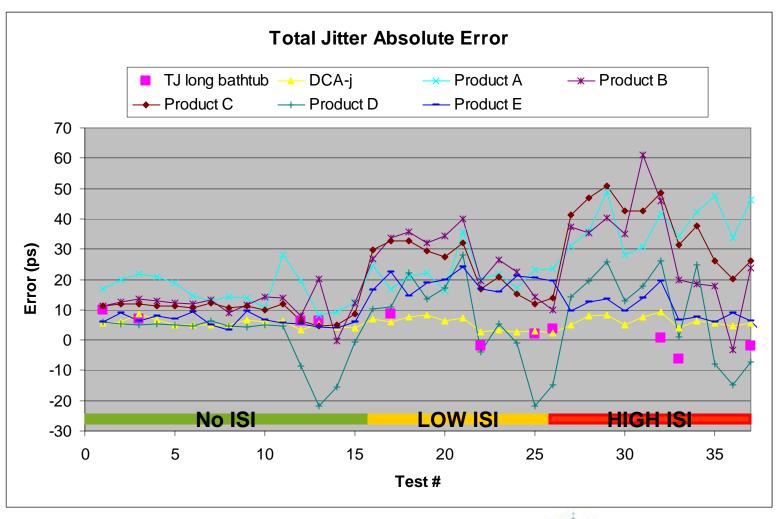
5. Total Jitter Measurement



5. TJ: Some Test Results



5. TJ: Some Test Results



Summary

- A precision jitter source, the 'Golden Transmitter', has been designed and used to compare jitter measurement devices.
- Standards were used in the calibration of the transmitter to declare the highest accuracy possible.
- The Gold Transmitter provides an ideal construct to exhaustively characterize jitter measurement devices or receiver circuits.
- Jitter measurement using extrapolative techniques, can give inaccurate results. Intersymbol Interference is poorly handled.
- The Golden Transmitter is <u>NOT</u> a product. It is constructed and calibrated with many RF components and would be expensive to build.

