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SONET/SDH - Jitter (& Wander) Measurements and Standards

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presented by:

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Your Presenters Today

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Data over SONET/SDH Seminar Series

Objective

- Comprehensive tutorial seminar series for engineers involved in the design, verification, manufacturing, deployment and maintenance of Data over (next generation) SONET/SDH equipment and networks.

Series Topics

- DoS Technologies - Standards, Structures & Design.
- DoS Equipment - Architectures & Test Challenges
- SONET/SDH Jitter Measurements & Standards

What is Data over SONET/SDH (DoS) ?

- Evolution of legacy SONET/SDH networks to transport a variety of data traffic services bandwidth-efficiently.
  - More than Packet over SONET/SDH (PoS)
  - More than Ethernet over SONET/SDH (EoS)
  - More than proprietary solutions.

"Legacy evolution not new network revolution"

SONET/SDH Jitter Measurements

Why discuss jitter measurements and standards ?

Jitter measurements and standards are equally as important to new DoS equipment and networks, as they were to legacy SONET/SDH. Despite many years of study and debate, much confusion still surrounds the topic of jitter measurements.

This seminar, focussed on jitter in its entirety, will address most of the key questions and issues associated with the topic, including tester versus operational equipment standards, intrinsic jitter measurement correction factors and much more.

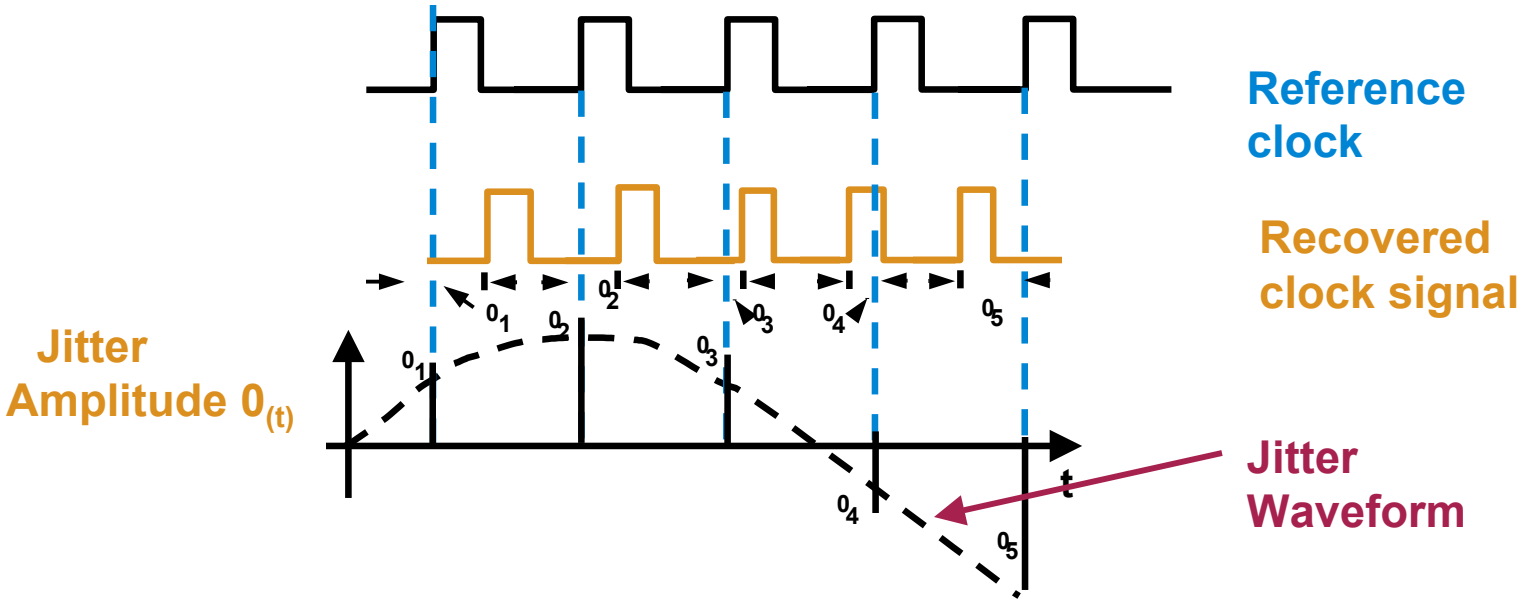
Seminar 3: Jitter Measurements & St'ds

Seminar Content

- Jitter measurement and standards
  - introduction (including standards)
  - jitter tolerance, transfer and output measurements
- Wander measurement and standards
  - introduction (including standards)
  - MTIE and TDEV measurements
- Impact of tester performance on intrinsic output jitter results
  - tester intrinsic jitter performance
  - tester transient detection performance
  - tester filter effects
- Wrap Up + question & answer session

What is Jitter ?

"Short term variations of the significant instants of a digital signal from their ideal positions in time"



Jitter/wander = unwanted phase modulation
Jitter >10Hz; Wander <10Hz

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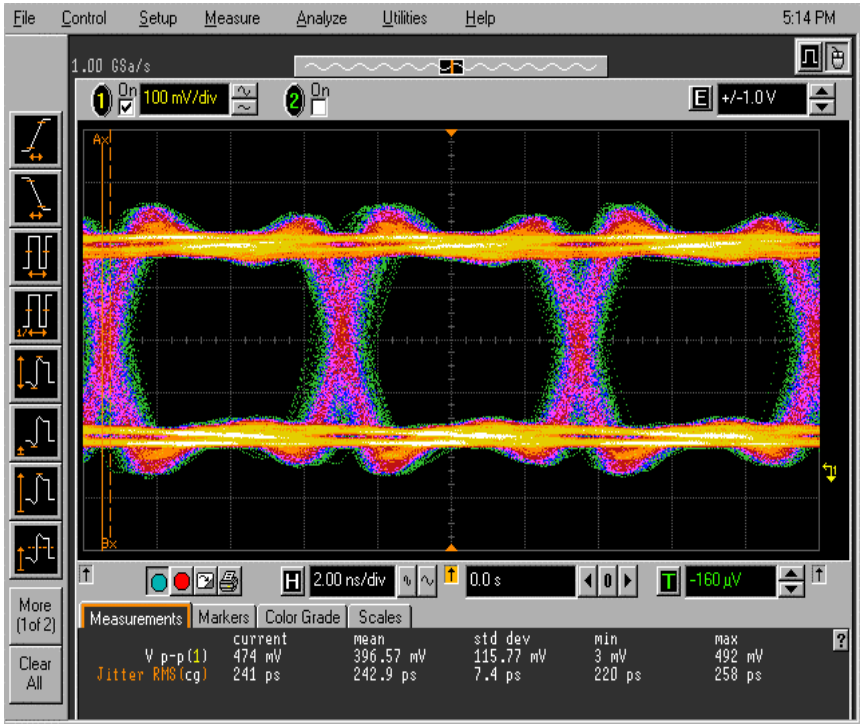
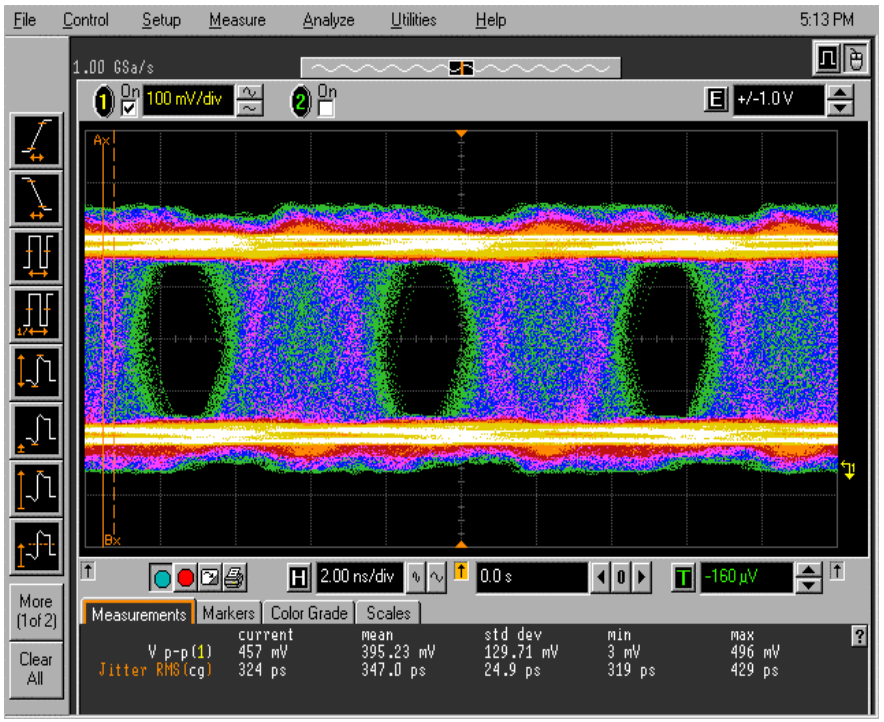
Effects of Jitter (viewed on a scope)

Eye diagram with good eye opening



Eye diagram with (jitter) eye closure



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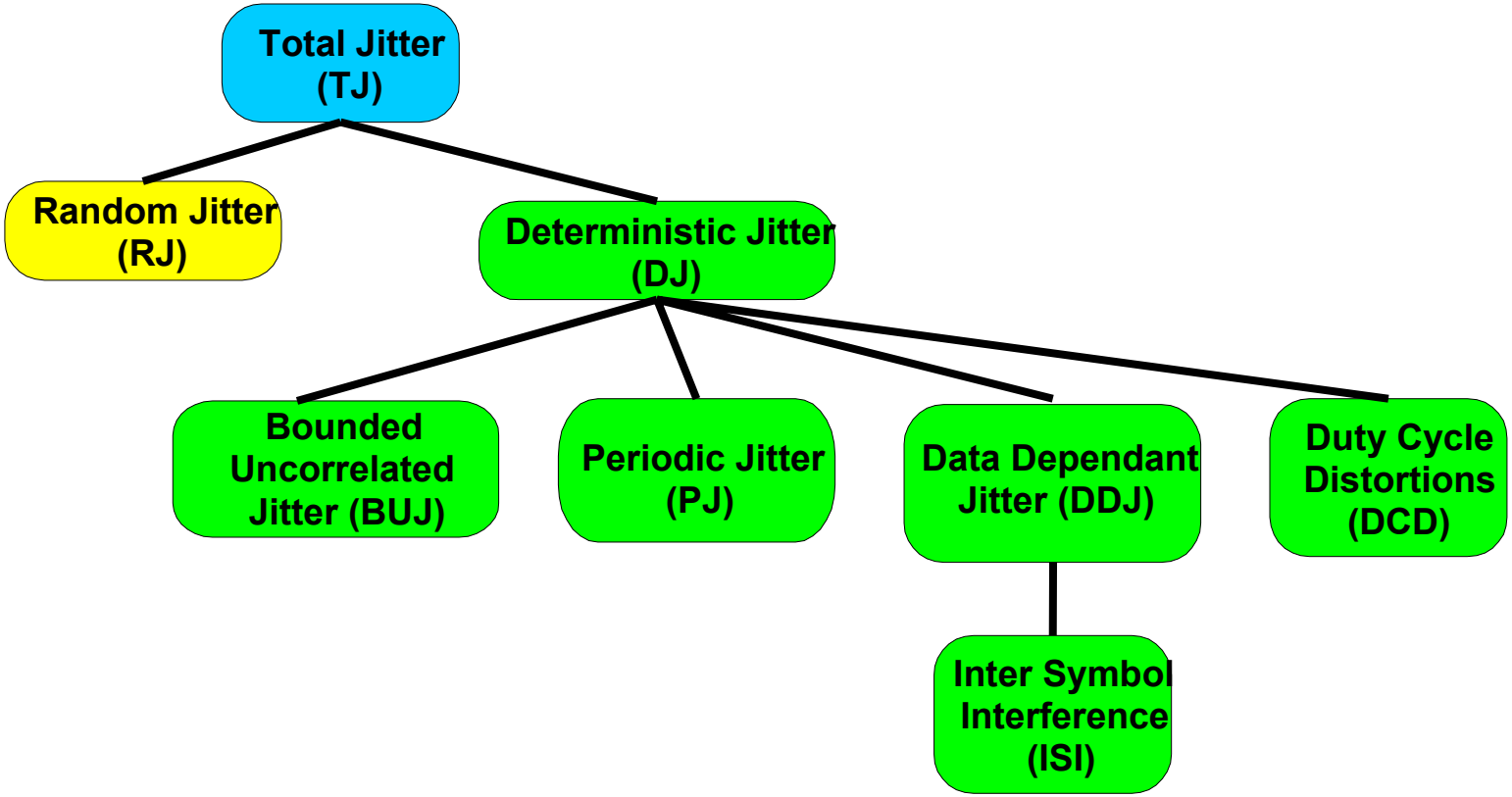
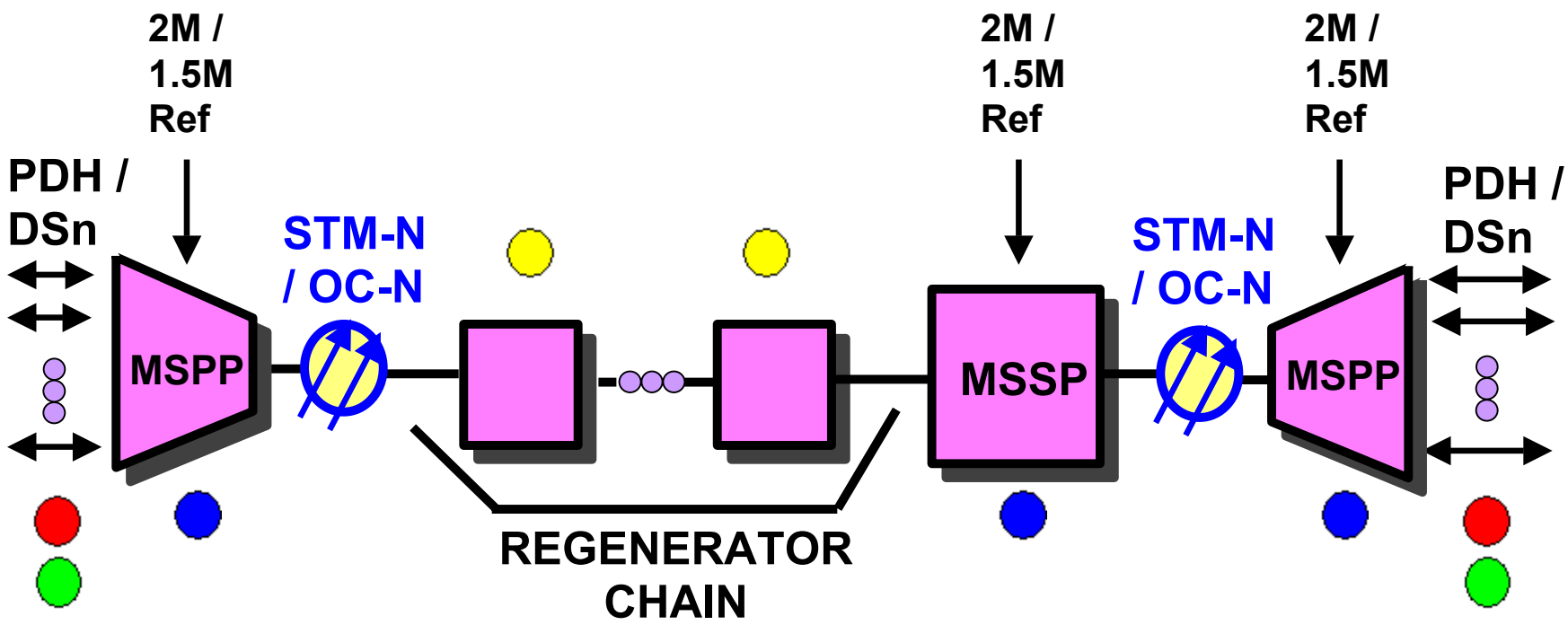
Random & Deterministic Jitter



Key Sources of Jitter & Wander



- Mapping jitter due to justification process
- Accumulated jitter (& jitter gain) due to multiple timing imperfections
- Tributary jitter due to SONET/SDH pointer adjustments
- Wander due to clock instability and noise.

Jitter Standards

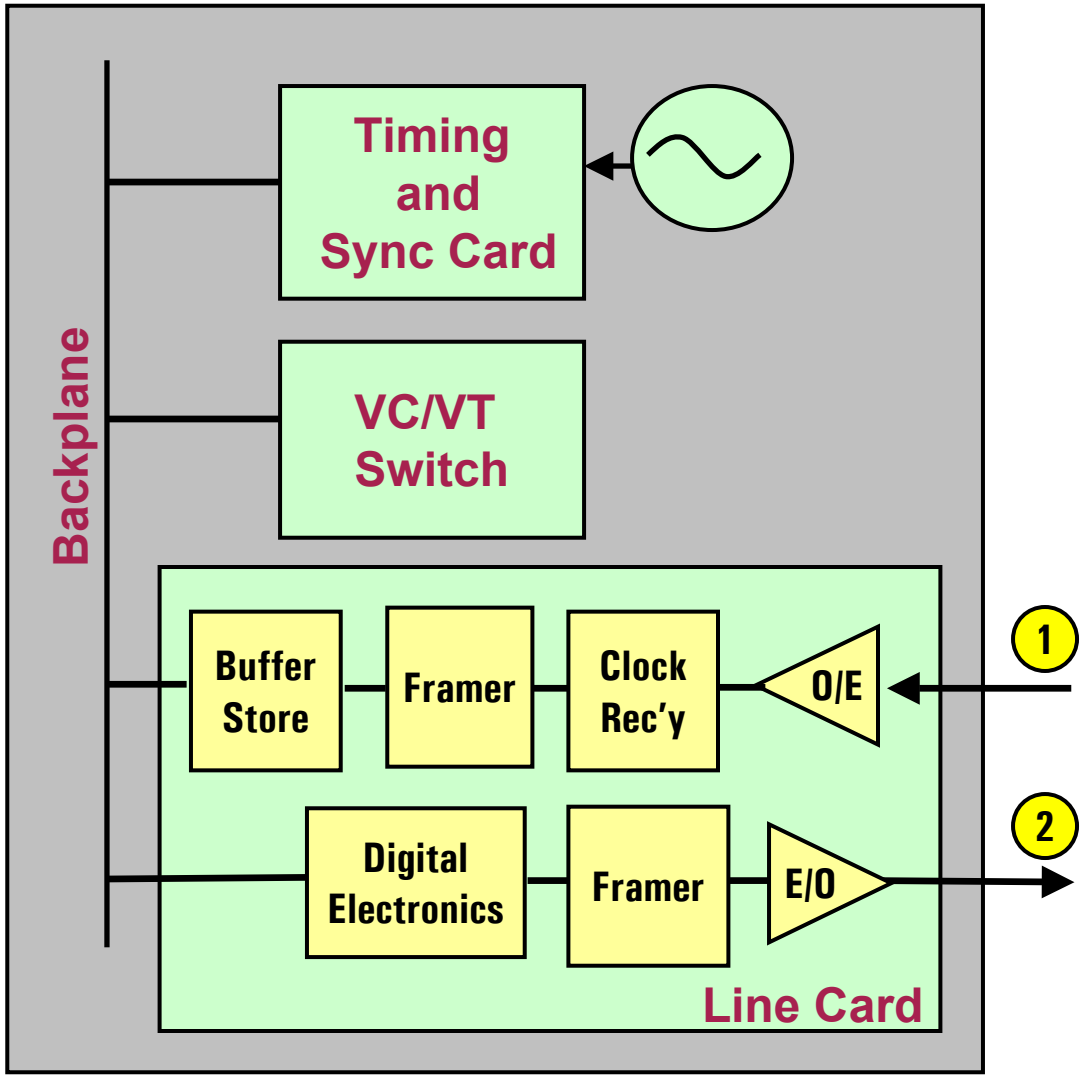
- **Jitter standards bodies**
  - ITU-T
  - Telcordia
  - Above also influenced/referenced by ETSI and ANSI
- **Jitter Standard Categories**
  - Line equipment standards
  - Network interface standards
  - Jitter and wander test equipment standards

    ITU-T O.171 - test equipment for PDH networks
    ITU-T O.172 - test equipment for SDH networks
    ITU-T O.173 - test equipment for OTN networks

Jitter Equipment & Network Standards

		Output Jitter	Input Jitter Tolerance	Jitter Transfer Function	Pointer/ Mapping Jitter
Network Equipment	SDH (DXC, ADM)	G.813	G.813 G.825		G.783
	SDH (Regen)	G.783	G.783	G.783	
	PDH	G.735 G.742 G.751 GR-499	G.832	G.735 G.742 G.751	
	PRC Clock	G.811			
	SSU Clock	G.812	G.812		
Network Interface	PDH Transport	G.823	G.823		
	SONET Transport	GR-253	GR-253	GR-253 GR-499	GR-253
	SDH Transport	G.825	G.825		
	OTN Transport	G.8251			

Equipment Jitter Measurements



Ensure jitter does not cause transmission errors by testing DUTs for the following:

Jitter Tolerance	1
Jitter Transfer	1-2
Output Jitter	2

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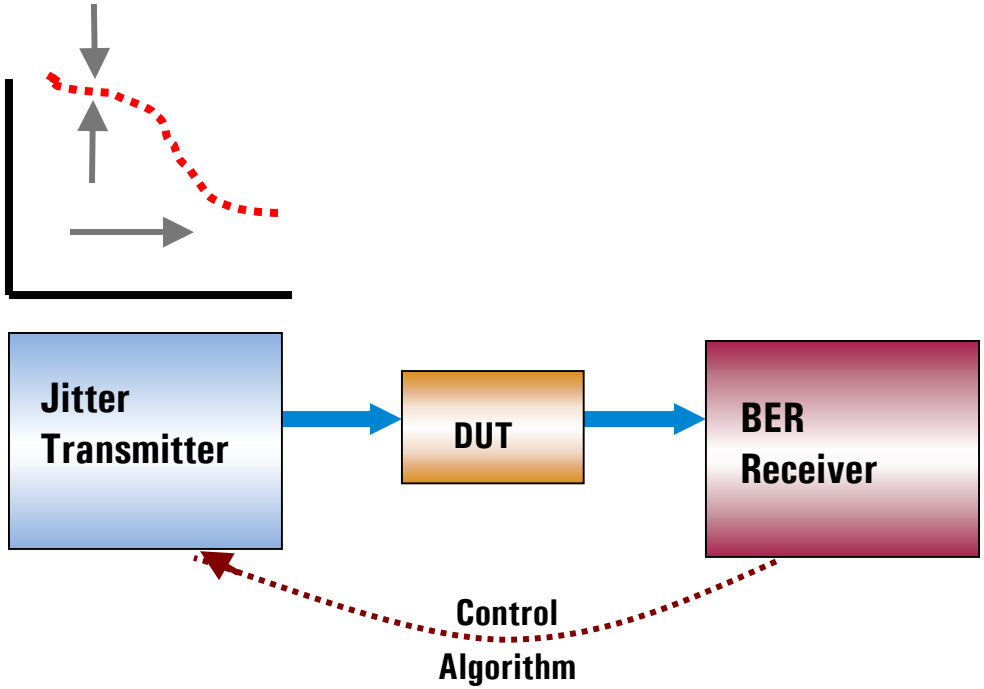
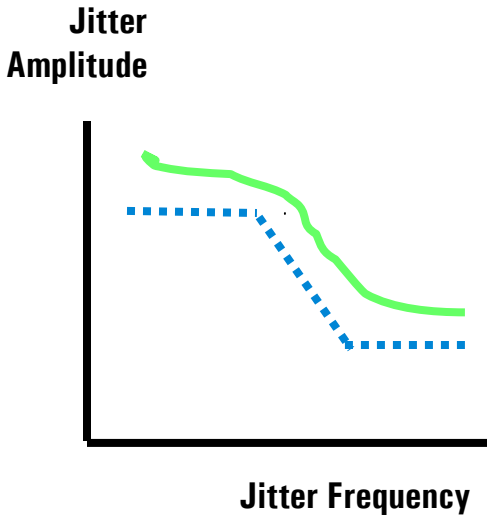
1 Jitter Tolerance - MTJ Example





Process: Jitter Amplitude is incremented/ decremented at the selected jitter frequency until error threshold is found and process repeated for subsequent frequency points.

Result: Measured MAX tolerance plot for DUT showing pass margin over requirement

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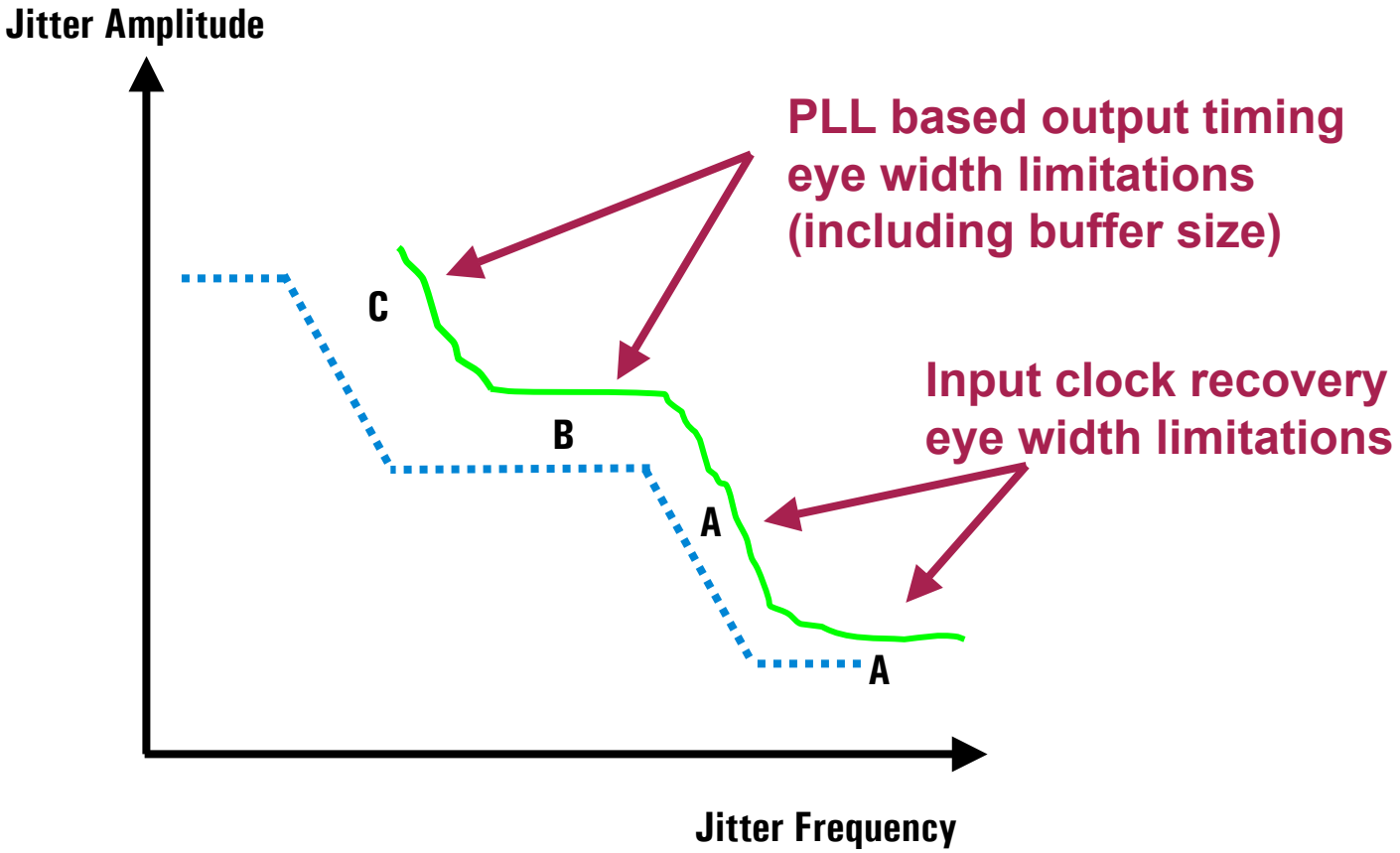
1 MTJ Error Threshold Methods

- **Onset of Errors**
  - Performed at Nominal DUT signal level
  - Used at Optical/Electrical Interfaces
  - Suited to testing buffer store tolerance/capacity
- **BER Penalty Method (1dB Power Penalty)**
  - Performed at Optical Interfaces under simulated worst case SNR
  - Tests tolerance of clock recovery in presence of noise

1 Typical Tolerance Mask



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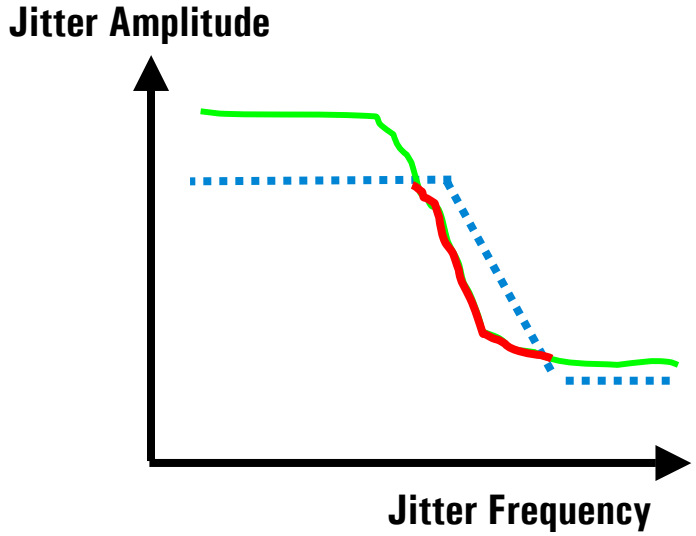
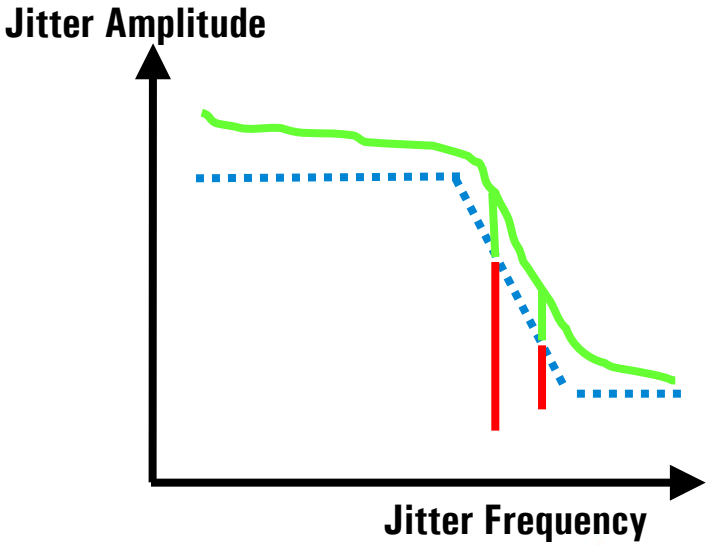
1 Typical Tolerance Fails

DUT Issue A
Line rate recovery bandwidth limited



DUT Issue B
Excess settlement time (after jitter amplitude change)



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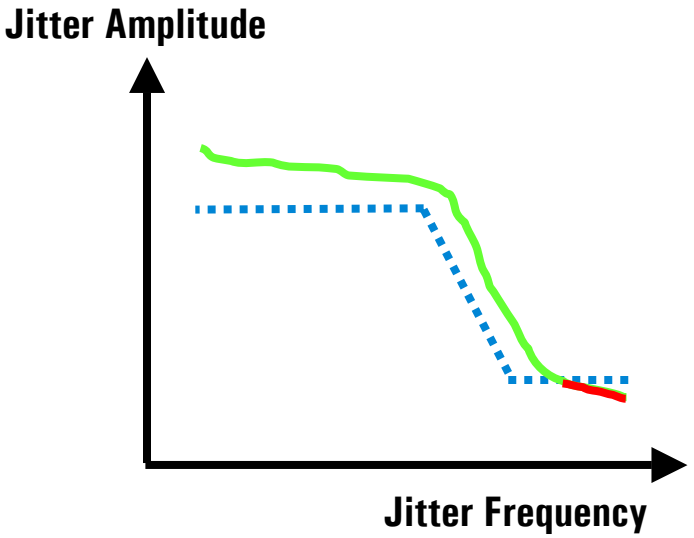
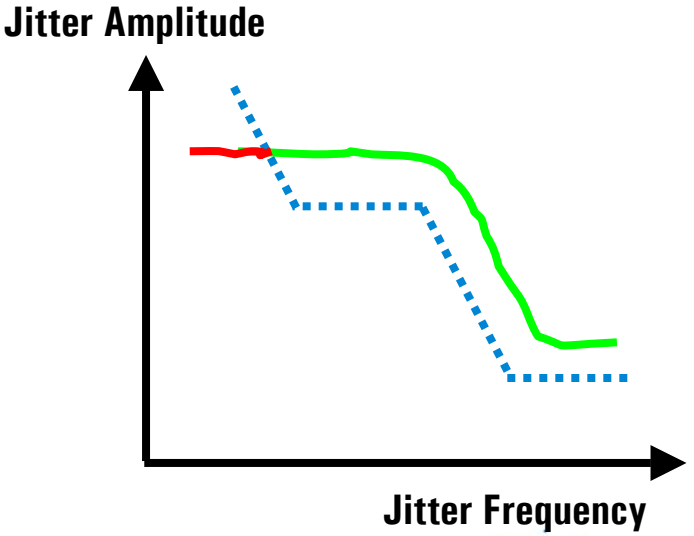
1 Typical Tolerance Fails (cont.)

DUT Issue C
Marginal retiming
- likelihood of limited eye width alignment or noise.



DUT Issue D
Fails to meet a buffer store limit.



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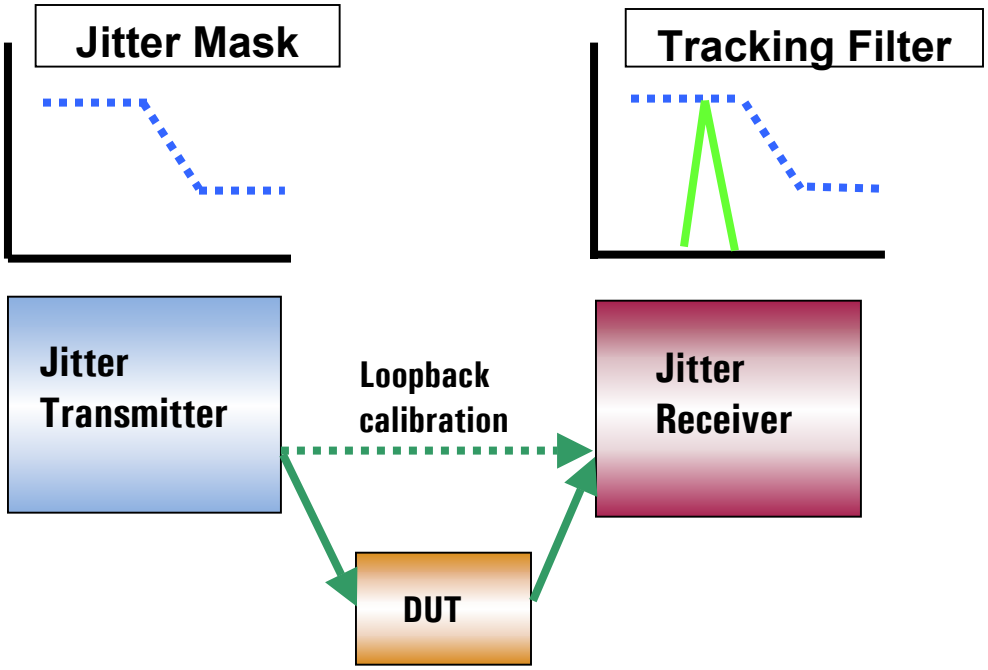
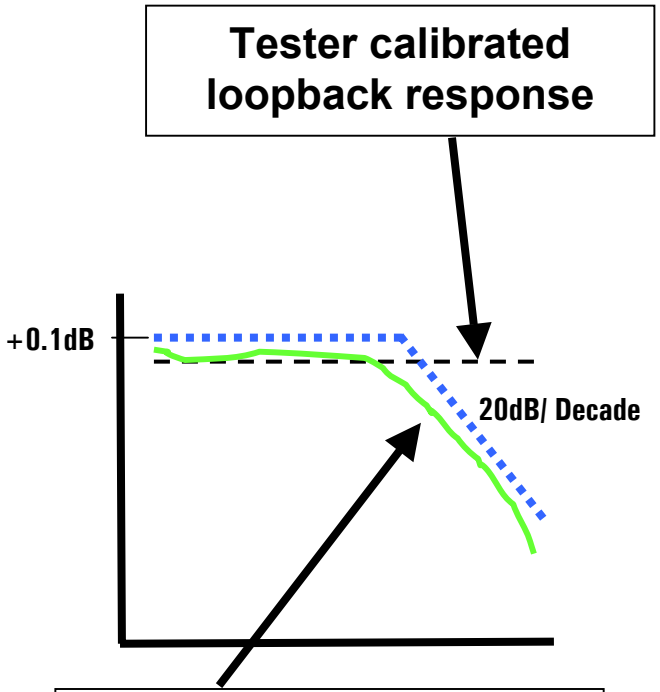
1-2 Jitter Transfer





Process: Jitter Amplitude is set at tolerance mask level for the selected jitter frequency. Jitter amplitude level after passing through the DUT is then measured using a filter to select only the required frequency.

Result: Measured MAX gain plot for DUT showing pass margin over requirement

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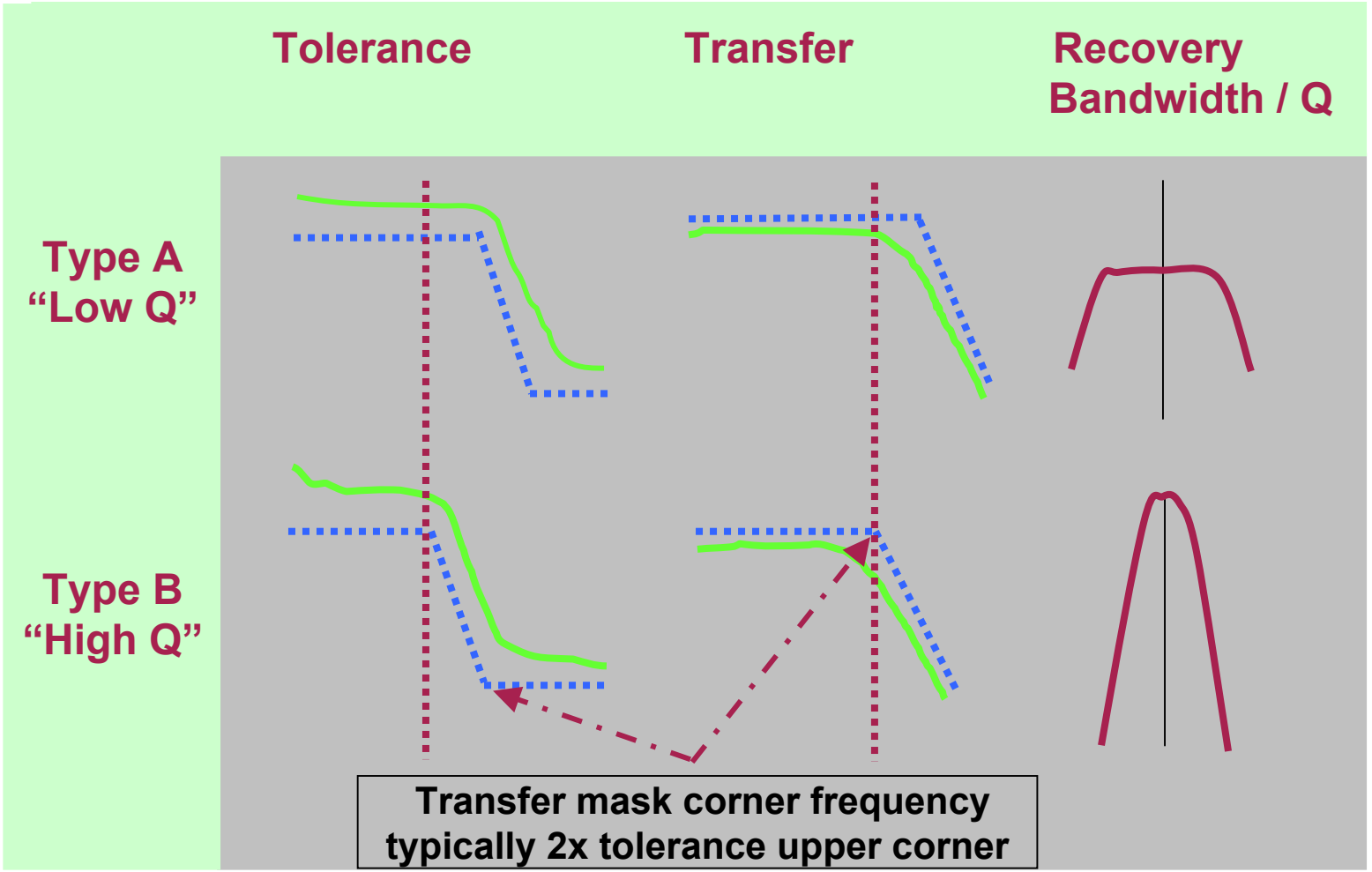
System Bandwidth Characteristics



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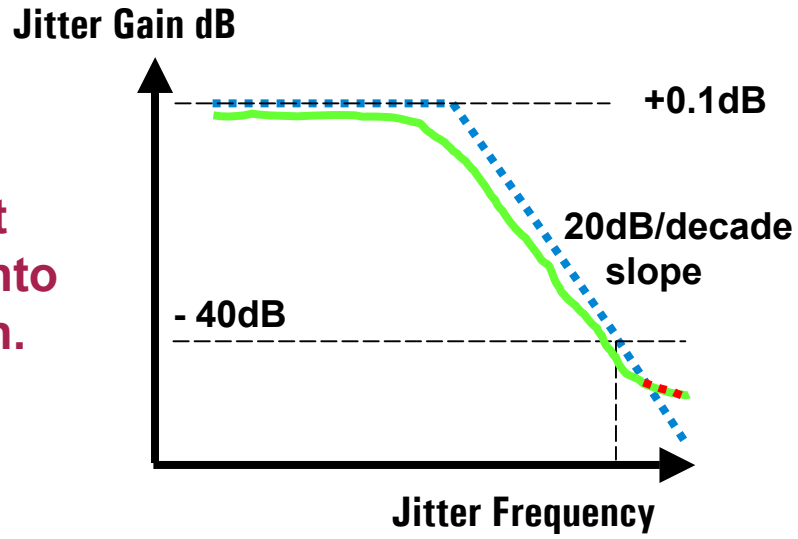
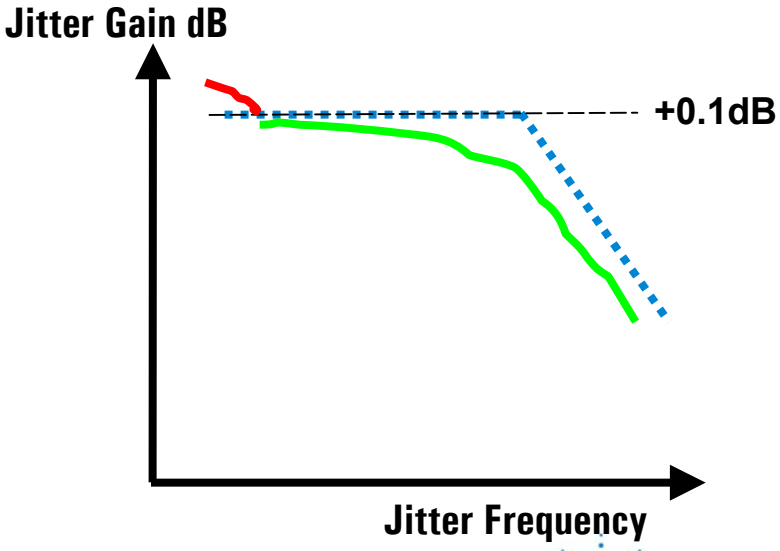
1-2 Typical Transfer Results

DUT Issue A
Testing beyond test set-up noise floor into an undefined region.



DUT Issue B
Peaking at low frequencies



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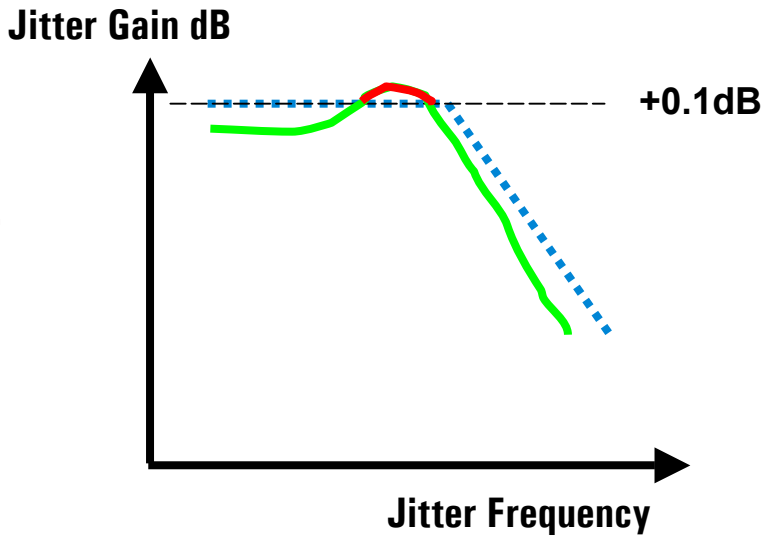
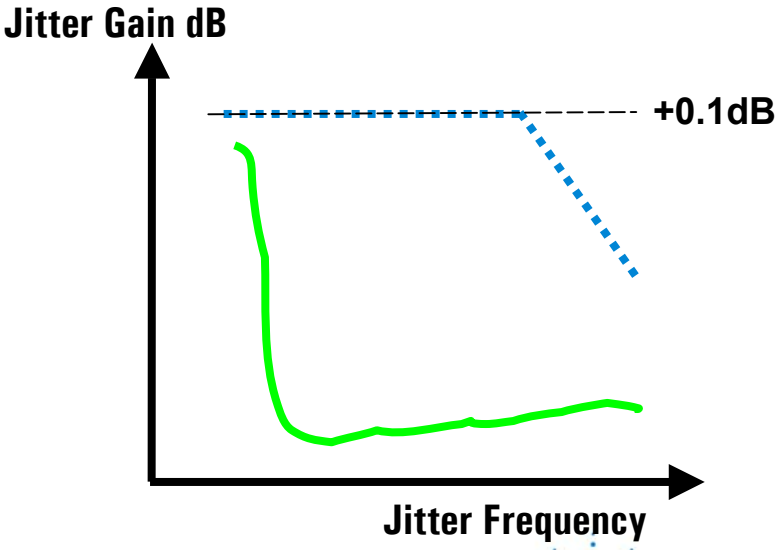
1-2 Typical Transfer Results (cont)

DUT Issue C
Peaking near clock-recovery bandwidth limit.



DUT Issue D
Jitter attenuation, except very low frequencies.



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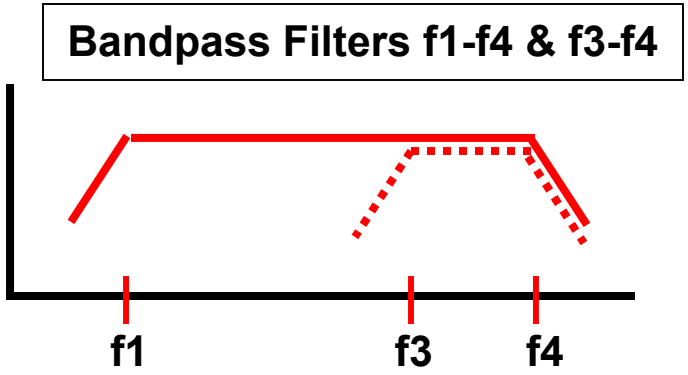
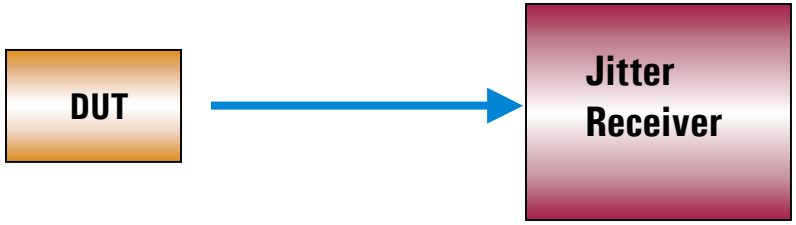
2 Output Jitter (Intrinsic Example)





f1 - f4: x mUI
f3 - f4: y mUI

Process: With no jitter applied to the input of the DUT, measure the jitter amplitude (peak - peak and/or RMS) on the DUT output signal within two frequency bands - f1 to f4 and f3 to f4.

Result: Two numerical results, one for each frequency band.

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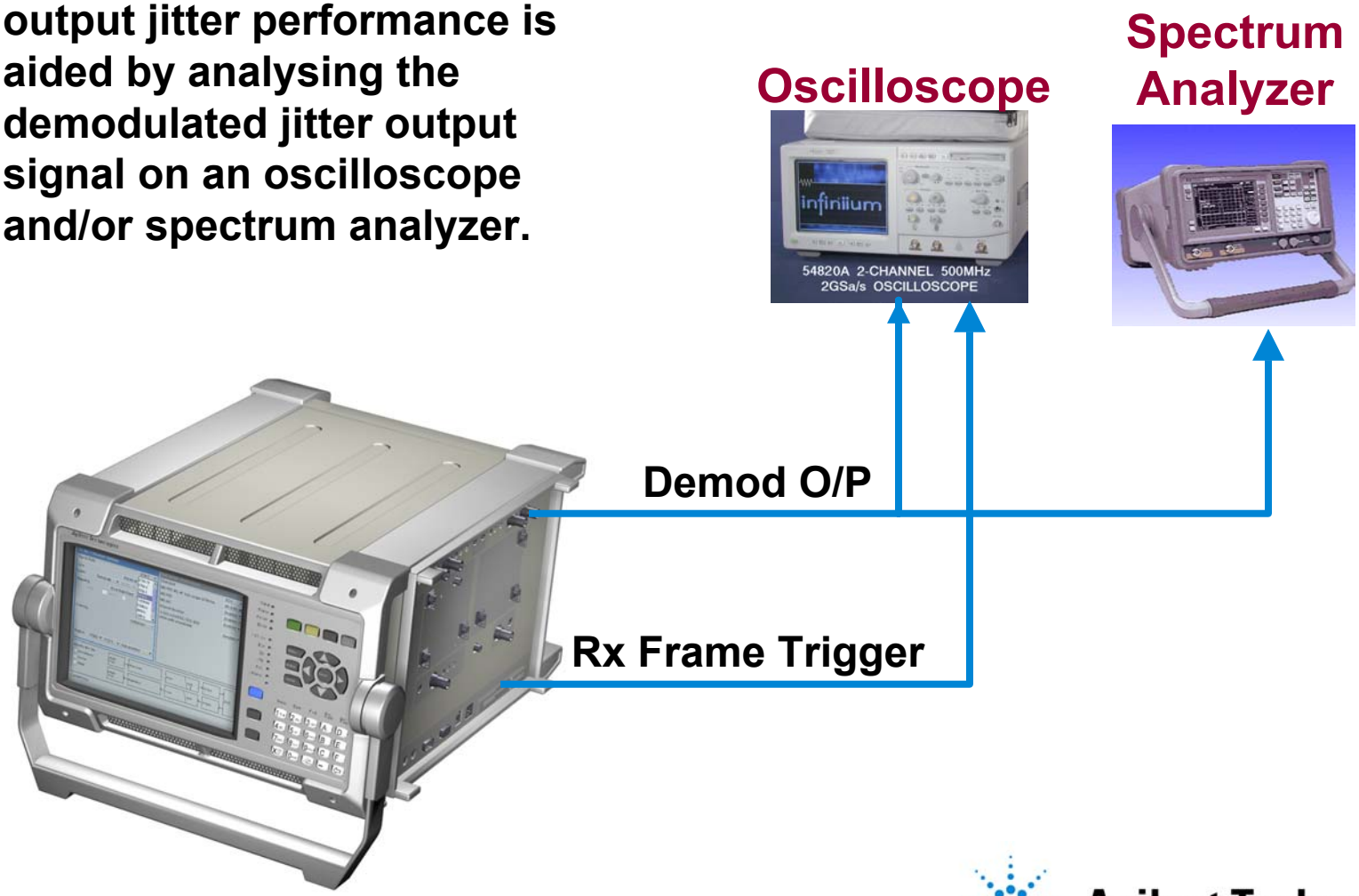
2 Investigating Output Jitter

Trouble-shooting poor output jitter performance is aided by analysing the demodulated jitter output signal on an oscilloscope and/or spectrum analyzer.



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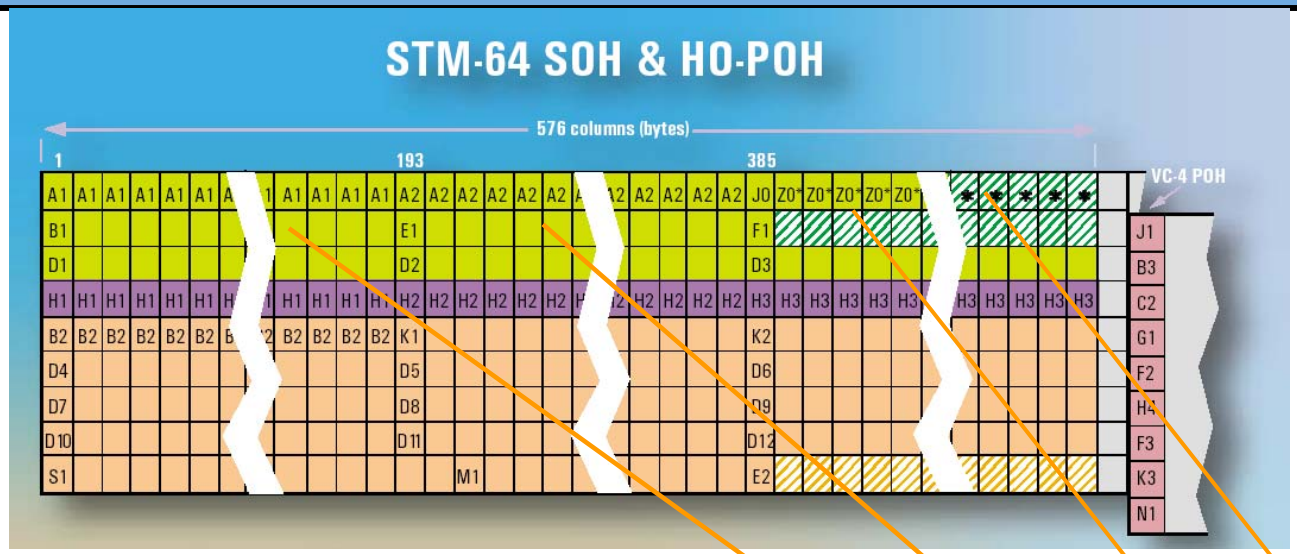
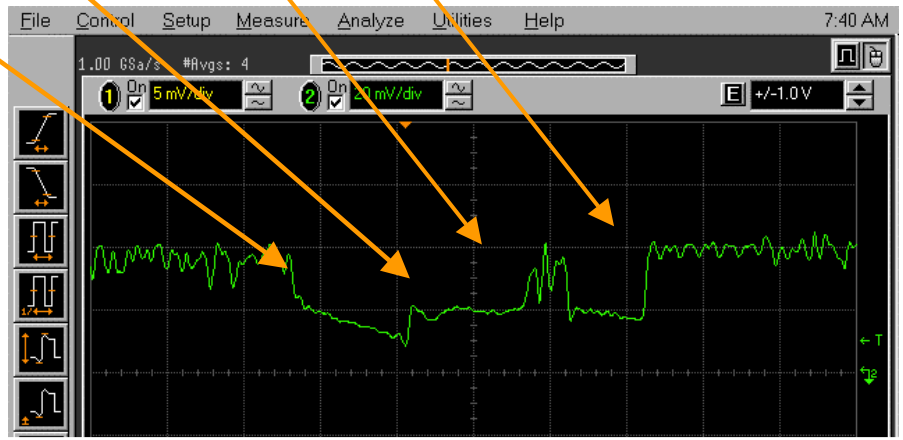
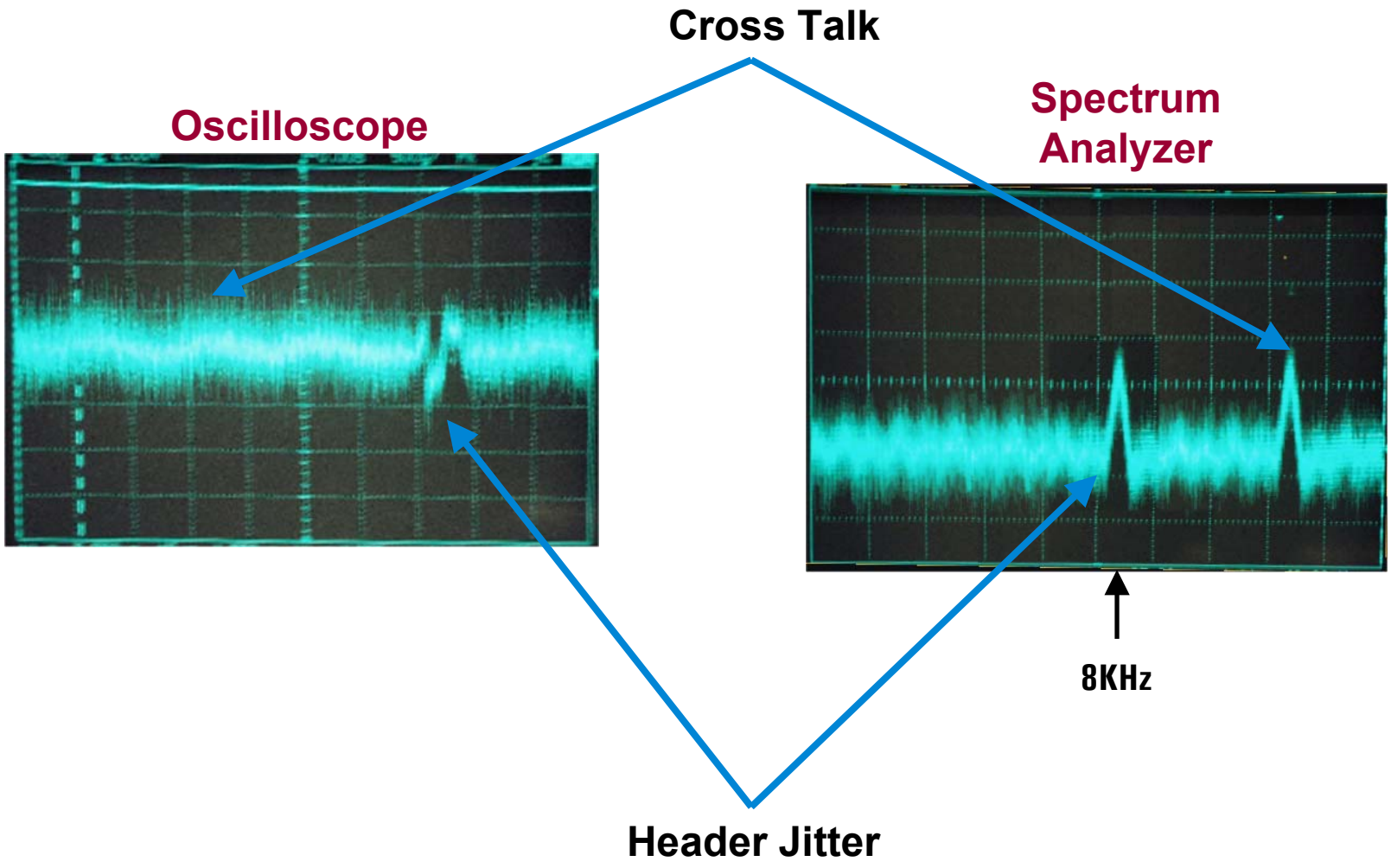
2 SONET/SDH Header Jitter





Oscilloscope

2 Crosstalk + Header Jitter



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Seminar 3: Jitter Measurements & St'ds

Seminar Content

- Jitter measurement and standards
  - introduction (including standards)
  - jitter tolerance, transfer and output measurements
- Wander measurement and standards
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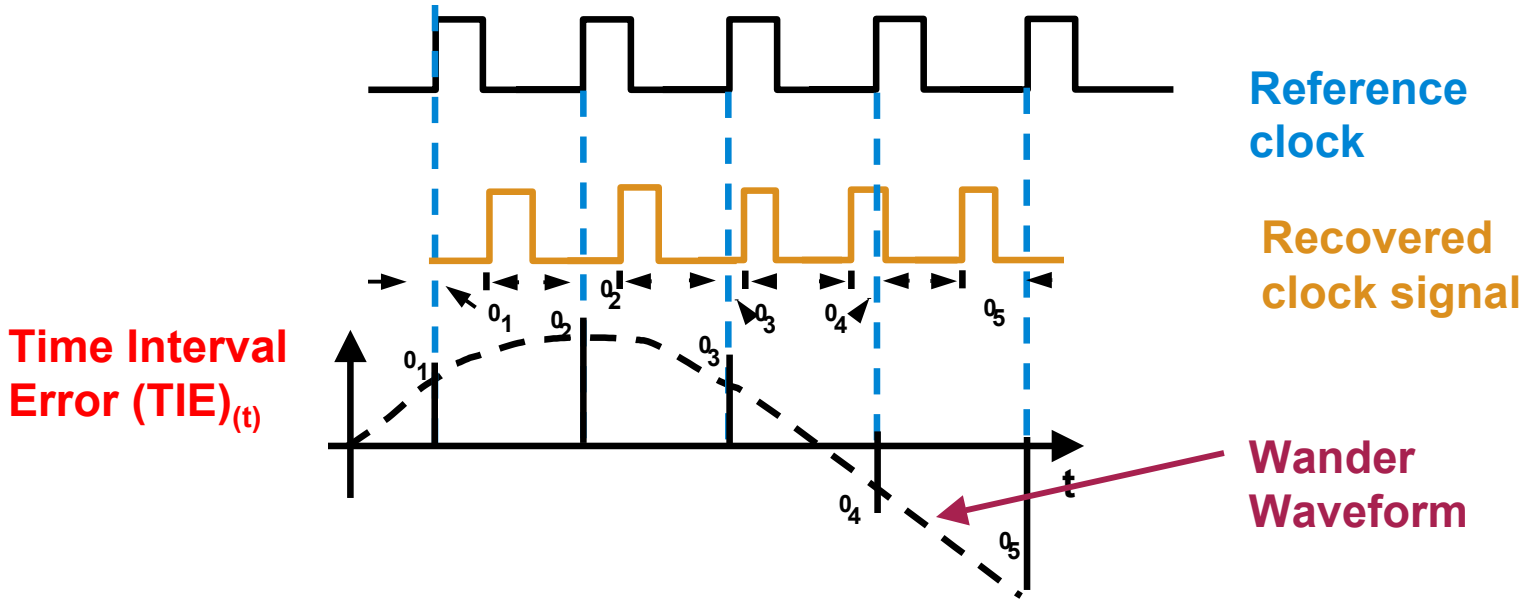
  - MTIE and TDEV measurements
- Impact of tester performance on intrinsic output jitter results
  - tester intrinsic jitter performance
  - tester transient detection performance
  - tester filter effects
- Wrap Up + question & answer session

What is Wander ?

"Long term non-cumulative variations of the significant instants of a digital signal from their ideal positions in time"



Jitter/wander = unwanted phase modulation
Jitter >10Hz; Wander <10Hz

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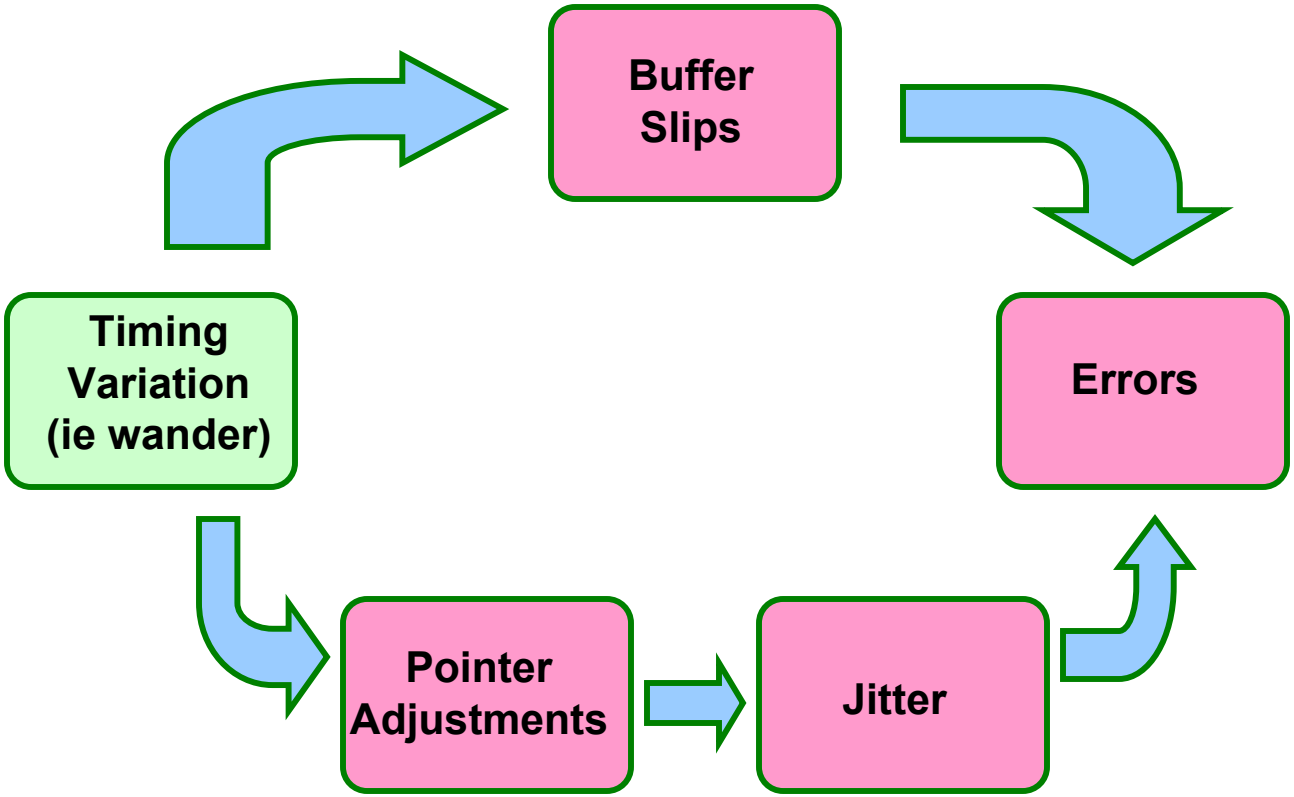
Effects of Wander



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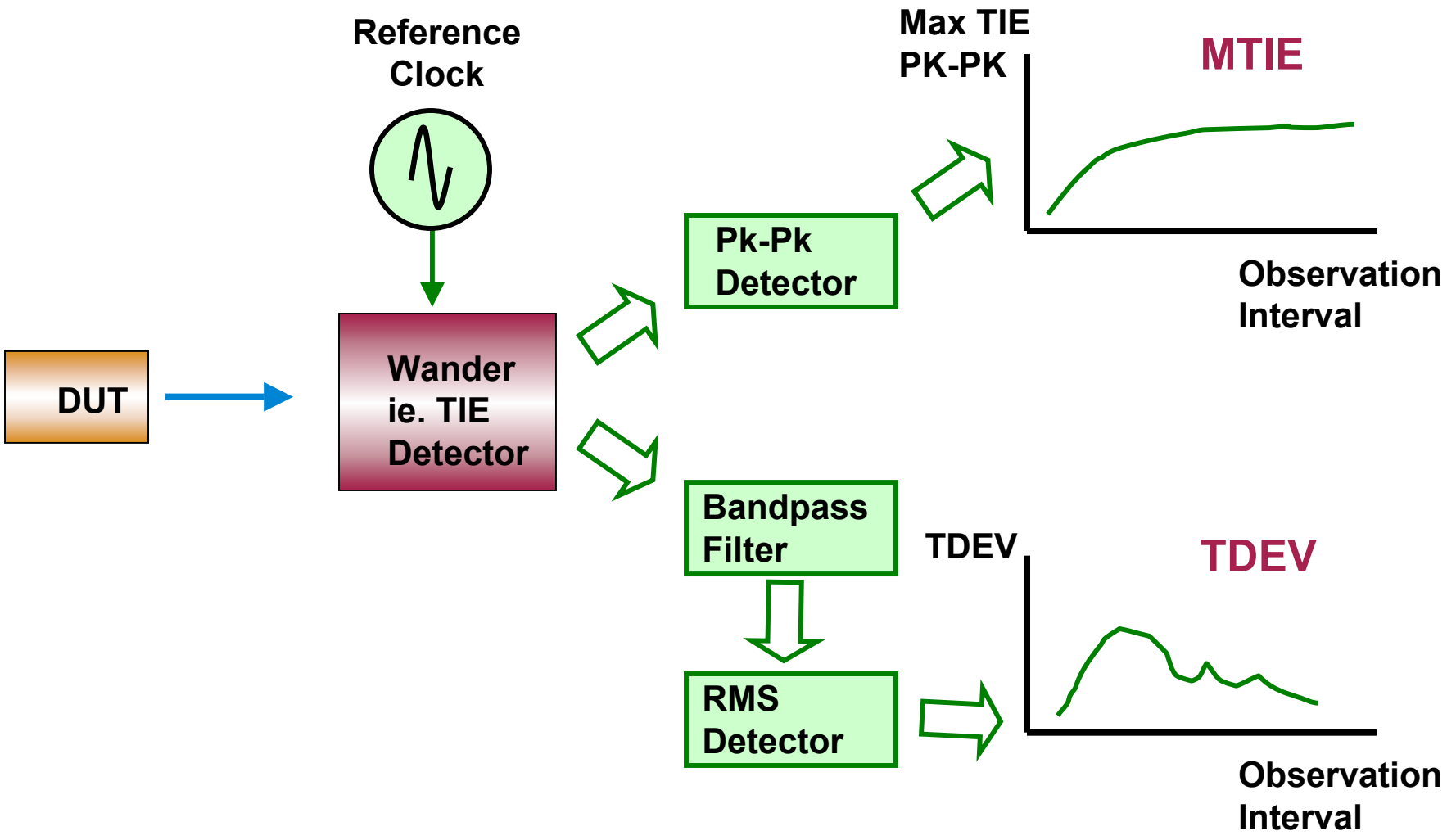
Wander Standards

		Output Wander - MTIE - TDEV	Input Wander Tolerance	Wander Transfer Function	Phase Transients
Network Equipment	SDH (DXC, ADM)	G.813	G.813 G.825	G.813	G.813
	SDH (Regen)				
	PDH		G.823		
	PRC Clock	G.811			
	SSU Clock	G.812	G.812	G.812	G.812
Network Interface	PDH Transport		G.823		
	SONET Transport	GR-253	GR-253	GR-253	
	SDH Transport				
	OTN Transport	G.8251			

2 Output Wander Measurement



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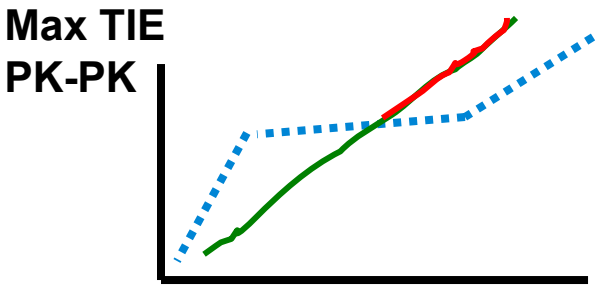
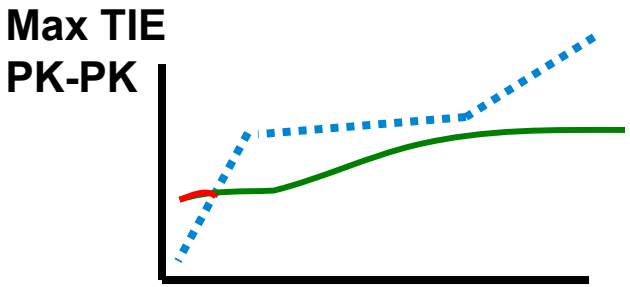
2 Typical Output Wander Results

MTIE Results

Mask

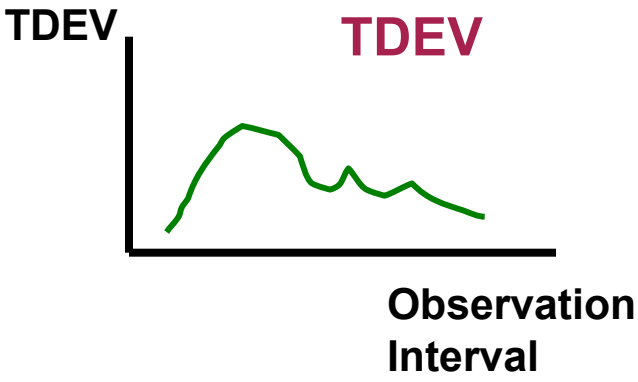


Frequency Offset



Phase Transient

TDEV Results



TDEV slope gives noise source indication, eg.
- white phase modulation
- flicker phase modulation
- white freq' modulation
- flicker freq' modulation

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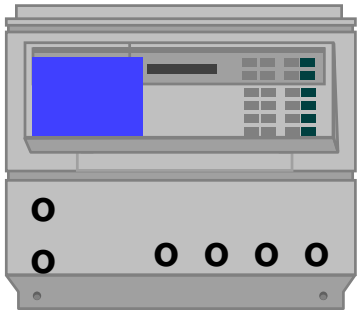
Tester Intrinsic Jitter: The Real Story

The problem … "I don't believe the results from these jitter testers"

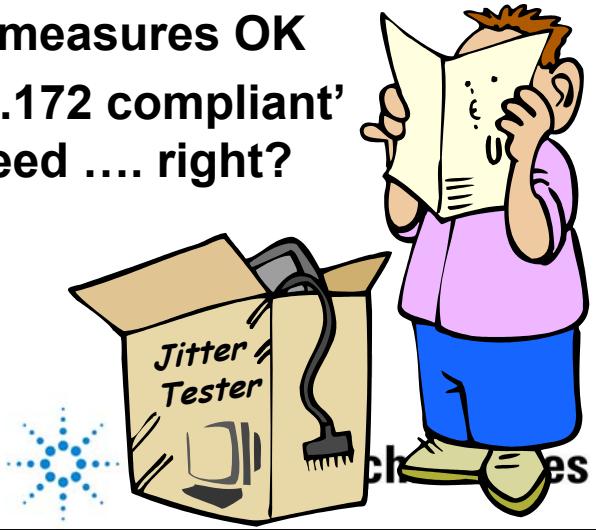
Brand X

- Reads 35mUI back-back
- I add jitter: it measures OK
- I'm told it has low intrinsics and exceeds standards



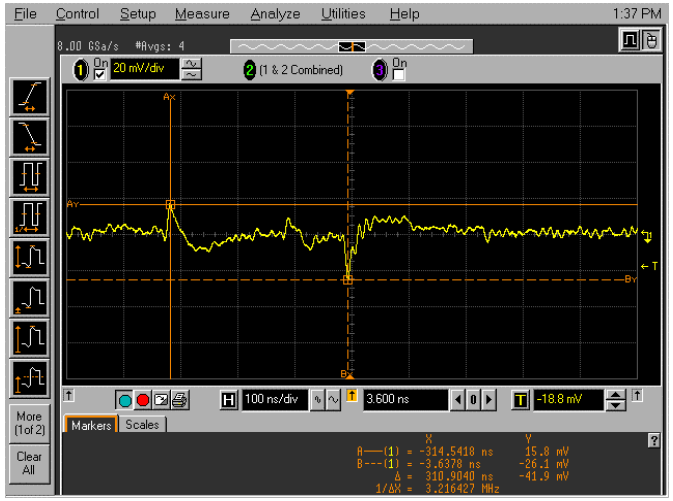
Brand Y

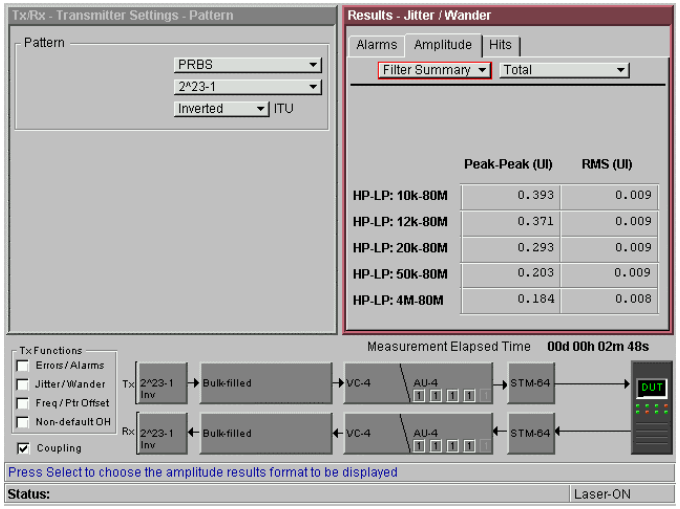
- Reads 35mUI back-back
- I add jitter: it measures OK
- I'm told its 'O.172 compliant' and its all I need …. right?



Correlating Tester Results

- Essentially, there are two results which come from a jitter tester
- Demodulated output (viewed on a ‘scope) shows the baseband jitter
- Display shows the calculated numerical results of this waveform
- Consider the demodulated output to be the ‘shop window’ into the performance of the tester
- Clearly, the front panel display can have software algorithms applied





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Tester Standards are Not Enough

Interface standard (GR-253) quotation:

"for very high bit rate SONET signals, **it may not be feasible** for test equipment to support the capability to provide **accurate** measurements of both rms and pk-pk jitter.

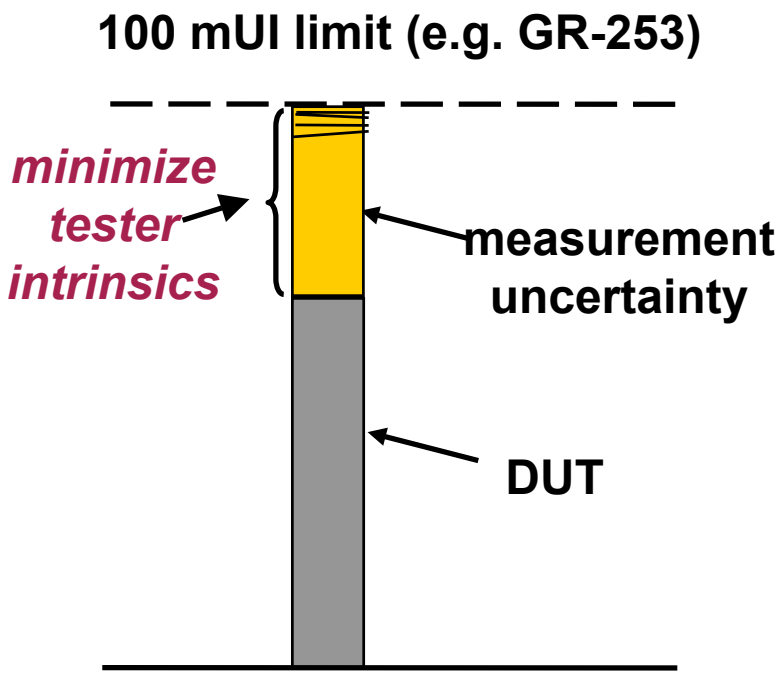
If that is the case, the determination of the conformance of a NE to this requirement should be based on the measurement that **can be made**"

Transmission rate	HP (kHz)	LP (MHz)	Interface limit (rms)	Interface limit (pk-pk)	O.172 Test Equipment Fixed Error
2.5G	12	20	10mUI	100mUI	50mUI
10G	50	80	10mUI	100mUI	Unspecified

?

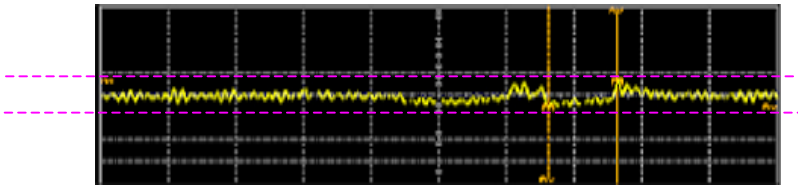
Calibration or Over Correction ?

- I understand the concept of signal-to-noise ratio
- In this case the DUT 100mUI intrinsic specification is what I need to measure
- How is this different for jitter?
- How do we deal with the test equipment intrinsics ?



Calibration only valid if jitter components are additive under all conditions

Tester Demodulated Intrinsic Examples

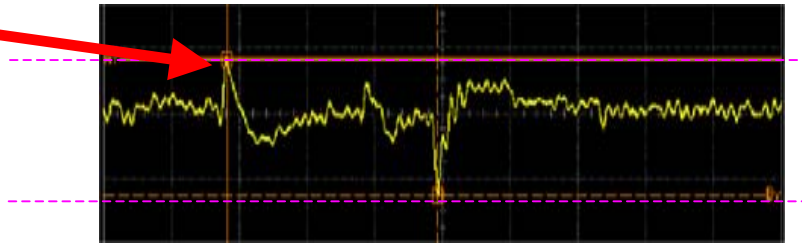


Brand X
~ 25 mUI

Frame header jitter

Brand Y
>100 mUI

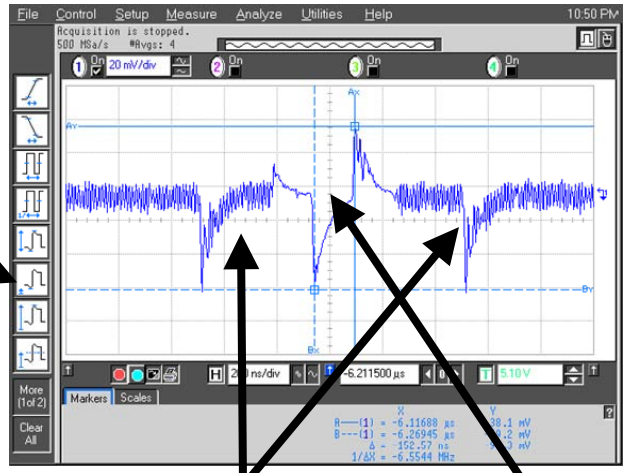
Frame header jitter
- 8 kHz peaks



Brand Z
>100mUI

Measuring True DUT Jitter

Poor tester performance, can't measure DUT jitter below its noise floor



DUT jitter

Tester jitter

- **The DUT jitter can be swamped by a tester high noise floor**
- **Some calibration schemes can be used, but if tester is noisy or has strong pattern dependency, erroneous results can occur.**

Good tester performance, can measure *all* jitter

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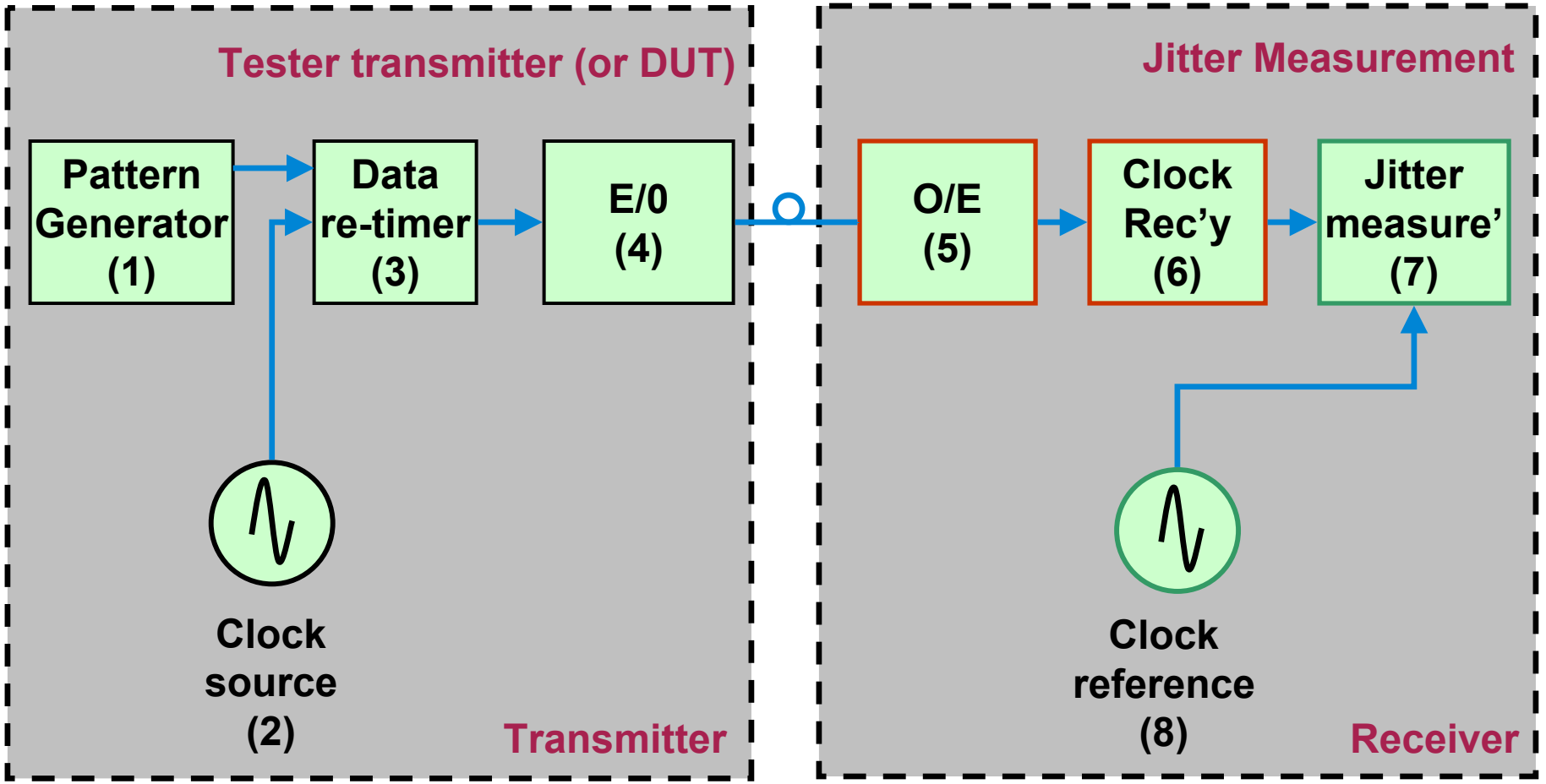
Calibration Guidelines

- The tester must measure its own generated jitter and over calibration (or correction) can render DUT measurement results meaningless
- Deterministic Jitter (DJ) does not add linearly, reliable calibration for DJ effects may be impossible.
- Large components of Random Jitter (RJ) cannot be compensated without a detrimental effect on measurement accuracy.
- In summary, calibration can be applied but only to enhance the overall accuracy of an already good measurement.

Tester Intrinsics - Design Principles



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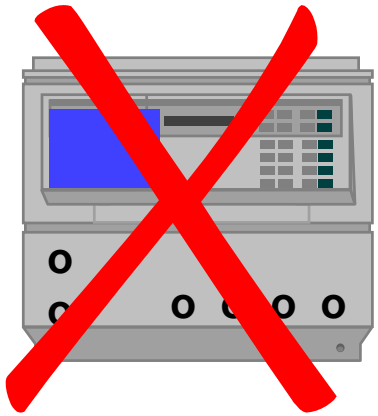
Tester Intrinsic Jitter: The Real Story

The answer … "Despite similar readings, I now understand the true performance of these jitter testers better and know what to look for"

Brand X

- True low intrinsic noise floor
- No calibration 'fiddle factors'
- Low pattern dependence
- Accurate characterisation

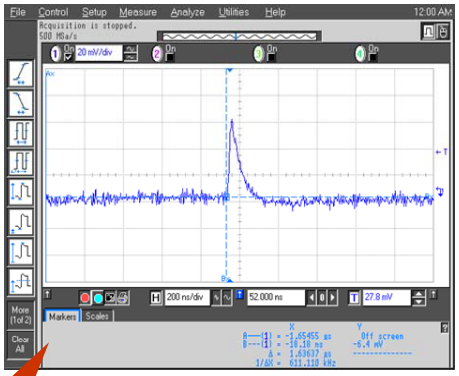


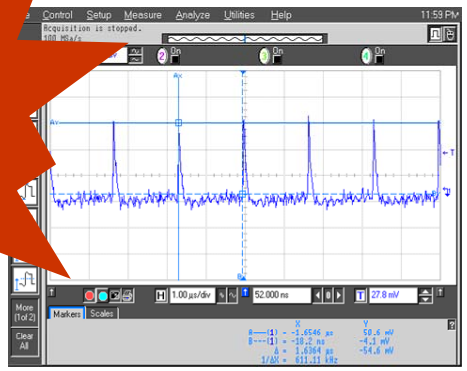
Brand Y

- Suspect high intrinsics
- Dubious calibration
- Seems affected by patterns
- I'm told its ...
  "all in the software correction"

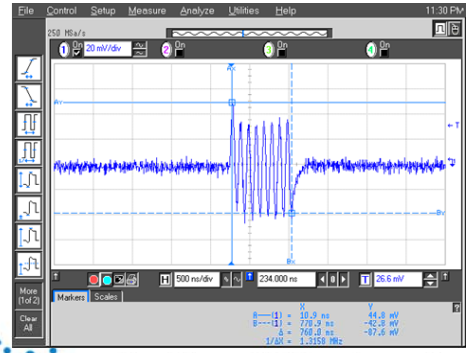
Transient Jitter - Cause & Effect

- Isolated jitter transient
  - timing slip in multiplexer
  - synchronizing clock or PLL glitch
- Repetitive jitter
  - switched mode power supply (SMPS) breakthrough
- Bursts of jitter
  - interference from a data bus
  - processor breakthrough





Peaks could be high enough to cause BER



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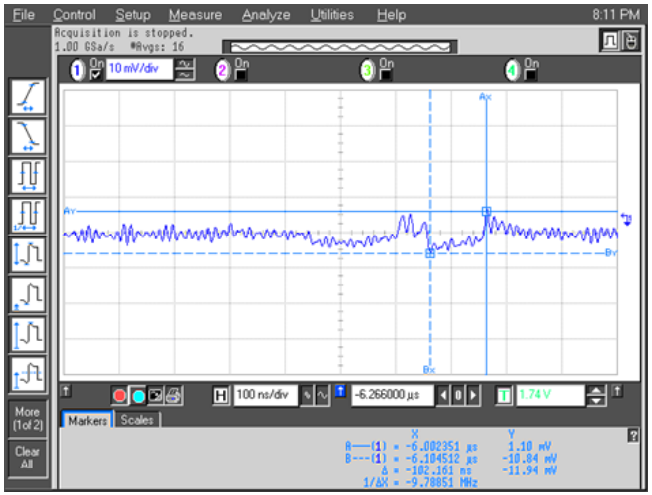
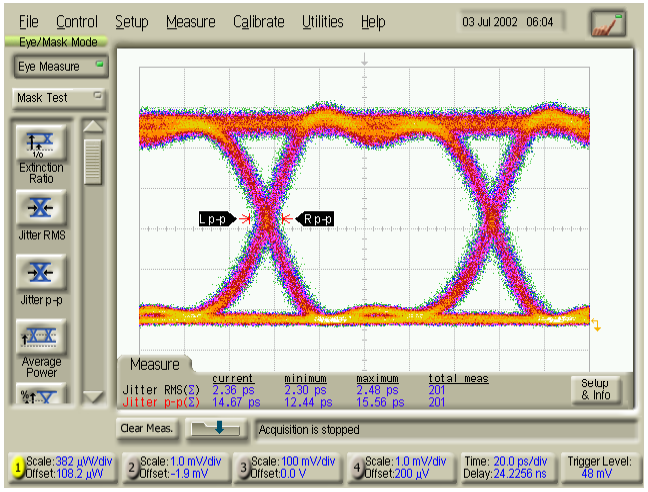
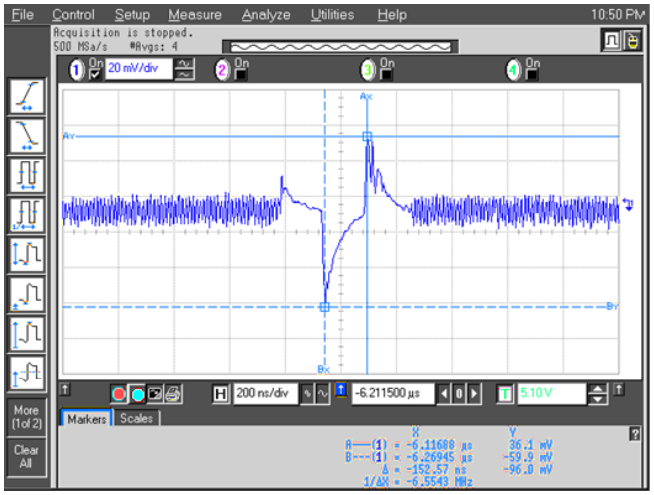
Transient Peak Detection Importance

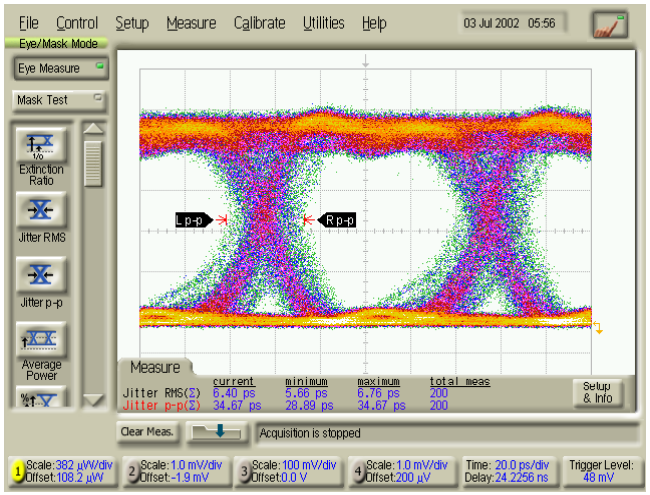
- 20mUI pk-pk
- Operation as design
- Large margin





- 108 mUI pk-pk
- Manufacturing fault - faulty connection between mux and laser
- <u>Pass eye mask</u>





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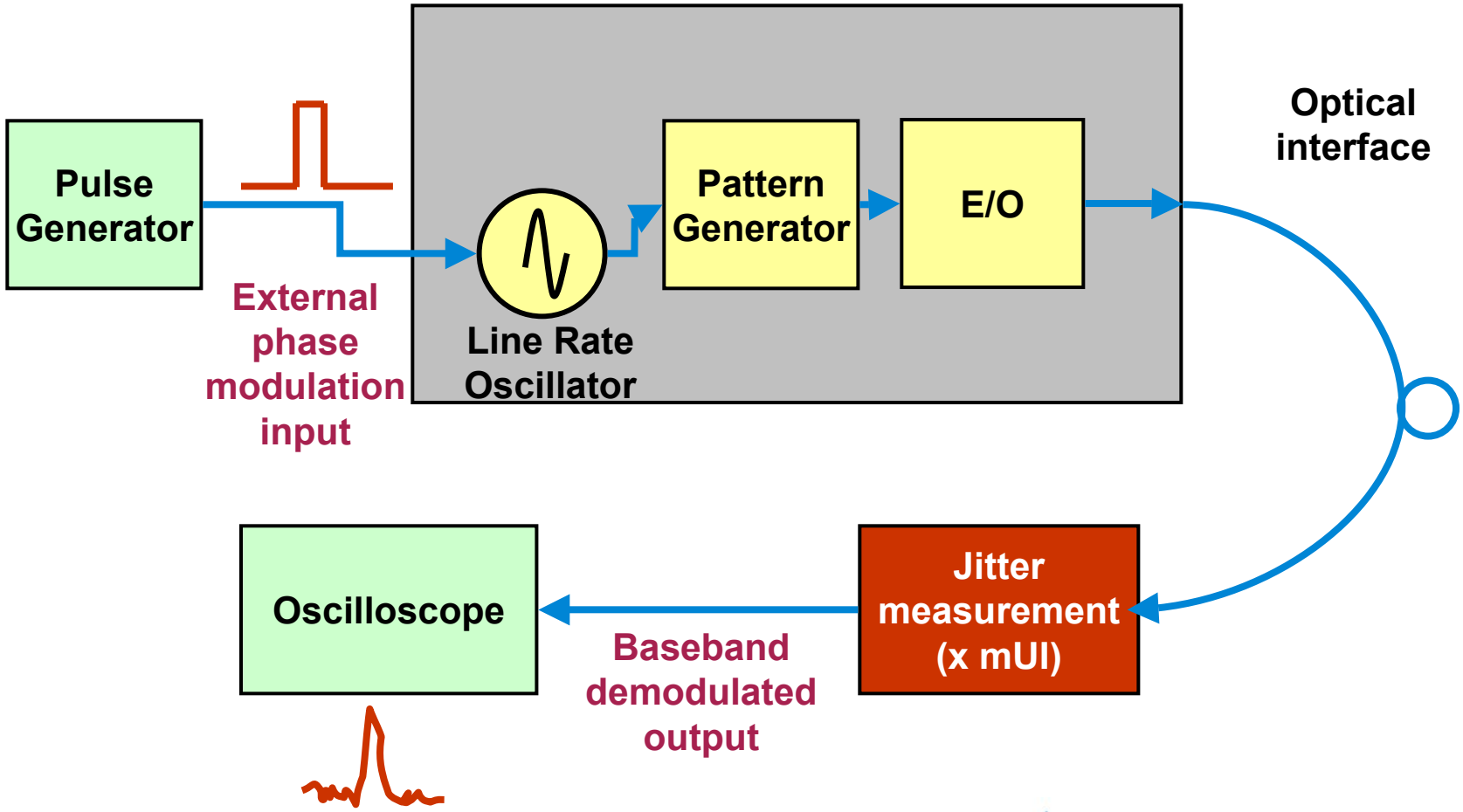
New Conformance Test for Jitter Tester

Test designed to check for intrinsics and transient peak detection



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ITU-T 0.172 Update

3.2.8 Jitter Transient Measurement Accuracy

"WD.05 and WD.17 proposed that **jitter measurement accuracy be specified for jitter pulses** (as well as for sinusoidal jitter, as currently specified).

There was agreement that a test similar to this is needed to ensure better agreement between test sets of different manufacturers. But there were questions about the height and width of the pulses and their repetition rate (if, in fact, they should repeat). The proposal was not accepted, pending further investigation and contributions".

Principle accepted, detail to be agreed

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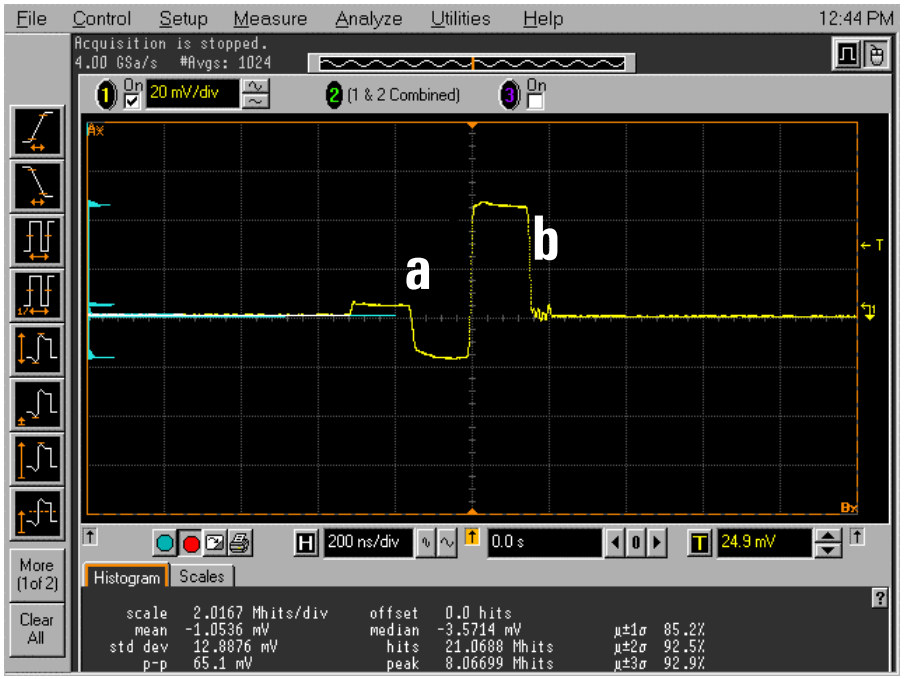
Output Jitter Result Monotonicity Issue

- On occasions results appear inconsistent between filter settings.
- Expect…….
  - 10kHz – 80MHz result should be > than 50kHz – 80MHz result
  - 50kHz – 80MHz result should be > than 4MHz – 80MHz result
- In the presence of DUT header jitter this may not be true.

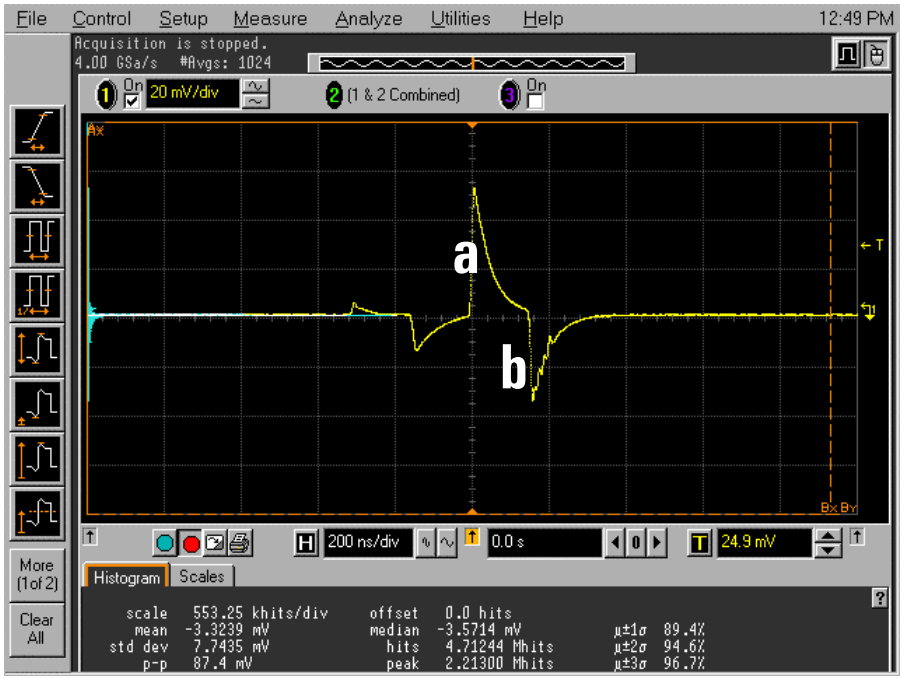
Why……?

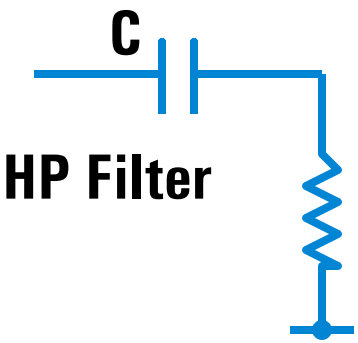
Demodulated Header Jitter + Filters

50KHz – 80MHz



4MHz - 80MHz





HP Filter

$i = C\,dv/dt$

Pk-Pk Result = a + b

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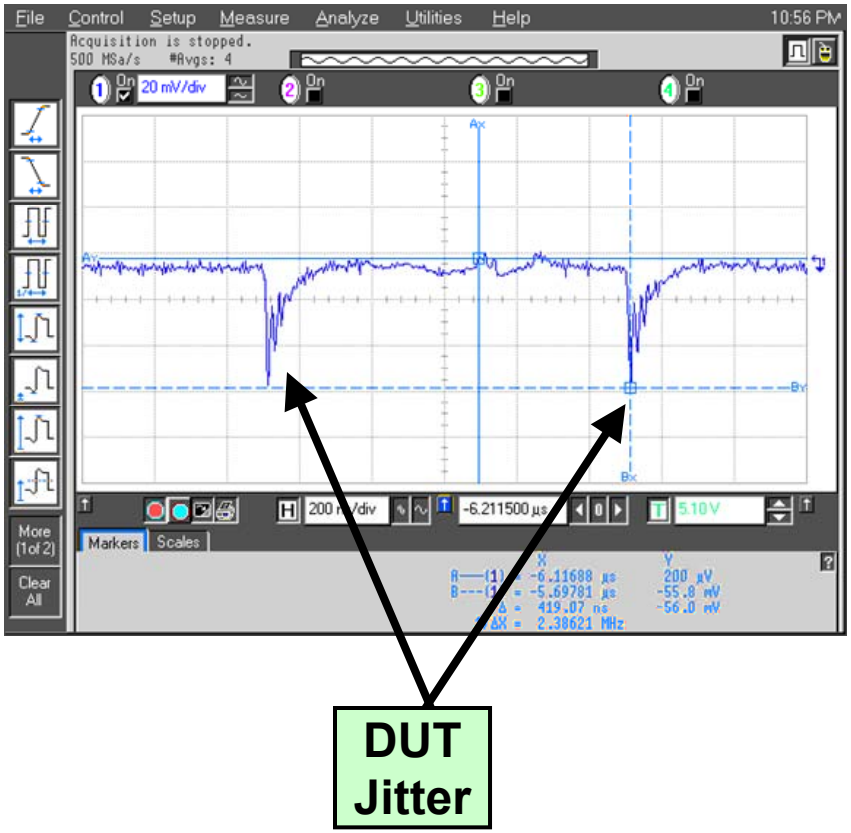
Tester Performance Impact Summary

- Accurate testing of DUT jitter performance is key to ensuring error-free performance in SONET/SDH and OTN networks.
- Low intrinsic performance of the jitter tester is key:
  - Poor intrinsics cannot be ‘corrected’ or ‘subtracted out’
  - High intrinsic noise floor renders jitter measurement worthless
  - Back-back jitter readings are meaningless without thorough examination of true performance
- Transient peak detection of the jitter tester is key:
  - Test equipment should detect any and all jitter components
  - Could be only one glitch (causing errors), but this still accounts for the true peak value.
  - Ability to only measure accurately continuous sine wave modulation is insufficient for true DUT jitter measurement

OmniBER OTN J7231B Jitter Analyzer

An example high accuracy jitter (and wander) analyzer



- **Industry best intrinsic jitter performance, exceeding O.172.**
- **Industry best jitter transient peak detection, capturing all jitter events.**
- **Unique parallel filter architecture speeds testing & event correlation.**
- **All optical SONET/SDH/G.709 OTN jitter test, 52 Mb/s to 10.71 Gb/s.**

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Agilent Jitter Tutorial Booklet

Short papers individually authored by Agilent engineers; discusses areas of concern in jitter test

- **Challenging the standards**
- **Recommended test signals**
- **Results interpretation**
- **Understanding tester performance**

…… not a jitter theory text book!

Data over SONET/SDH Seminar Series

Objective

- Comprehensive tutorial seminar series for engineers involved in the design, verification, manufacturing, deployment and maintenance of Data over (next generation) SONET/SDH equipment and networks.

Series Topics

- DoS Technologies - Standards, Structures & Design.
- DoS Equipment - Architectures & Test Challenges
- SONET/SDH Jitter Measurements & Standards

Seminar 3: Jitter Measurements & St'ds

Seminar Content

- Jitter measurement and standards
  - introduction (including standards)
  - jitter tolerance, transfer and output measurements
- Wander measurement and standards
  - introduction (including standards)
  - MTIE and TDEV measurements
- Impact of tester performance on intrinsic output jitter results
  - tester intrinsic jitter performance
  - tester transient detection performance
  - tester filter effects
- Wrap Up + question & answer session

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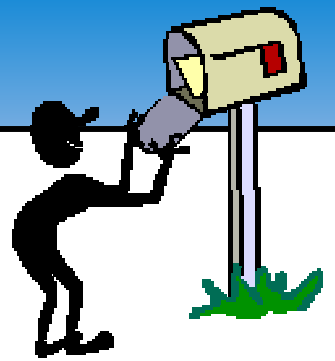

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