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USB 3.1 Gen2 10G - Gen1 5G Receiver Testing with J-BERT M8020A

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BY
NeuHelium

Agenda

USB 3.1 gen1 vs. gen2 overview

LFPS

Repeater / Re-Drivers / Re-Timers

128b/132b

SKPOS

Jitter Tolerance

USB 3.0 ECN 015 and ECN 018

N5990A Test Automation SW

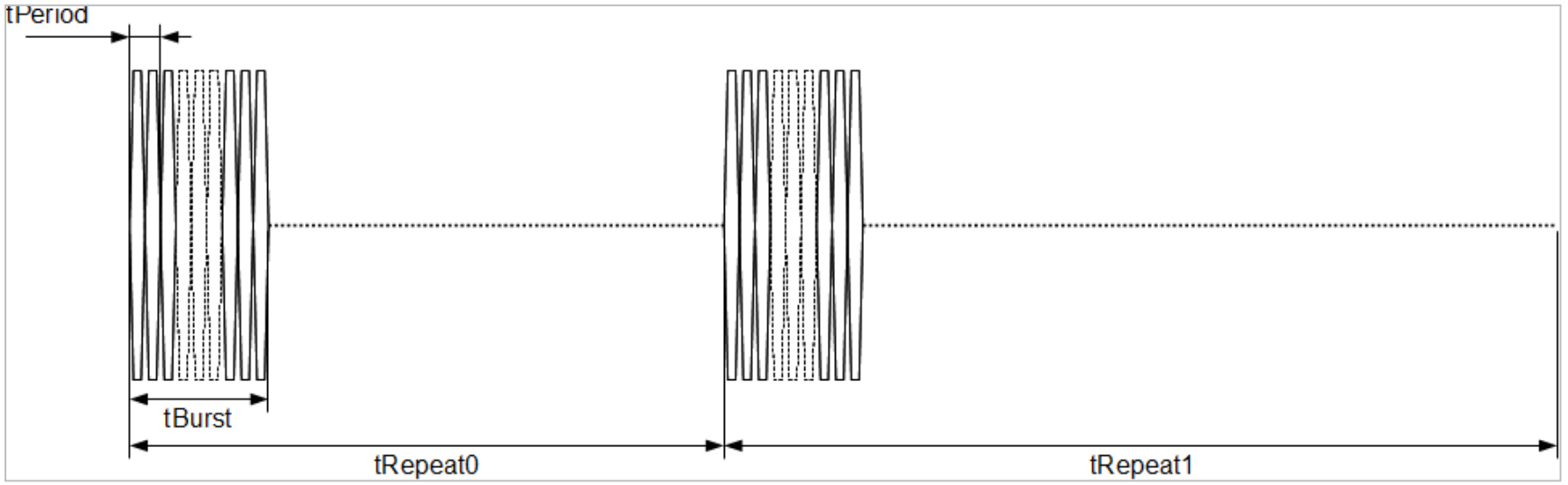
Channel Add Setup for HighSpeed and LFPS Testing

RX Test Setup

USB 3.1 Gen 1 vs. Gen 2 Overview

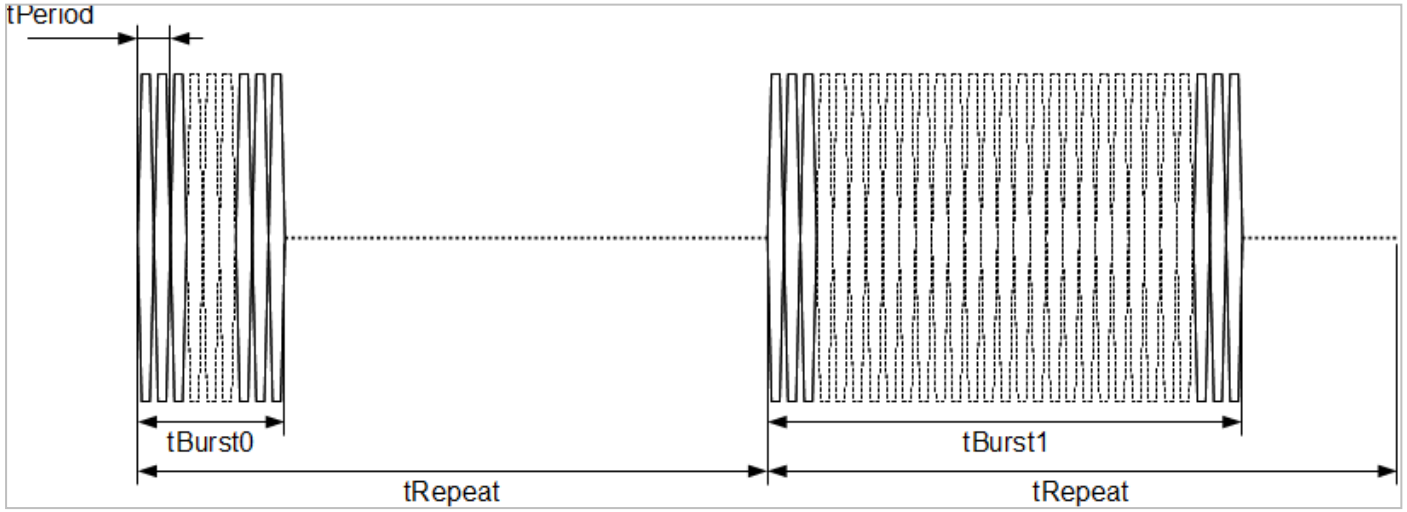
	Gen 1	Gen 2
Data rate	5Gb/s ±300ppm (SSC variations not accounted for)	10Gb/s ±300ppm (SSC variations not accounted for)
Coding	– 8b/10b – scrambler: $G(X) = X^{16} + X^5 + X^4 + X^3 + 1$ scrambler reset by COM (K28.5) or BRST seed: FFFFh – Symbol lock: K28.5, some implementations might be able to use K28.1or K28.7	– 128b/132b scrambler: $G(X) = X^{23} + X^{21} + X^{16} + X^8 + X^5 + X^2 + 1$ scrambler reset by SYNC OS seed: 1D BFBCh – Block alignment: SYNC OS + SDS OS and realignment through SKP OS
SKP	K28.1, K28.1	SKPOS with variable number of SKPs
LFPS		Device host capability negotiation is done during LFPS phase using LFPS modulation schemes
CDR	PLL transfer: – f_{3dB} = 10MHz – $peaking_{max}$ = 2dB HPF transfer: – f_{3dB} = 4.9MHz – peaking ≈ 0dB – damping factor = 0.707	PLL transfer: – f_{3dB} = 15MHz – $peaking_{max}$ = 2dB HPF transfer: – f_{3dB} = 7.5MHz – peaking ≈ 0dB – damping factor = 0.707
SSC	– Modulation rate: 30kHz to 33kHz – Deviation: +0 to -4000(min)/-5000(max) – Max slew rate: 10ms/s	– Modulation rate: 30kHz to 33kHz – Deviation: +0 to -4000(min)/-5000(max) – New df/dt requirement: 1250 (max) ppm/μs instead of max slew rate spec
De-emphasis	Post: -3dB	Pre: 2.7dB Post: -3.3dB

LFPS – SCD1 & SCD2 – tRepeat Modulation



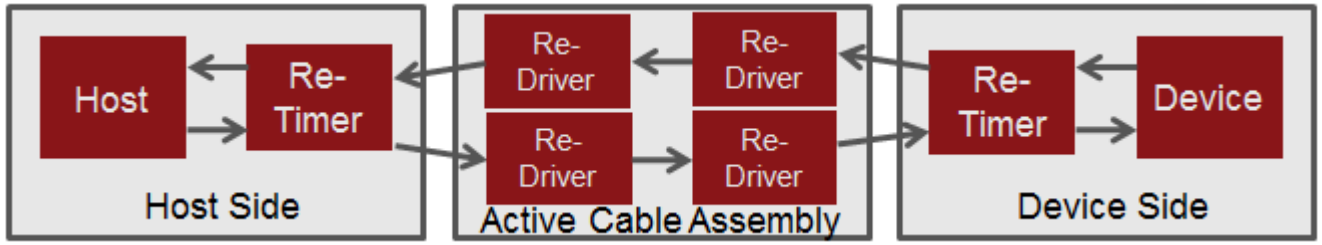
- tRepeat is modulated to express 0 (short) and 1 (long)
- SCD1.LFPS (4’ b0100), and SCD2.LFPS (4’ b1101)
- SuperSpeed+ identity check

LFPS – LBPM Encoding



- Rate (speed and lane) announcement and negotiation
- Repeater declaration
- Power state transition in repeater
- Can be expanded to:
  - VBus control on/off, overcurrent sensing
  - Power delivery
  - Vendor specific operation

Repeater – Re-Driver – Re-Timer



- A link can contain multiple repeaters
- Repeater devices can be of different types
  - Re-timer
  - Re-driver
- Repeaters are declared in LBPM
- A maximum of 10 elastic buffers could be involved in loopback
  - more SKPOS required
  - send 5 SKPOS instead of 1 SKPOS every 22 blocks

128b/132b Coding

- 4 bit header to avoid link reset problems from PCIe 8G
- 0011 marks a data block and 1100 a command block
- Same scrambler polynomial as PCIe 8G:
  $G(X) = X^{23} + X^{21} + X^{16} + X^{8} + X^{5} + X^{2} + 1$
  Block header bypasses scrambler and does not advance scrambler
- Command block scrambler rules
  - TS1, TS2, TSEQ
    - symbol 0 bypasses but advances scrambler
    - symbols 1 to 13 are scrambled
    - symbols 14 and 15 bypass scrambler but advance scrambler if used for DC balance otherwise they are scrambled
  - SKP OS bypasses scrambler and does not advance scrambler
  - SDS OS bypasses scrambler but advance scrambler
- All blocks are 132b long except SKPOS which can be shorter or longer

SKPOS – gen2

- SKPOS: 2n *SKPs + SKPEND symbol + 3 symbols for LTSSM state; n = 0 to 18
  - SKP..CCh
  - SKPEND..33h
- SKPOS in average every 22 blocks

➔ The variable length of SKPOS is challenging for BERT EDs

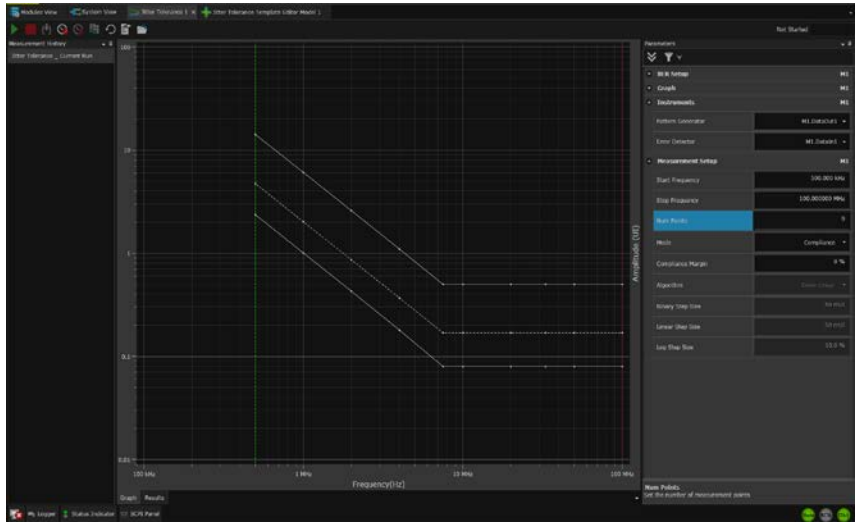
➔ No BERT system currently on the market is able to deal with this

- Remark:
- SKPOS rules might change to
  - 4n *SKPs + SKPEND symbol + 3 symbols for LTSSM state; n = 1 to 9
- This would ensure that every receiver in the link has at least 4 SKPs for clock compensation available

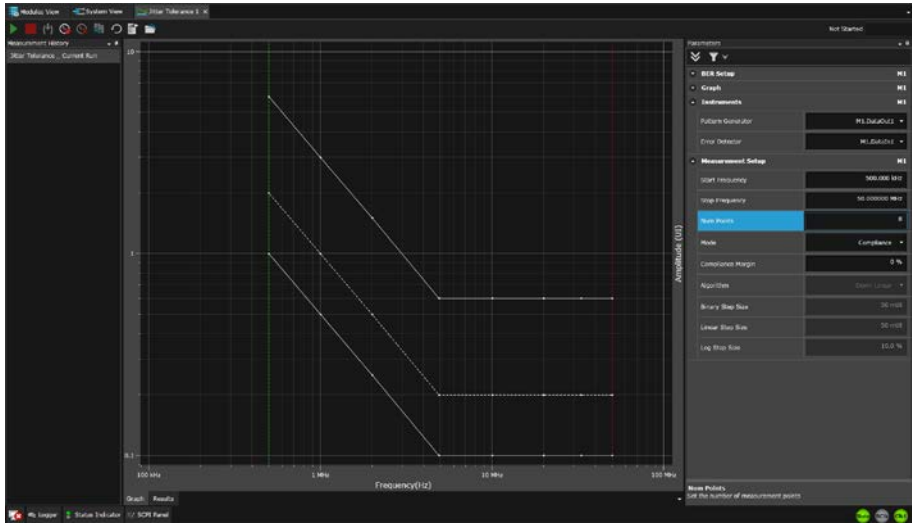
Jitter Tolerance – Stress Components – Base Spec

	Gen1 5G	Gen2 10G
TJ after RX EQ	450mUI	394mUI
RJ_{rms} / $RJ_{pp\ ber=1E-12}$	12.1mUI / 177.9mUI	13.08mUI / 192.3mUI
$SJ_{out\ of\ CDR\ tracking\ range}$	200mUI	170mUI
Channel	channel -20.6dB @ 5GHz ➔ M8048A-001 12.8” + M8048A-002 14.4” is close. Shorter traces are available on the M8048A-001 to compensate for fixture and cable losses	

Jitter Tolerance Settings – Base Spec

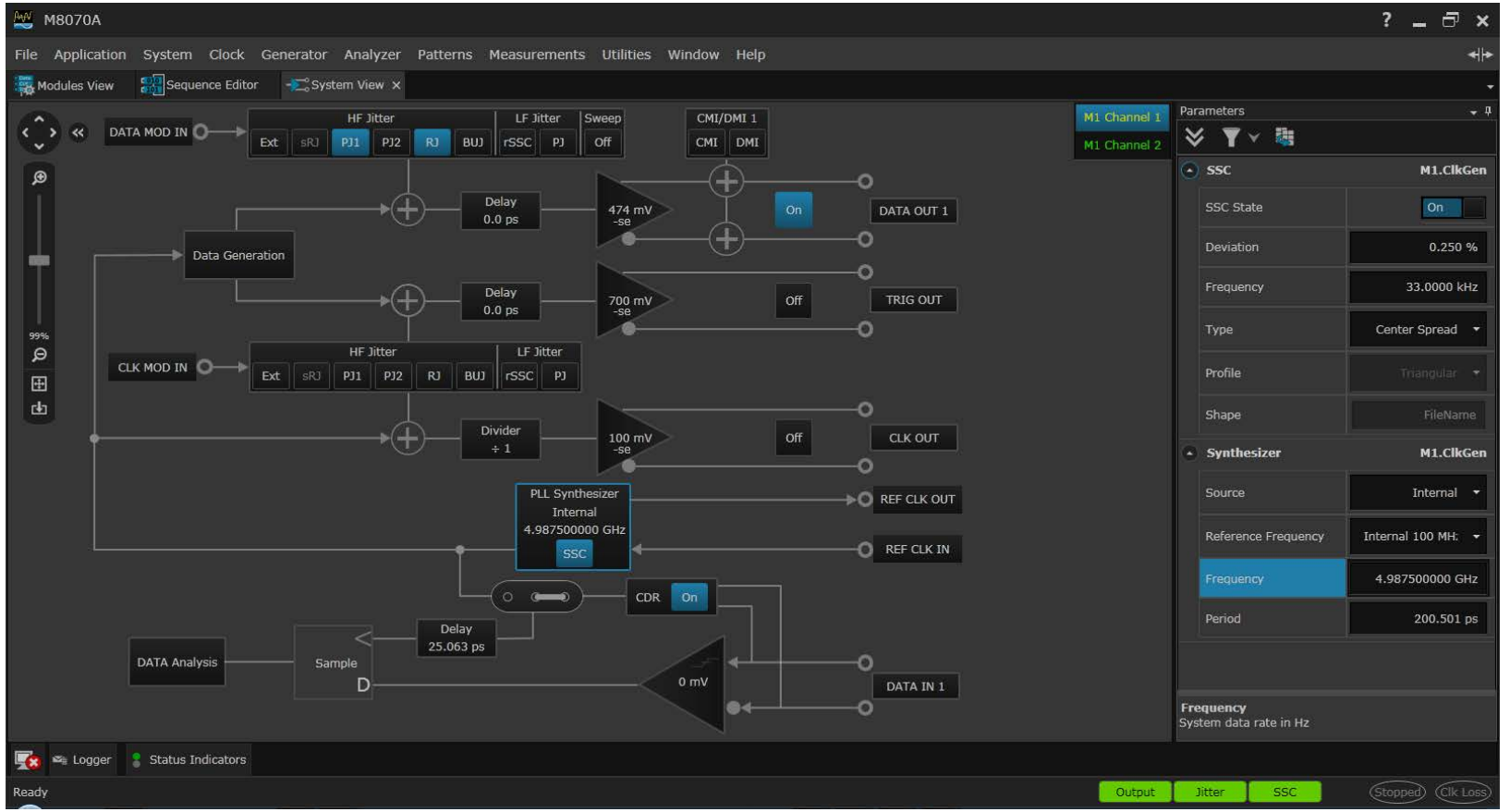


- Center Data Rate with SSC: 9.975Gb/s
- SSC: Center Spread 33kHz with 0.25%
- Voltage Swing @ TP1: 800mV
- Pre-shoot @ TP1: 2.7dB
- De-Emphasis @TP1: -3.3dB
- RJ: 1.308ps RMS



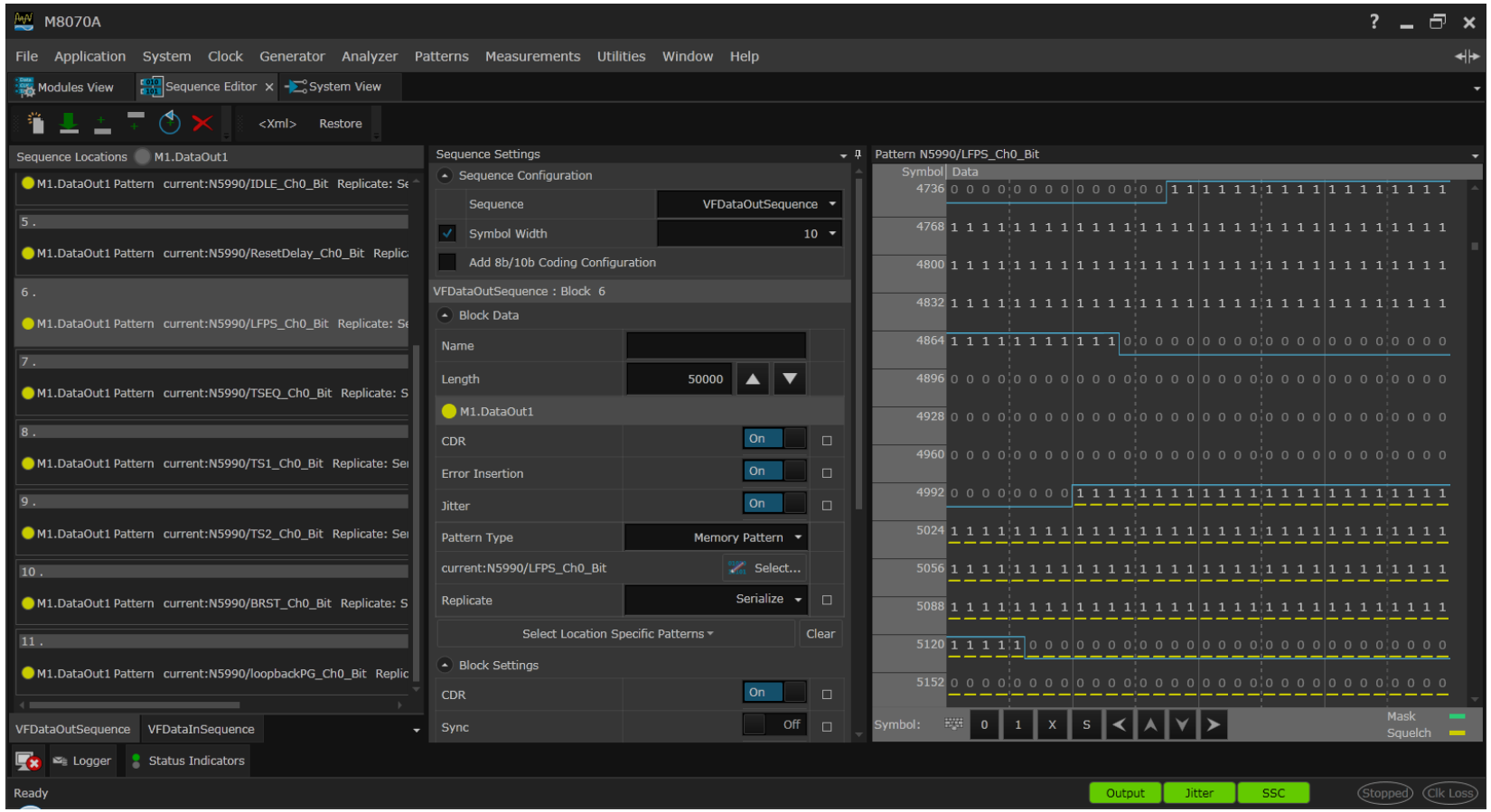
- Center Data Rate with SSC: 4.9875Gb/s
- SSC: Center Spread 33kHz with 0.25%
- Voltage Swing @ TP1: 750mV
- De-Emphasis @TP1: -3.0dB
- RJ: 2.42ps RMS

System View



The System View provides a quick overview on stressor and output states

Sequencer



Squelch is used on the outputs for a real electrical idle between LFPS bursts

USB 3.0 – ECN 015 and ECN 018

ECN 015:

- Changed minimum SSC spread from -0.4% to -0.2%
- New SSC spec:
  - +0% to min. -0.2% / max. -0.5%
- Compliance testing is done with 0.5% spread

ECN 018:

- Allows a -0.2% offset on data rate to be more wireless friendly
- Limits SSC deviation for wireless friendly data rate
- New data rate and SSC spec for wireless friendly use case:
  - Data rate is 5Gb/s -0.2% ➔ 4.99Gb/s +/- 300ppm
  - SSC for 4.99Gb/s is +0% to min -0.2% / max. -0.3%

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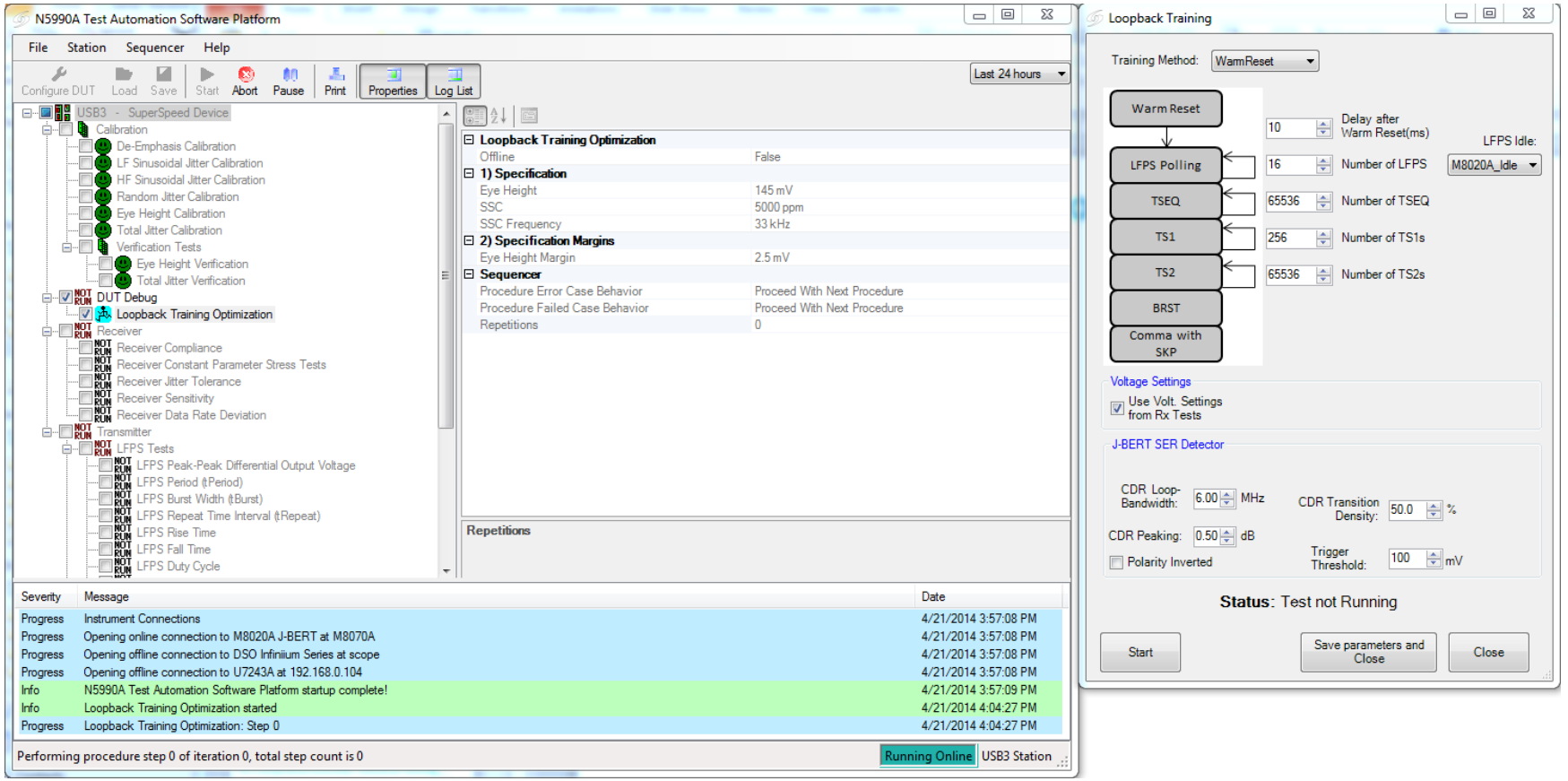
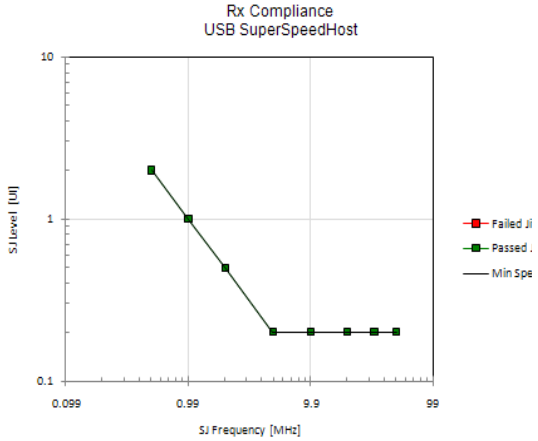
N5990A USB 3.0 Test Automation SW

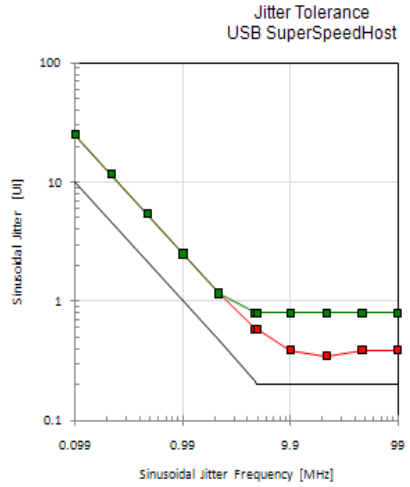


SuperSpeed Receiver Tests

Rx Compliance and Jitter Tolerance Testing

- Automated instrument control for:
  - Setup calibration
  - Compliance test
  - Characterization test
  - Support for debugging
- Operator guidance
- Sophisticated test reports
- Controls J-BERT, Oscilloscope.
- Supports full product characterization including transmitter measurements





Result	SJ Frequency [MHz]	Failed Jitter [UI]	Passed Jitter [UI]	Min Spec [UI]	Symbol Errors
pass	0.500		2.00	2.000	0
pass	1.000		1.00	1.000	0
pass	2.000		0.50	0.500	0
pass	4.900		0.20	0.200	0
pass	10.000		0.20	0.200	0
pass	20.000		0.20	0.200	0
pass	33.000		0.20	0.200	0
pass	50.000		0.20	0.200	0

Channel Add – LFPS Tests and USB 2.0 RX Tests

- A channel add allows to create real electrical idle signaling with very fast transitions from data swing to 0 and vice versa
- Channel add can be used to
  - Test and characterize LFPS timing
  - Test and characterize USB 2.0 receivers

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Instrument Setup for RX Testing

Expected RX Test Setup Without Accessories:
J-BERT M8020A with following options:

- C16 – 16G BERT (C08 – 8.5G BERT would be sufficient for USB 3.x 5G)
- 0G4 – De-emphasis
- 0G3 – Jitter Injection
- 0S1 – Clock Compensation for Error Detector (USB 3.x 5G supported with initial release; support for USB 3.1 10G is scheduled for late summer 2014)

Useful Additional Options:

- 0G2 – Second Pattern Generator for USB 2.0 Tests and USB 3.x LFPS Tests
- 0A3 – Error Detector CTLE

Control and Automation SW:

- M8070A – 0TP or M8070A – 0NP – M8020A System SW
- N5990A – 010 + N5990 – 102 USB 3.0 RX Test Automation
- TBD – USB 3.x Link Training Suite

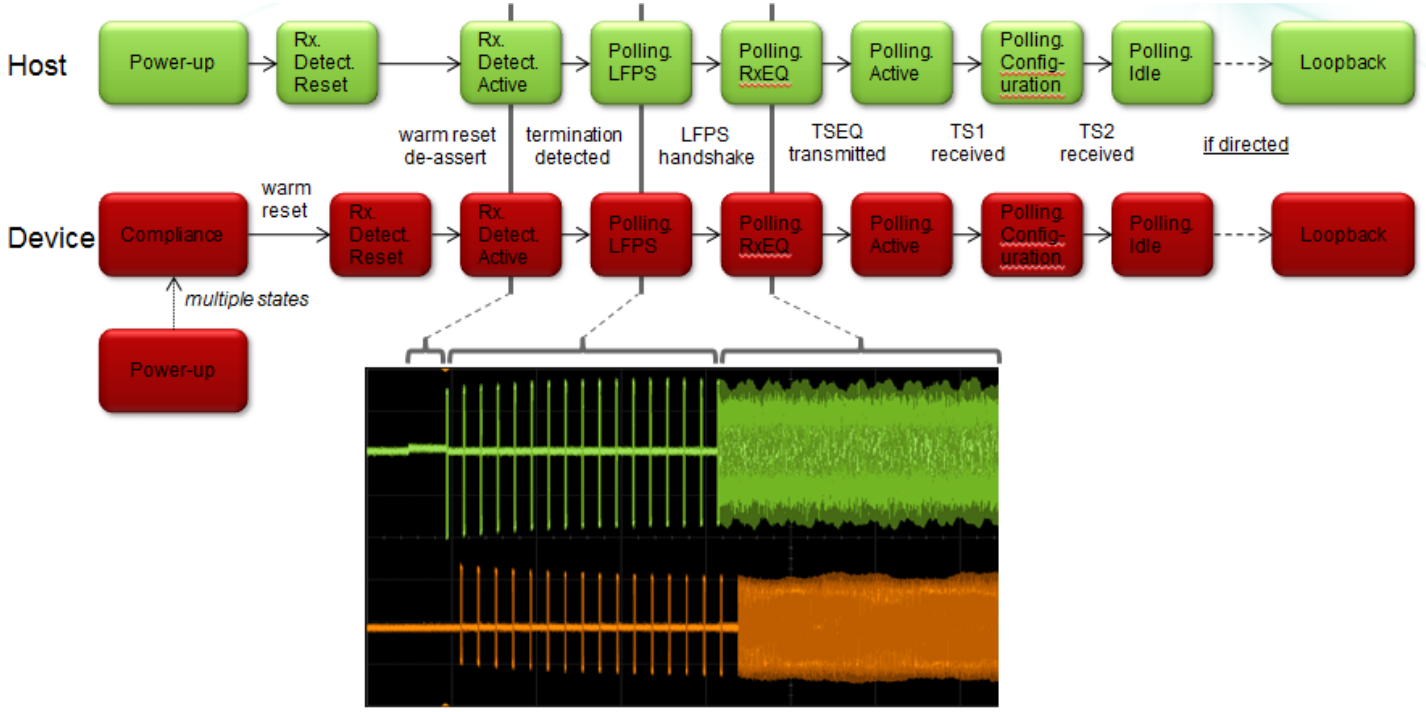
Mainframe:

- M8020A – BU2 – 5-slot AXIe chassis with USB option

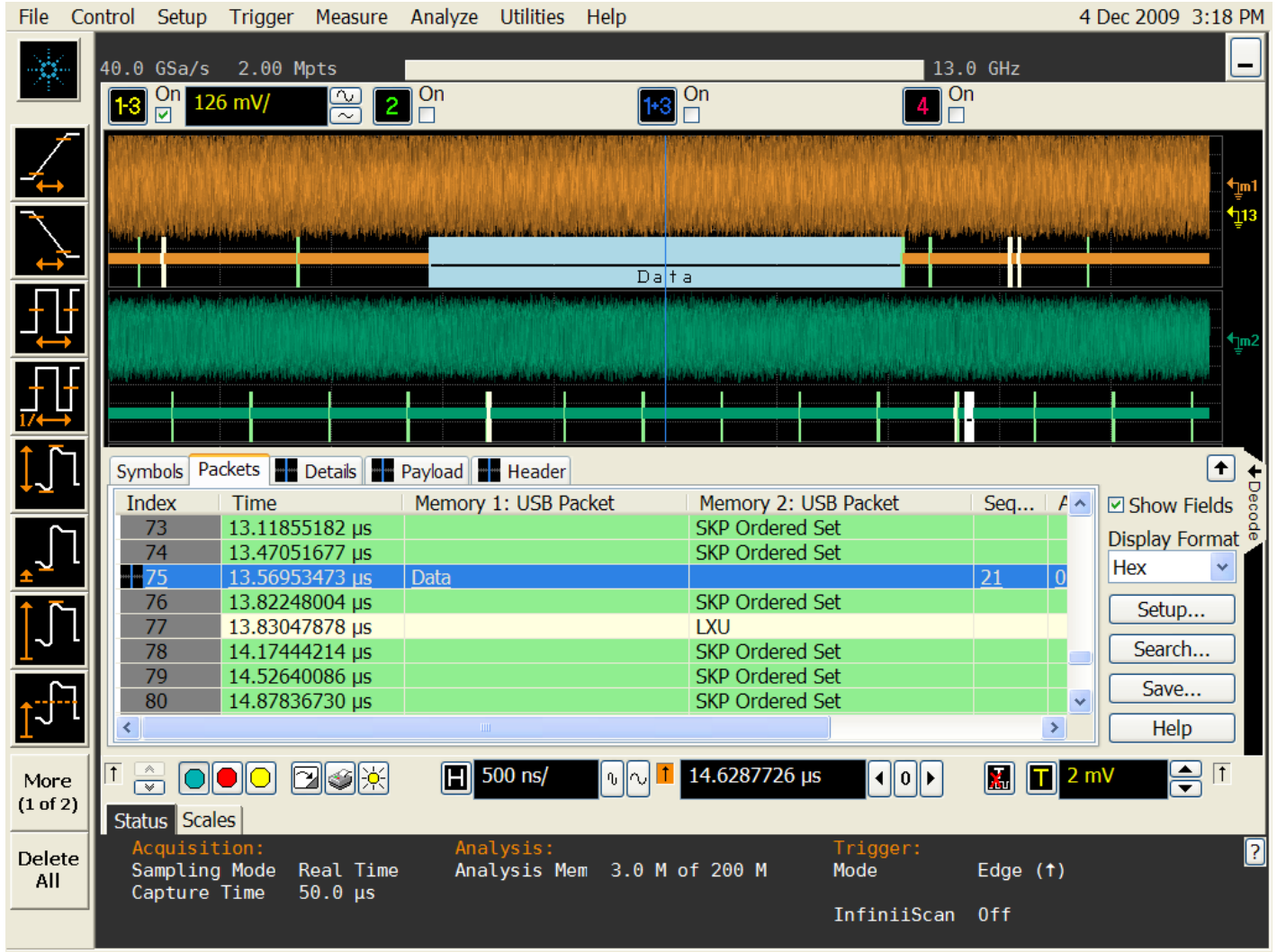
Typical SuperSpeed Link

Turn-on Sequence

LTSSM states:



– J-BERT’s sequence trigger can be used to trigger scope captures for each trainings step ➔ in combination with scope’s protocol decode very helpful for debugging a trainings sequence



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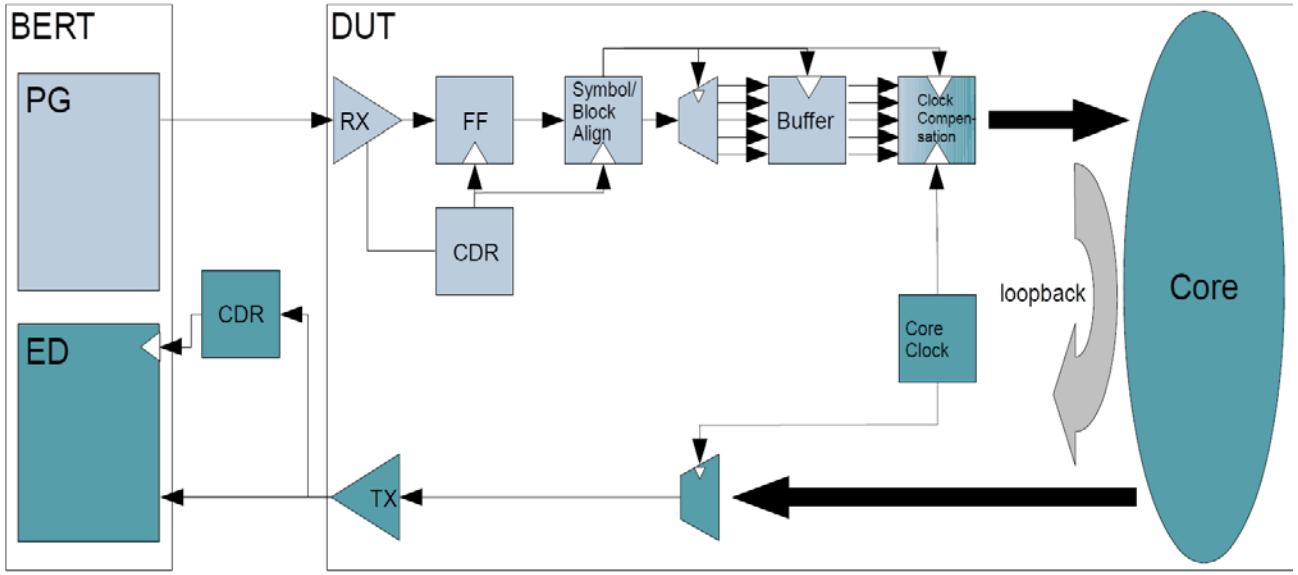
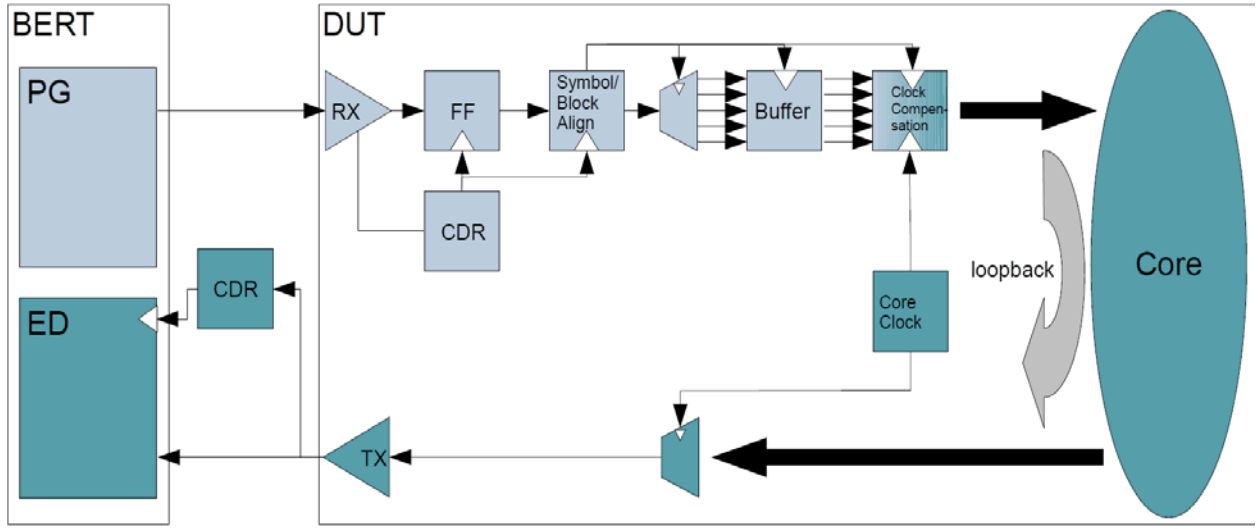
Loopback – 1

- BERT and DUT run in separate clock domains
- DUT has to modify SKPOS for clock compensation
- Test pattern is modified ➔ normal BER comparison does no longer work
- What to do?

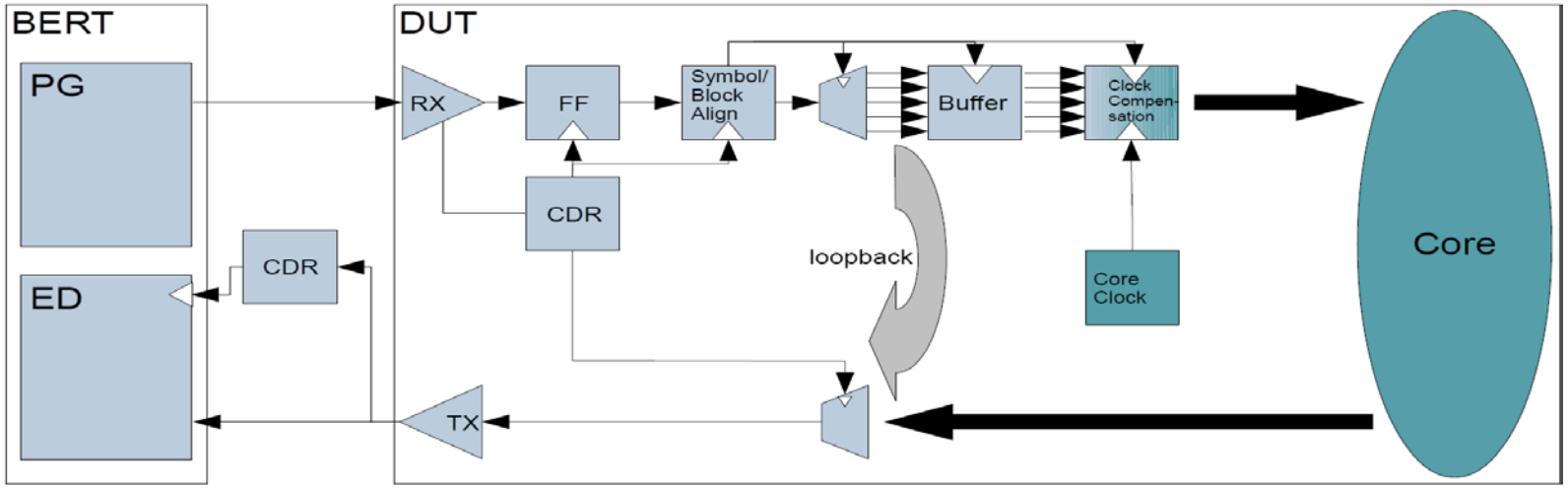


Loopback – 2

- Modification is within SKPOS only
- BERT ED needs to filter SKPOS on expected as well as received pattern and compare remaining bits
- Not available yet but will be available within August / September 2014
- What if testing is required in the meantime?



Loopback – Near End Loopback



If chipset control is possible use near end loopback

- Near end loopback bypasses the clock compensation and both the DUT RX as well as the DUT TX run in the BERT’ s clock domain
- The DUT does not modify the pattern and normal BER comparison can be used
- BUT since the DUT uses the clock recovered by the RX to clock the TX jitter is transferred back to the BERT ED. Choose BERT ED clocking with respect to DUT jitter transfer characteristics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