KEYSIGHT

1.6Tbps output jitter decomposition associated with high loss AUI-C2M channel conditions Version 1.2

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Based on draft release of IEEE 802.3dj™/D1.0/1.1/1.2

Abstract: Performing JNu operations near the limits of current channel profiles is a highly technical proposition, and may require some methodology revisions. This contribution will offer an overview of current state of the art jitter decomposition methods and offer some technical proposals designed to reduce the channel based jitter amplification impact on random jitter.

Supporters/Collaborators (Version 1.2)

Mike Dudek (Marvell)
Luke Wang (Credo)
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Adee Ran (Cisco)
Geoff Zhang (AMD)
Richard Mellitz (Samtec)

Reference:

Previous IEEE P802.3dj version 1.2. https://www.ieee802.org/3/dj/public/24_05/calvin_3dj_01b_2405.pdf

Instrumentation used in this contribution

- M8042A/M8050A PG
  - No Tx de-emphasis
- M8067A-005/003-Trace (1mm)
  - 31.1dB @53.125GHz – (35mm + 185mm Traces)
  - 2X pair of 1mm 8” phase matched cables (1.2dB each)
  - Net TP1a test channel loss 33.5dB
- UXR 1104B Real-Time scope
  - DSP/SW Clock Recovery
  - ~SIRC: 60GHz 4th order Bessel Thomson rolling off to -9dB @ 90GHZ
- N1000A+N1046A Sampling scope
  - Prototype Clock Recovery
  - SIRC: 60GHz 4th order Butterworth

Overview

The draft 1.0 P802.3dj comment resolution sessions have indicated interest in consolidating physical layer Jitter operations at C2M and CR interfaces.

The question of whether 12Edge Jitter operations can be accurately evaluated in a worst case AUI-C2M (33dB) configuration is the focus of this contribution.

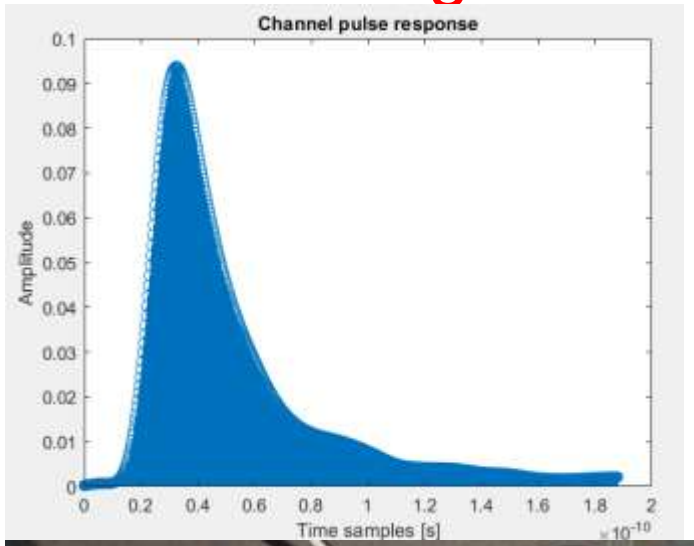
Slew rate decreases by 2 when you cut bandwidth by a factor of 2. However, the noise only drops by sqrt(2). So the jitter due to noise increases by sqrt(2)

The operations demonstrated in this contribution focus on both Real-Time instrumentation (Keysight UXR 1104B), digital clock recovery (1'st order 4MHz) and a 60GHz 4'th order Bessel, as well as its Equivalent-Time counterpart (DCA N1046/N1071) with early experimental CDR capability.

Signal generation in this contribution is with a Keysight M8042A PG transmitting a PRBS13Q test pattern, no TX EQ, with a single **ended amplitude** of 300mV at the source.

The signal path interconnect is all performed via 1mm interconnects.

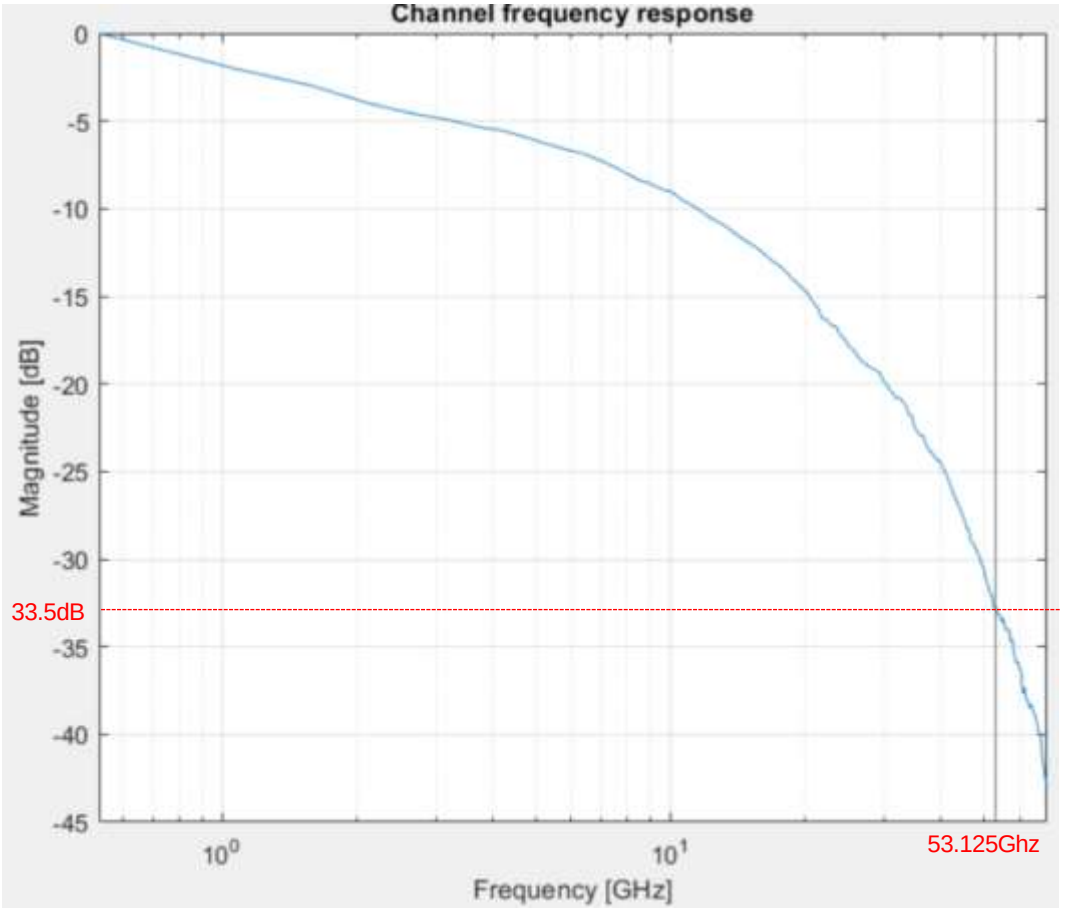
Channel configuration and Real-Time instrument used in this study:

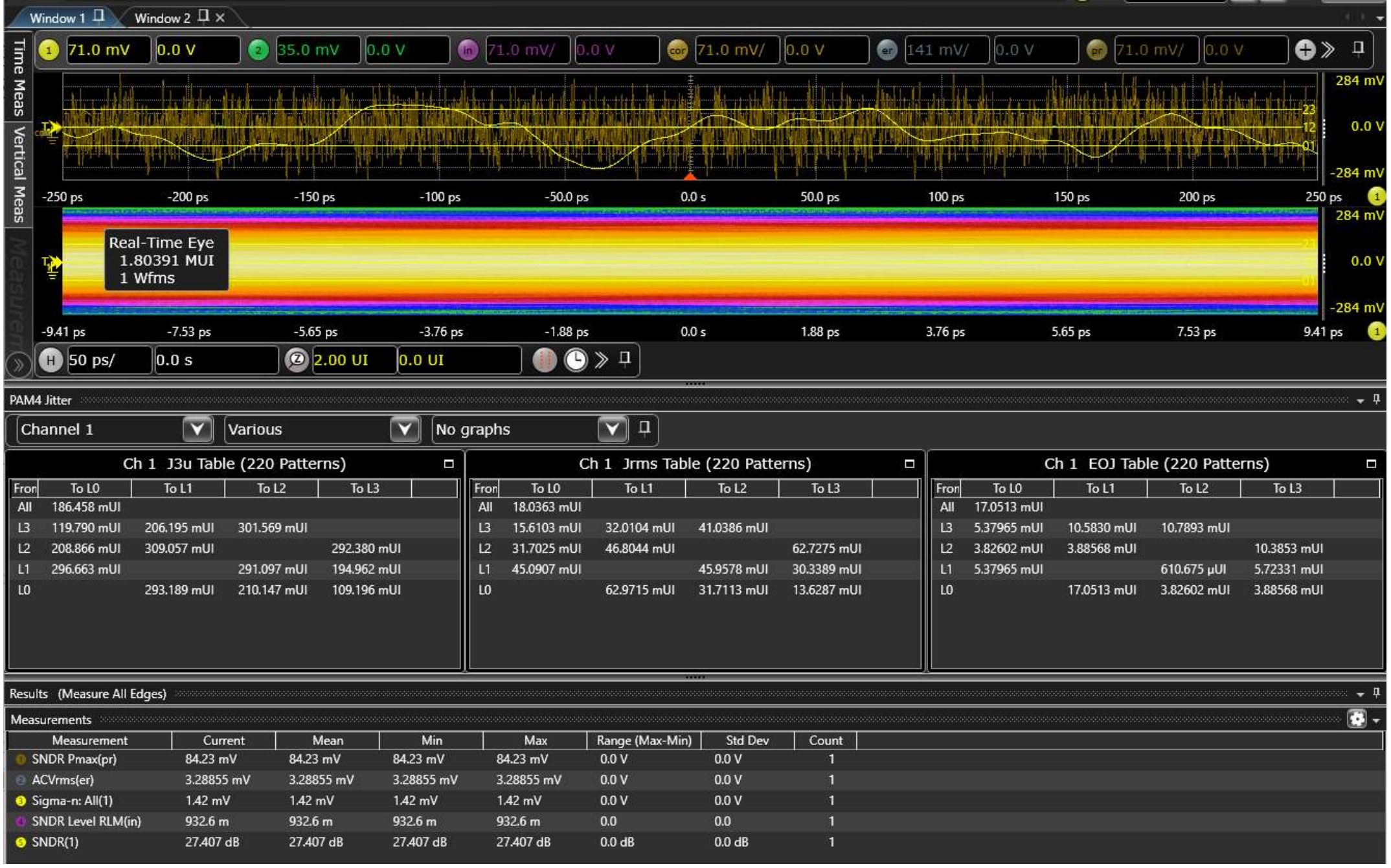


Closest attainable physical proxies for (35mm + 185mm) C2M/TP1a targeting (HL-HL) ~33dB

Reference： https://www.ieee802.org/3/dj/public/23_11/lusted_3dj_04_2311.pdf pg 5

PR ->SR ->IR->(FFT) =>





PAM4 Jitter

Channel 1 | Various | No graphs

Ch 1 J3u Table (220 Patterns)

From	To L0	To L1	To L2	To L3
All	186.458 mUI			
L3	119.790 mUI	206.195 mUI	301.569 mUI	
L2	208.866 mUI	309.057 mUI		292.380 mUI
L1	296.663 mUI		291.097 mUI	194.962 mUI
L0		293.189 mUI	210.147 mUI	109.196 mUI

Ch 1 Jrms Table (220 Patterns)

From	To L0	To L1	To L2	To L3
All	18.0363 mUI			
L3	15.6103 mUI	32.0104 mUI	41.0386 mUI	
L2	31.7025 mUI	46.8044 mUI		62.7275 mUI
L1	45.0907 mUI		45.9578 mUI	30.3389 mUI
L0		62.9715 mUI	31.7113 mUI	13.6287 mUI

Ch 1 EOJ Table (220 Patterns)

From	To L0	To L1	To L2	To L3
All	17.0513 mUI			
L3	5.37965 mUI	10.5830 mUI	10.7893 mUI	
L2	3.82602 mUI	3.88568 mUI		10.3853 mUI
L1	5.37965 mUI		610.675 µUI	5.72331 mUI
L0		17.0513 mUI	3.82602 mUI	3.88568 mUI

Results (Measure All Edges)

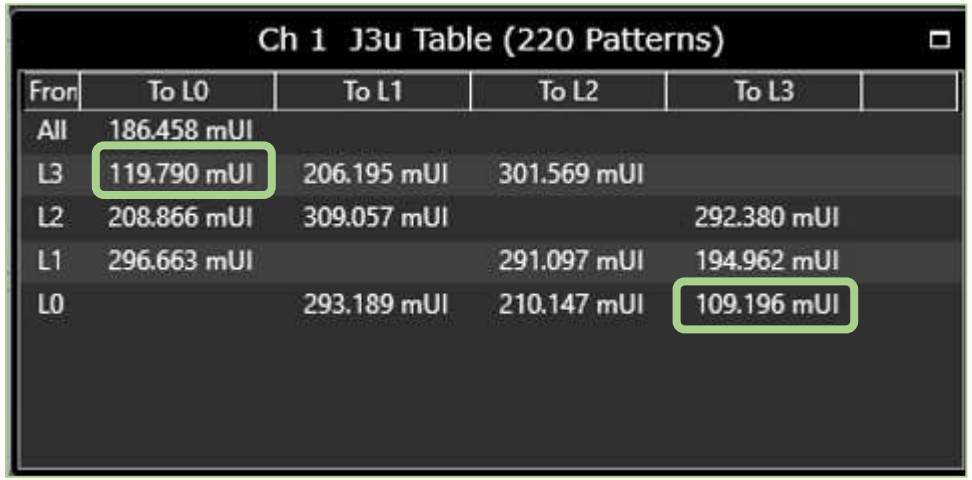
Measurements

Measurement	Current	Mean	Min	Max	Range (Max-Min)	Std Dev	Count
SNDR Pmax(pr)	84.23 mV	84.23 mV	84.23 mV	84.23 mV	0.0 V	0.0 V	1
ACVrms(er)	3.28855 mV	3.28855 mV	3.28855 mV	3.28855 mV	0.0 V	0.0 V	1
Sigma-n: All(1)	1.42 mV	1.42 mV	1.42 mV	1.42 mV	0.0 V	0.0 V	1
SNDR Level RLM(in)	932.6 m	932.6 m	932.6 m	932.6 m	0.0	0.0	1
SNDR(1)	27.407 dB	27.407 dB	27.407 dB	27.407 dB	0.0 dB	0.0 dB	1

Output jitter (max) analysis

Table 179–7—Summary of transmitter specifications at TP2 *(continued)*

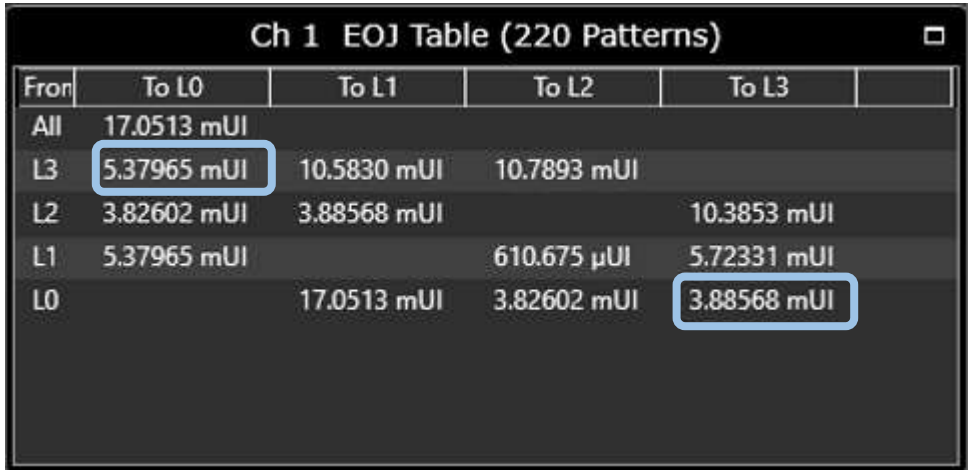
Parameter	Subclause reference	Value	Units
Transmitter steady-state voltage, v_f (min) Host designation Host-Low Host designation Host-Nominal Host designation Host-High	179.9.4.1.2	 TBD TBD TBD	 V V V
Transmitter steady-state voltage, v_f (max)	179.9.4.1.2	0.6	V
Linear fit pulse peak ratio, R_{peak} (min) Host designation Host-Low Host designation Host-Nominal Host designation Host-High	179.9.4.1.2	 TBD TBD TBD	 — — —
Level separation mismatch ratio R_{LM} (min)	179.9.4.2	0.95	—
Transmitter output waveform absolute value of step size for all taps (min) absolute value of step size for all taps (max) value at minimum state for $c(-3)$ (max) value at maximum state for $c(-2)$ (min) value at minimum state for $c(-1)$ (max) value at minimum state for $c(0)$ (max) value at minimum state for $c(1)$ (max)	 179.9.4.1.4 179.9.4.1.4 179.9.4.1.5 179.9.4.1.5 179.9.4.1.5 179.9.4.1.5 179.9.4.1.5	 0.005 0.025 −0.06 0.12 −0.34 0.5 −0.2	 — — — — — — —
Signal-to-noise-and-distortion ratio, SNDR (min)	179.9.4.6	31.5	dB
Signal-to-residual-intersymbol-interference ratio, SNR_{ISI} (min)	179.9.4.3	26.7	dB
Output jitter (max) TBD	179.9.4.7	TBD	UI



$J3U_{03}$ is formed from a composite of targeted L3->0 and L0->3 uncorrelated edge jitter. The composite result has some questions but the the individual values are solid.
Similarly EOJ_{03} is formed from a composite of targeted L3->0 and L0->3 Even/Odd jitter elements. The composite value here is WIP, but the individual L3->0 and L0->3 values are correct.

Table 176E–1—Summary of host output specifications at TP1a *(continued)*

Output jitter (max) J_{RMS03} EOJ_{03} $J4u_{03}$	176E.6.9	 0.023 0.025 0.135	 UI UI UI

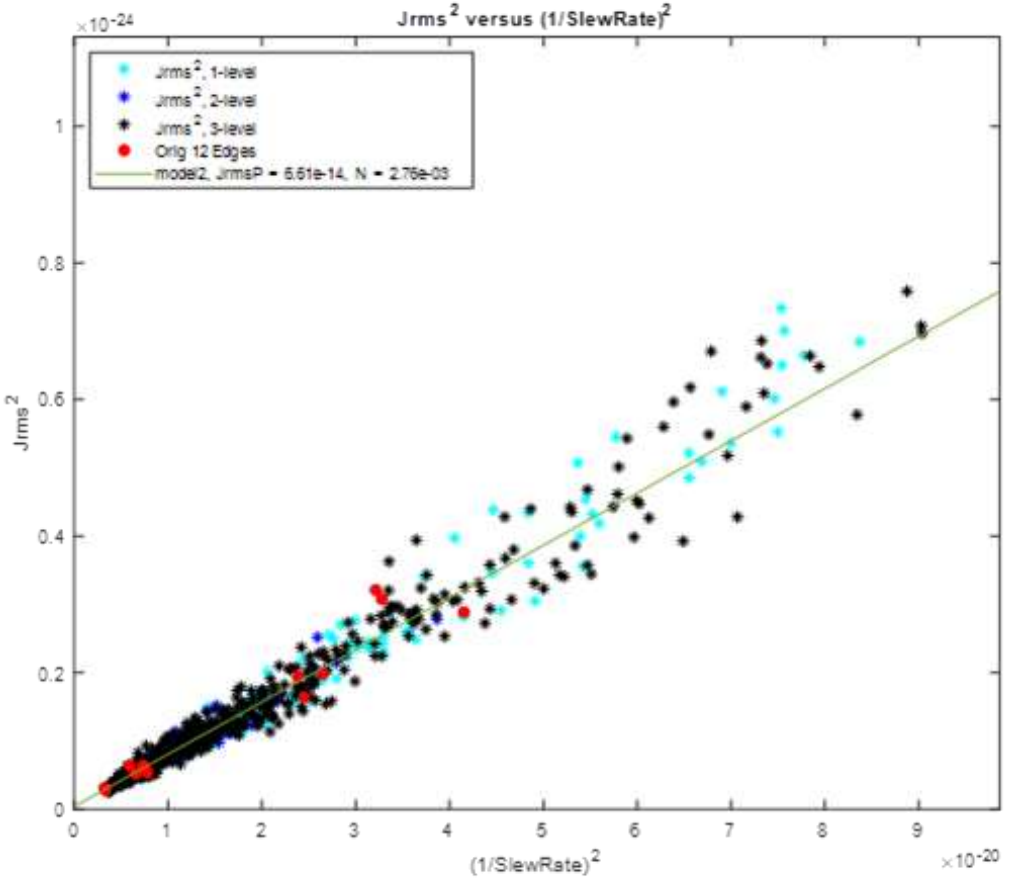


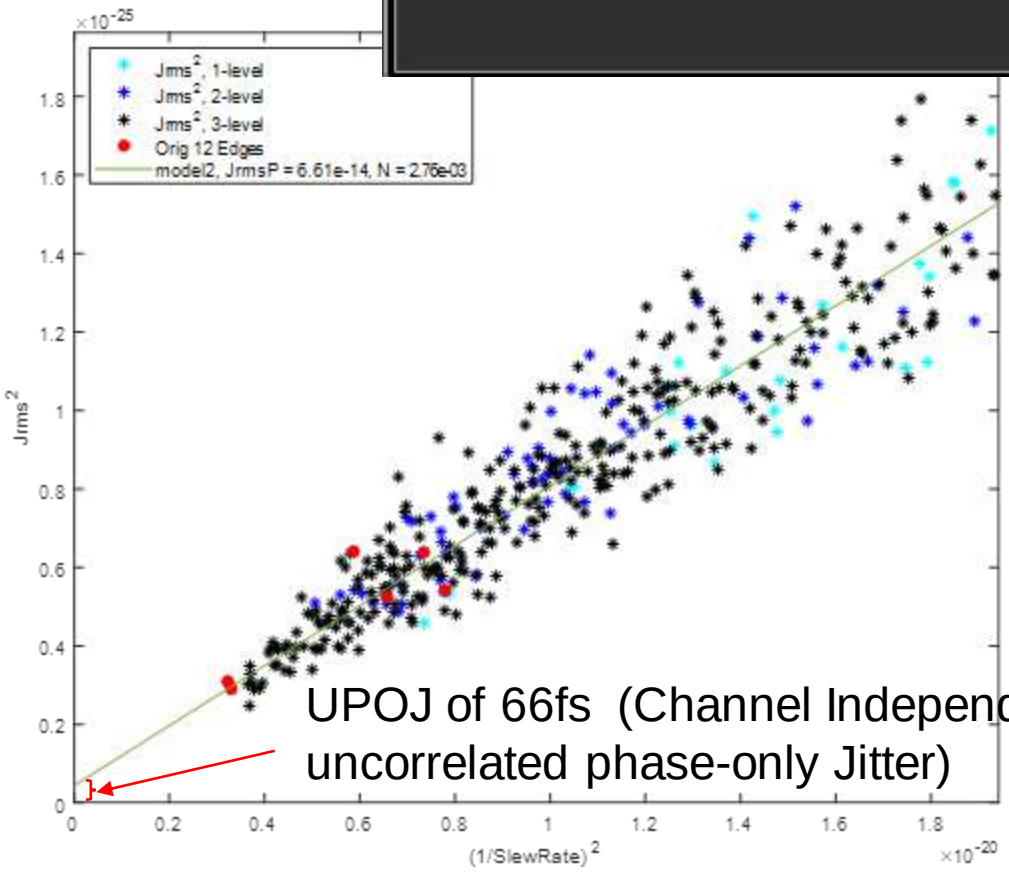
Output jitter (max) $JRMS_{03}$ analysis

Comments from the May 2024 Interim session recommended a method of refining our $JRMS_{03}$ to reduce the impact of channel induced random noise amplification (UPOJ: Uncorrelated Phase-only Jitter)

Ch 1 Jrms Table (220 Patterns)

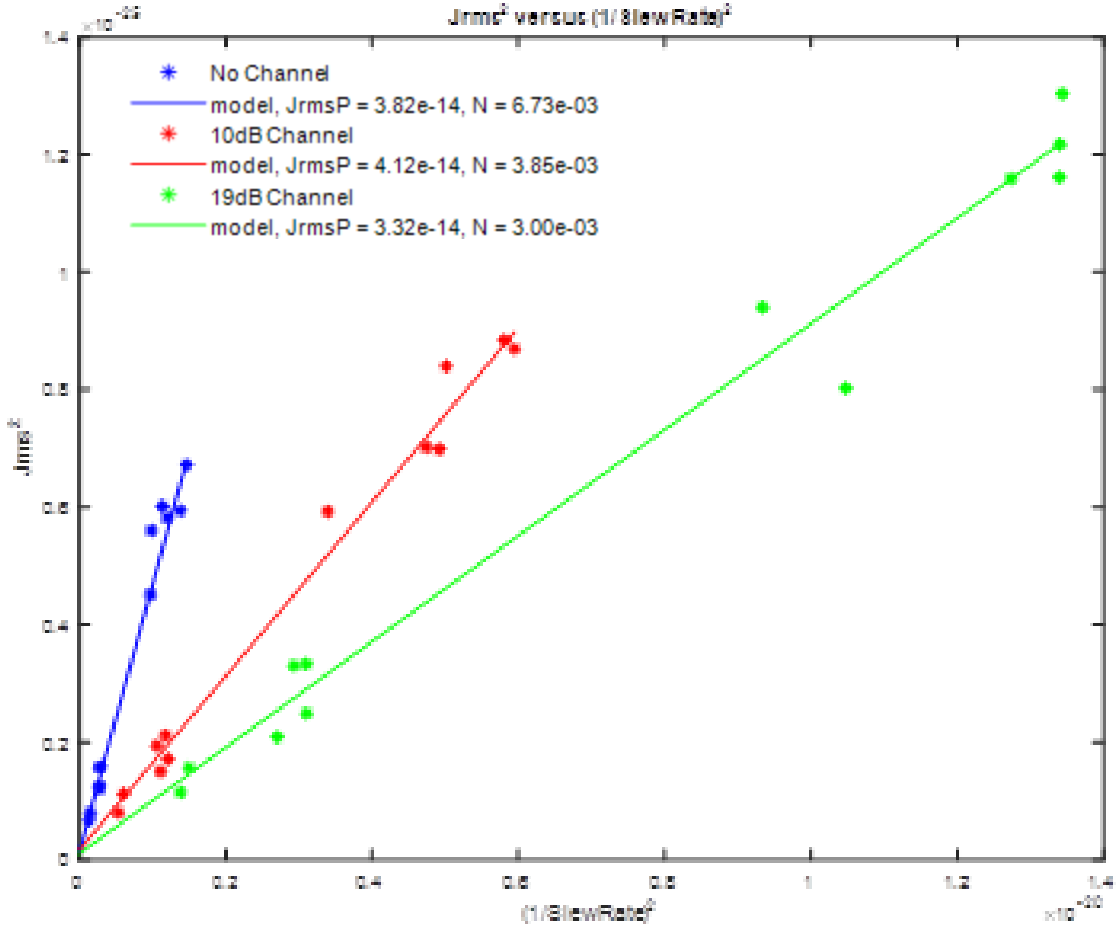
From	To L0	To L1	To L2	To L3
All	18.0363 mUI			
L3	15.6103 mUI	32.0104 mUI	41.0386 mUI	
L2	31.7025 mUI	46.8044 mUI		62.7275 mUI
L1	45.0907 mUI		45.9578 mUI	30.3389 mUI
L0		62.9715 mUI	31.7113 mUI	13.6287 mUI





UPOJ of 66fs (Channel Independent uncorrelated phase-only Jitter)

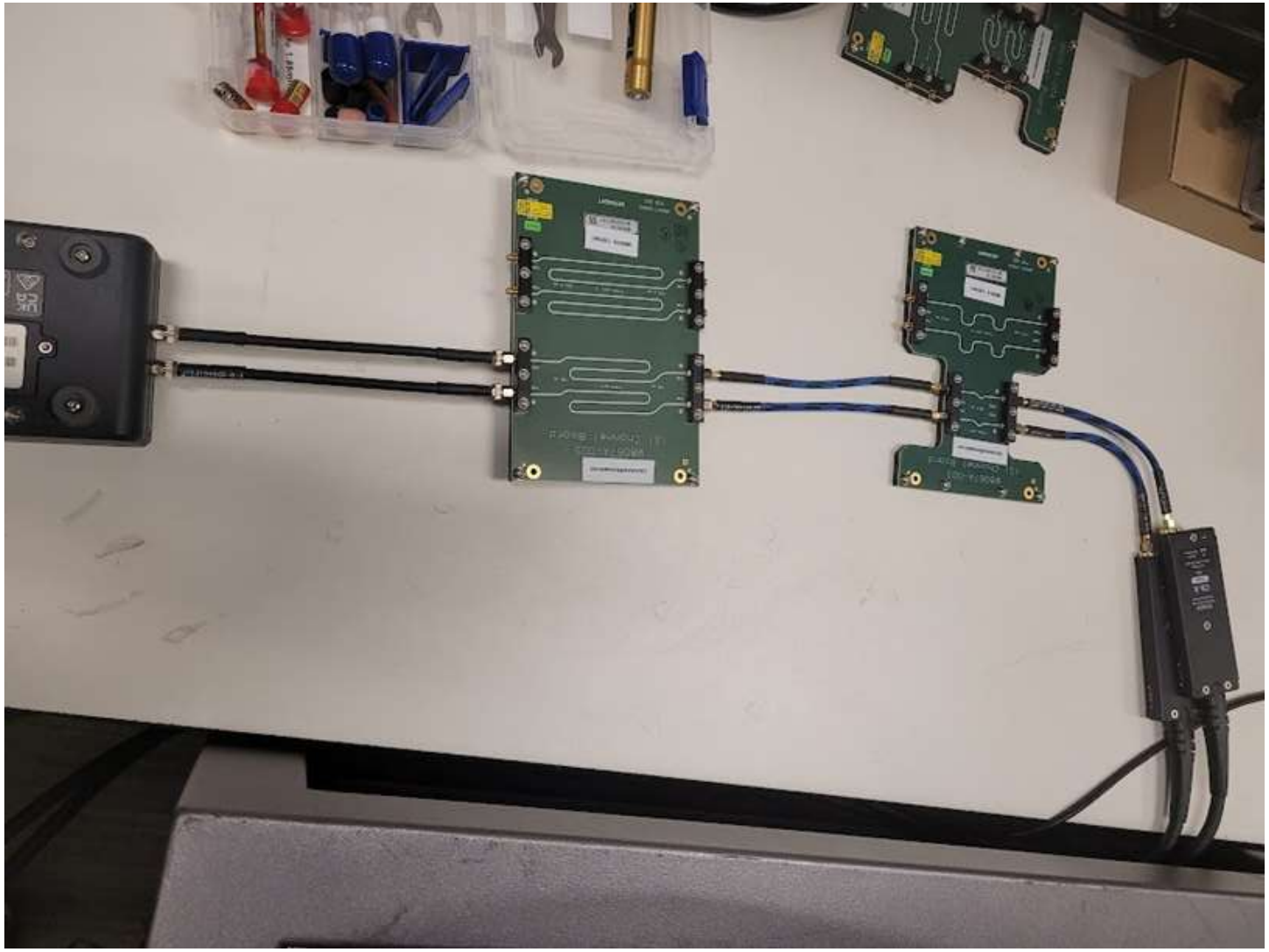
UPOJ: Uncorrelated Phase-only Jitter



The uncorrelated phase only jitter (UPOJ), when extrapolated back to the y-intercept (via linear regression), observes relatively stable UPOJ values ranging from 38fs, 41fs to 33fs. This process clearly benefits from more statistical sample points (previous slide), but nicely converges to a reasonable UPOJ number which appears to be channel independent.

Channel configuration and Equivalent-Time (ET) instrument used in this study:

- Physical Clock Recovery (CR) with early experimental systems are complex at TP1a (106GBd at 33.5dB), but reliable at TP2 (24dB).
- Driven with a 600mV Differential Tx signal.
- Low return loss channel (-15dB max)
- Phase Detector sensitivity in the CR is operating at it's design limits.




Jitter/Noise
KEYSIGHT File Setup Measure Tools Apps Help
Auto Scale
Run Stop
Single
Clear
Pattern Acquisition (100%)
Graphs
Output Jitter
Waveforms (Average) : 3
Src: 1A Rate: 106.27200 GBd Pat. Length: 8191
Intrinsic RN Removed: 686 µV
TF SP LJM
Time
Amplitude
Meas
RJ/PJ Histogram
DDJ Histogram
TJ Histogram
DDJ Vs Symbol
Composite TJ Histogram
Composite DDJ Histogram
More (1/2)
Measurement | To L0 | To L1 | To L2 | To L3
J3u (All) | 300 mUI
J3u (R03/F30) | 175 mUI
From L3 | 175 mUI | 190 mUI | 360 mUI | --
From L2 | 180 mUI | 300 mUI | -- | 340 mUI
From L1 | 300 mUI | -- | 320 mUI | 185 mUI
From L0 | -- | 320 mUI | 200 mUI | 180 mUI
Jrms (All) | 35 mUI
Jrms (R03/F30) | 27 mUI
From L3 | 26 mUI | 29 mUI | 50 mUI | --
From L2 | 28 mUI | 38 mUI | -- | 50 mUI
From L1 | 42 mUI | -- | 44 mUI | 28 mUI
From L0 | -- | 45 mUI | 30 mUI | 27 mUI
EOJ (All) | 28 mUI
EOJ (R03/F30) | 17 mUI
From L3 | 4 mUI | 4 mUI | 28 mUI | --
From L2 | 11 mUI | 10 mUI | -- | 0 UI
From L1 | 16 mUI | -- | 20 mUI | 10 mUI
From L0 | -- | 28 mUI | 22 mUI | 17 mUI
Details...
Limits...
[+|-]
Waveform
1A 26.8 mV/ 800 µV
1B 1.4 mV/ 2.25 mV
CDR
106.25000 GBd
LBW: 4.000 MHz
Timebase
1.57 ps/
Pos: 16.00900 ns
IPTB: 26.568000 GHz
Acquisition
Jitter Mode Acq
8 pts/UI
Frame Trigger
Src: Front Panel
106.27200 GBd
8191 UI
Pattern
Lock
Math
Signals

J3u comparison at 33dB

- This is two separate systems Real-Time (RT) and Equivalent-Time (ET) with the same model of generator and same model of ISI structures.
- “today” We are seeing similar jitter decomposition at 33dB on RT and ET based instrumentation.
- J3u03 on ET of 175mUI –vs- 186mUI on RT is typical variance.

Measurement	To L0	To L1	To L2	To L3
J3u (All)	300 mUI			
J3u (R03/F30)	175 mUI			
From L3	175 mUI	190 mUI	360 mUI	—
From L2	180 mUI	300 mUI	—	340 mUI
From L1	300 mUI	—	320 mUI	185 mUI
From L0	—	320 mUI	200 mUI	180 mUI
Jrms (All)	35 mUI			
Jrms (R03/F30)	27 mUI			
From L3	26 mUI	29 mUI	50 mUI	—
From L2	28 mUI	38 mUI	—	50 mUI
From L1	42 mUI	—	44 mUI	28 mUI
From L0	—	45 mUI	30 mUI	27 mUI
EOJ (All)	28 mUI			
EOJ (R03/F30)	17 mUI			
From L3	4 mUI	4 mUI	28 mUI	—
From L2	11 mUI	10 mUI	—	0 UI
From L1	16 mUI	—	20 mUI	10 mUI
From L0	—	28 mUI	22 mUI	17 mUI

Ch 1 J3u Table (220 Patterns)

Fror	To L0	To L1	To L2	To L3
All	186.458 mUI			
L3	119.790 mUI	206.195 mUI	301.569 mUI	
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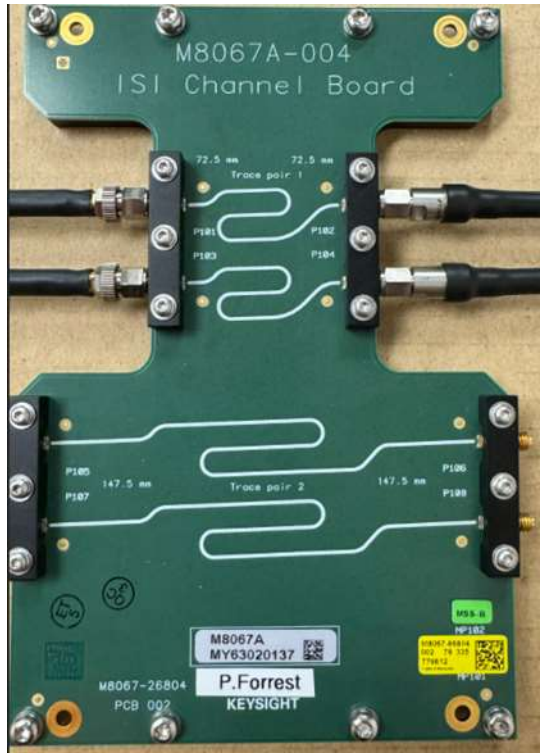
Summary

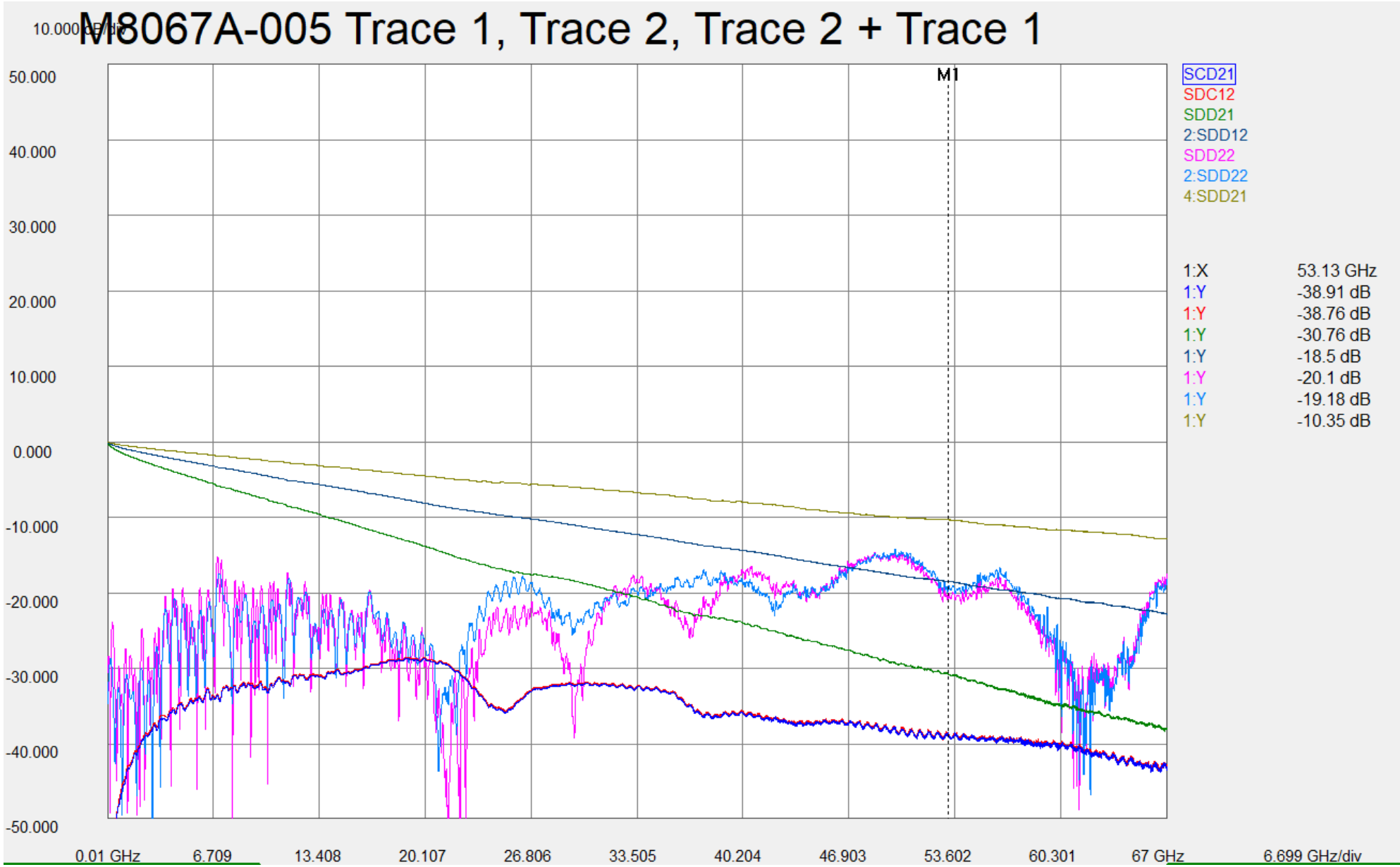
- With an un-equalized 600mV differential signal launch through a 33.5dB signal path representing a worst case TP1a condition, observing proper 1'st order 4MHz CDR and 60GHz 4BT Reference Receiver with no TX EQ, Jitter (Clause 162.9.4.7) can effectively be performed.
- Delicate noise management efforts are needed to reduce/remove the channel amplification effects on random noise originating in transmitters.
- Single level and two level transitions (defined in Clause 162.9.4.7) suffer from SNR losses after 33dB, and are marginally useful. The three level transitions are easily extracted however and extraction of $J3u_{03}$, $JRMS_{03}$ and EOJ_{03} are all viable validation methods using evolutionary steps from prior Clause 179 and162.9.4.7 methods.
- Steps to isolate true DUT phase jitter by eliminating the vertical noise contribution from the jitter are demonstrated here and offer an accurate (albeit sensitive) method of determining JRMS- "uncorrelated phase only jitter (UPOJ)" behavior. This needs additional effort to refine and to extend to the J3u operations.

Thank you

Backup

- M8067A-005 ISI trace Performance





Backup “Support of 178.9.2 Transmitter characteristics”

Unless otherwise specified, transmitter signal measurements are made for each lane separately using a fourth-order Bessel-Thomson low-pass response with a 3 dB bandwidth of 60 GHz, with AC-coupled connection from TP0v to the test equipment.

- Tx: 300 mV SE amplitude. 106.25GHz clock recovery. PRBS13Q (IEEE/PRBS13Q_Lane0_bit). 4PAM Gray coded. No de-emphasis. No impairments.
- Channel: 35 mm ISI board (approx.. 6.5 dB channel loss at 53 GHz counting cables).
- Real-Time instrumentation test case.

Test case	VEC [dB]	J3u all [mUI]	Jrms all [mUI]
No BW limit (113 GHz brick)	7.79	153	18.3
70 GHz brick	6.94	160.6	17.4
60 GHz Butter. 75 GHz brick	6.06	137.8	15.4
60 GHz Bessel. 90 GHz brick	5.67	125.2	15.2