HIGH SPEED NETWORKING
DECEMBER 2025 224G PLUGFEST REPORT

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V8.1

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NEXT ETHERNET ERA

ethernet alliance

Introduction

- The Ethernet Alliance held an Interoperability Plugfest with a special focus on 224G SerDes technology at the Keysight facilities in Cupertino, CA December 8th through 12th, 2025
  - Event is divided into two primary testing efforts, Interoperability and Conformance
  - Interop: Focused on assessing basic link functionality between participating devices
  - Conformance: Focused on measuring device Conformance to IEEE 802.3 electrical and optical signaling requirements
- One of the primary goals of the event was to assess the health of currently available 224G products from an interoperability and conformance standpoint
  - A key point of interest was TP2 module Conformance measurements, which this presentation will cover
- 5 Ethernet system vendors, 8 interconnect vendors, and 7 test and measurement vendors participated, including:
  - Keysight, Intel, MaxLinear, Jabil, Rohde & Schwarz, EXFO, VIAVI Solutions, Arista, Amphenol, Synopsys, BizLink, Hyper Photonix, Teledyne LeCroy, MultiLane Inc, Fast Photonics, Wilder Technologies, and others, as well as the University of New Hampshire Interop Lab and UL Solutions

Device Inventory

- Interoperability was tested across 20 Ethernet hosts and T&M equipment which support link establishment
  - 12/20 devices supported 224G based technologies
- Device connector form factor count:
  - 15 supporting OSFP IHS
  - 7 supporting QSFP-DD
  - 5 supporting QSFP
  - 3 supporting OSFP-RHS

Interconnect Inventory

- 70 integrated cables
  - 52 DAC
    - 28 OSFP
    - 10 QSFP-DD
    - 8 breakout cables
    - 6 QSFP
  - 10 ACC (active copper cable without retimer)
  - 5 AEC (active copper cable with retimer)
  - 3 AOC (active optical cable)
- 77 separable modules
  - 46 retimed DR, 21 LPO, 4 LRO, 2 FR, 2 VR, 2 BiDi
- 62/147 supporting 224G technologies

INTEROP ASSESSMENT

Interop Testing Coverage

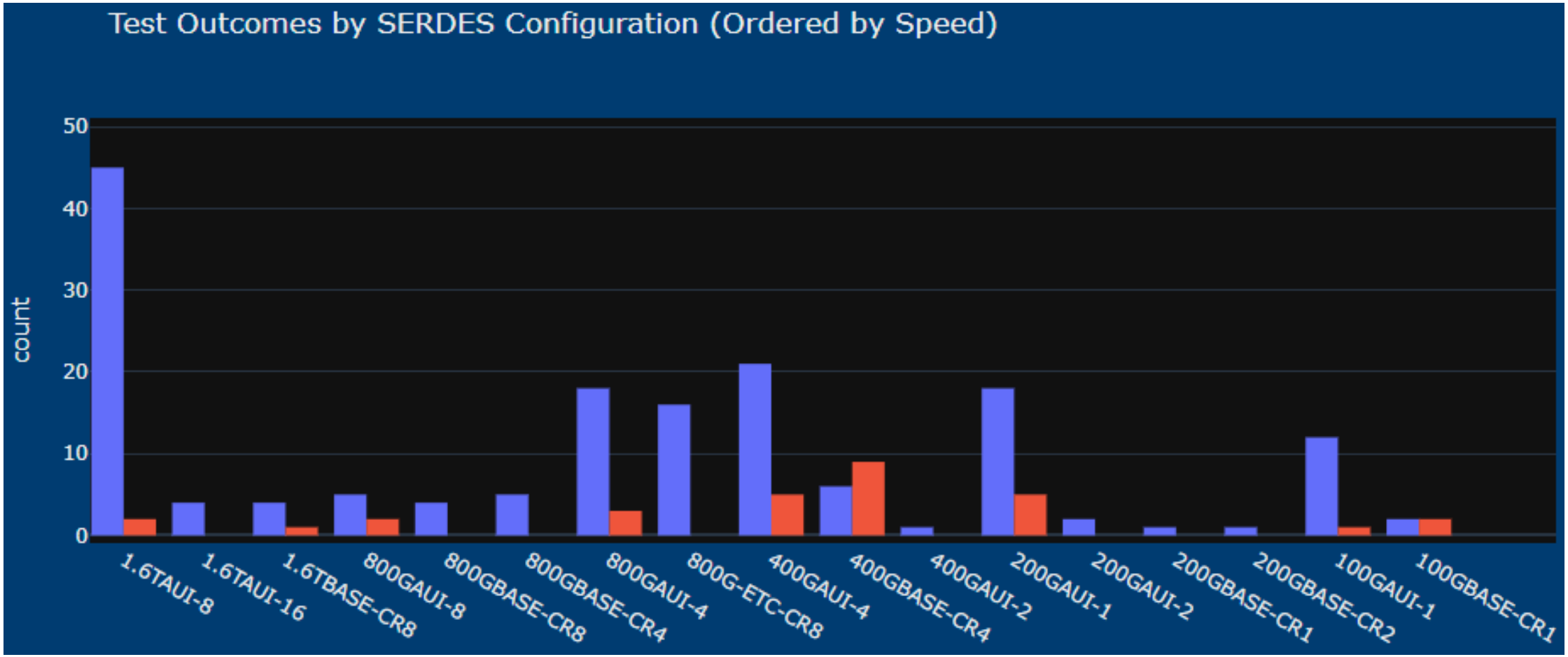
- Goal:
  - Assess basic device functionality and interoperability between various Ethernet hosts and interconnects, including test and measurement equipment with L1/L2 capabilities
  - Identify and debug any link establishment or link health issues across available configurations
- Testing included host-to-host and single host loopback (port-to-port or TX-to-RX) configurations
- Each interop test captured the following required results:
  - Link establishment assessment, FLR pass/fail, setup configuration, AN/LT usage
- Optional results captured:
  - Total data received, measured FLR, estimated Pre-FEC BER, highest non-zero FEC Bin counter, corrected codewords, link recovery, time to link

Interop Results Summary

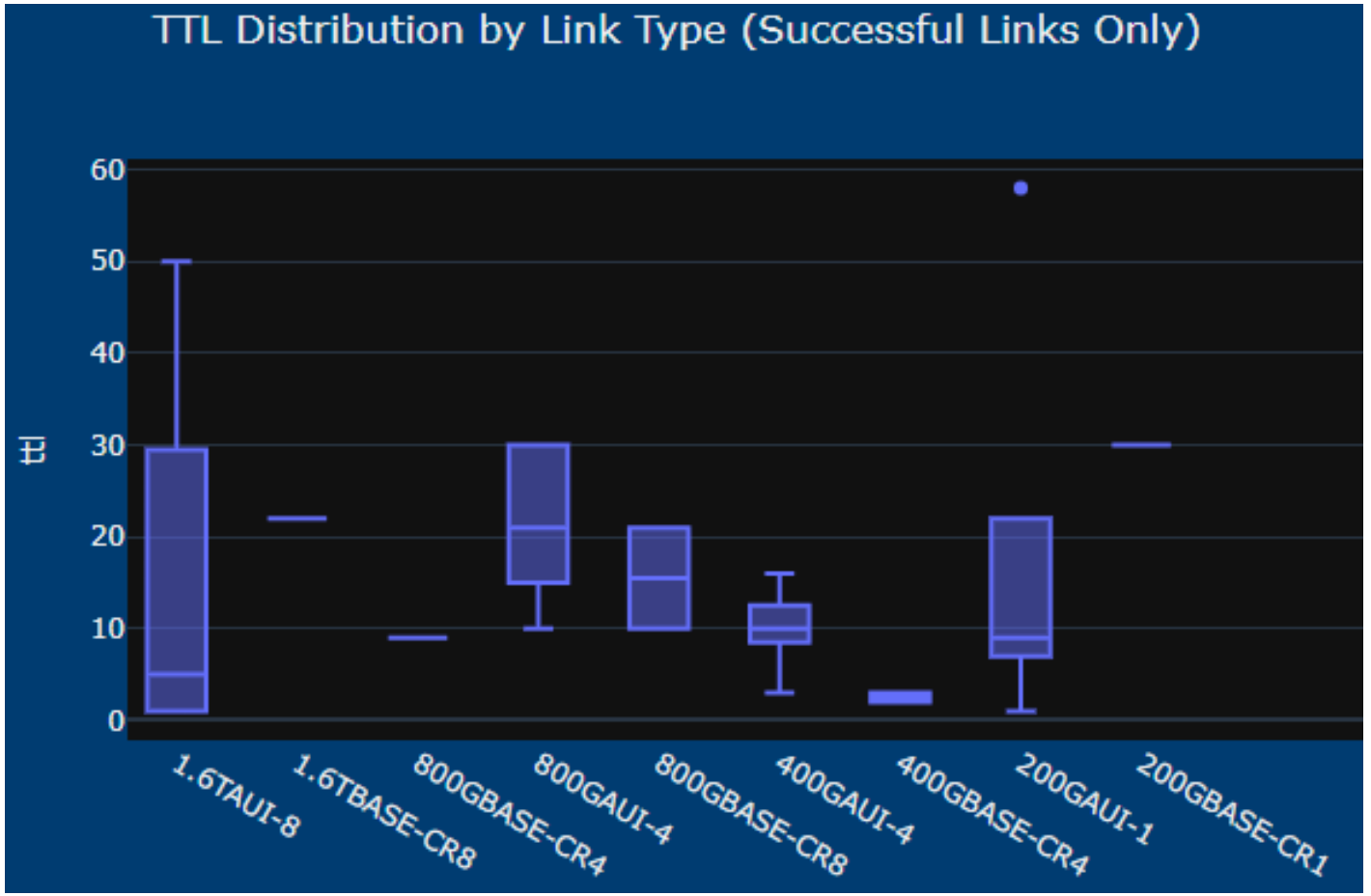
- 195 interop results from 45 host pairing combinations across 86 interconnects
- 107 results reported using 224G technology
  - 96 links established out of 107 attempts (90% success rate)
    - 63/68 link up using DR optical transceivers (93% success rate)
    - 15/16 link up using LPO/LRO (94% success rate)
    - 11/12 link up using DAC (92% success rate)
    - 7/8 link up using AEC (88%)
    - 0/3 link up using ACC (0%)
  - 9 claim AN/LT used, follow up needed
- 69/88 link up on results reported using 112G (78%)
  - 15/23 up with AN/LT used (65%)

Interop Data Summary – Link Establishment

Blue Link Establishment Succeeded
Red Link Establishment Failed



Interop Data Summary – Time to Link (seconds)



Interop Results Assessment

- 224G link establishment is relatively healthy compared to newness of technology
- 112G (especially AN/LT) continues to require attention to achieve reliable industry performance
- Time to Link notably higher on 224G links, as expected
- Based on reported results, 112G more problematic than 224G

CONFORMANCE ASSESSMENT

Conformance Test Setup Summary

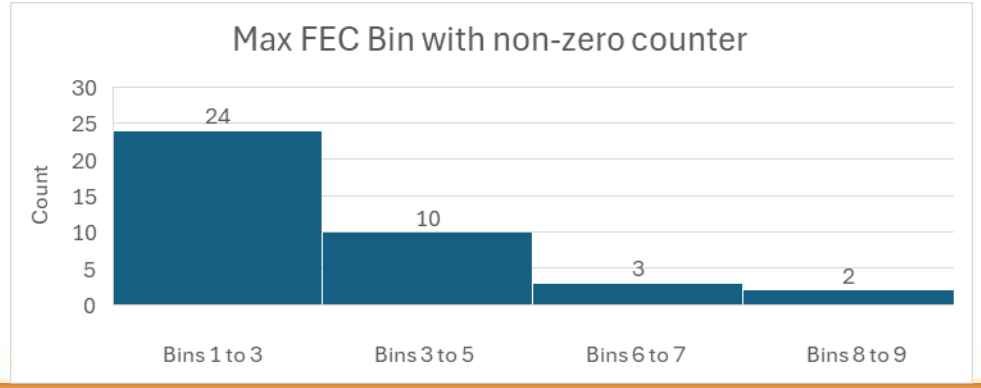
- A wide variety of Conformance test stations were optionally available to the host devices and interconnects
- Measurements taken independent of interoperability testing
- Test stations included:
  - 224G Optical TP2
    - TDECQ, TDECQ CER, and Jitter
  - 224G RX TP4
  - 224G electrical TX TP1a (host and module)
  - Multiple VNAs for cable validation and ERL up to 67GHz
  - Stressed BERT
  - Interconnect functional Conformance test station

Conformance Test Results Assessment

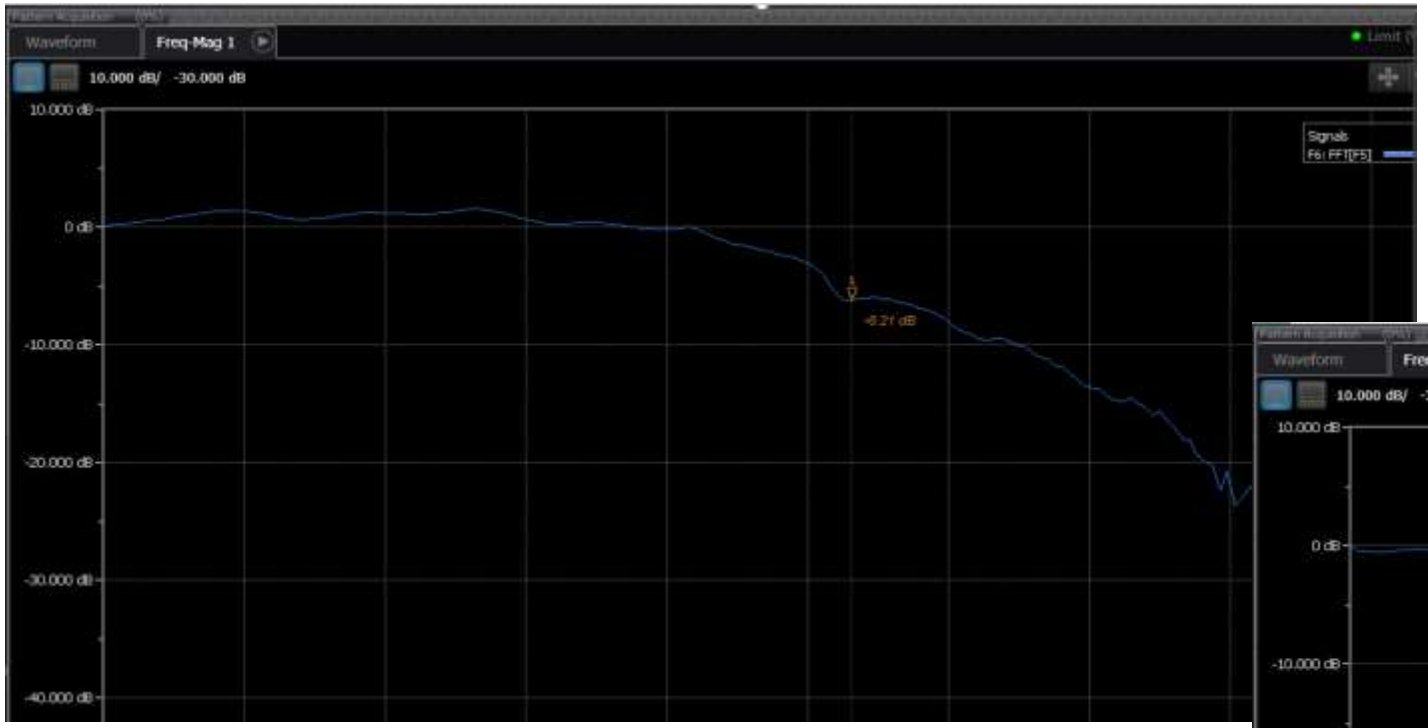
- The following slides highlight various correlation assessments of a variety of measurements and results
  - Further analysis can be completed upon request and reviewed with participants for possible sharing
  - Results include those both showing and not showing correlation
- The results are primarily based on 22 optical transceiver modules which support 224G and were assessed at TP2

Interop and Conformance Correlation

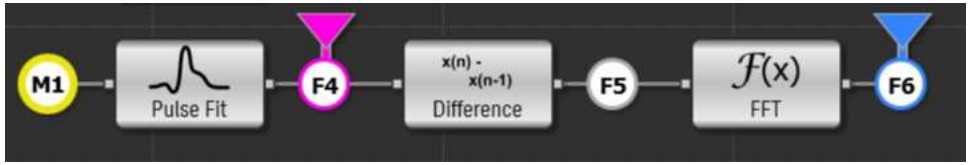
- 45 link interoperability results were captured on configurations exclusively using the 22 modules represented in the following measurements
- Link was established on 43/45 results (95%)
  - 17 TX to RX loopback (single module under test)
  - 6 port to port loopback (two modules under test)
  - 20 host to host connections (two modules under test)
- No FLR failures reported (46 Pass, 23 N/A)
- FEC bin 9 reported as the highest non-zero FEC Bin counter across all results
- Interop failures were not found to correlate with any Conformance results
  - This is somewhat expected given the limited size of the interop data set and the potential source of interop failures (host limitations, misconfiguration, protocol level, etc)

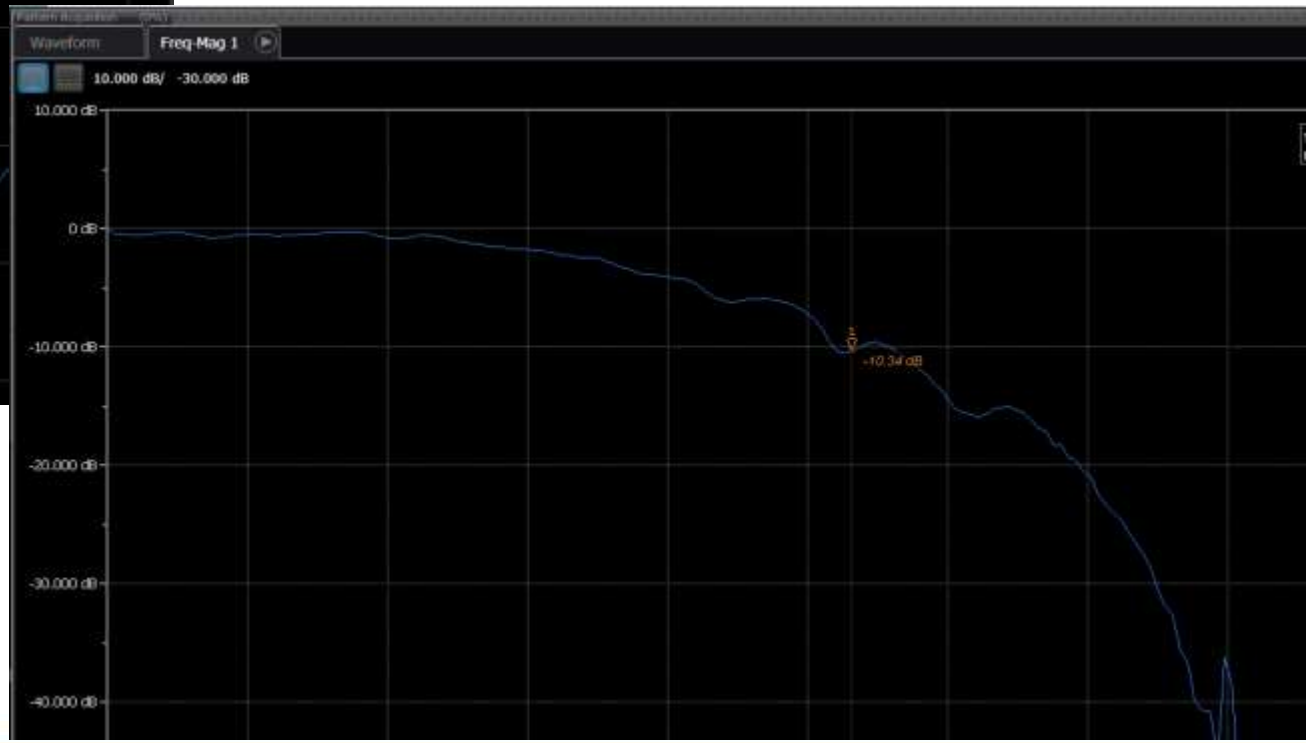


Discussion of f(N) (spectral magnitude at Nyquist) at TP2



TDECQ = 1.69dB



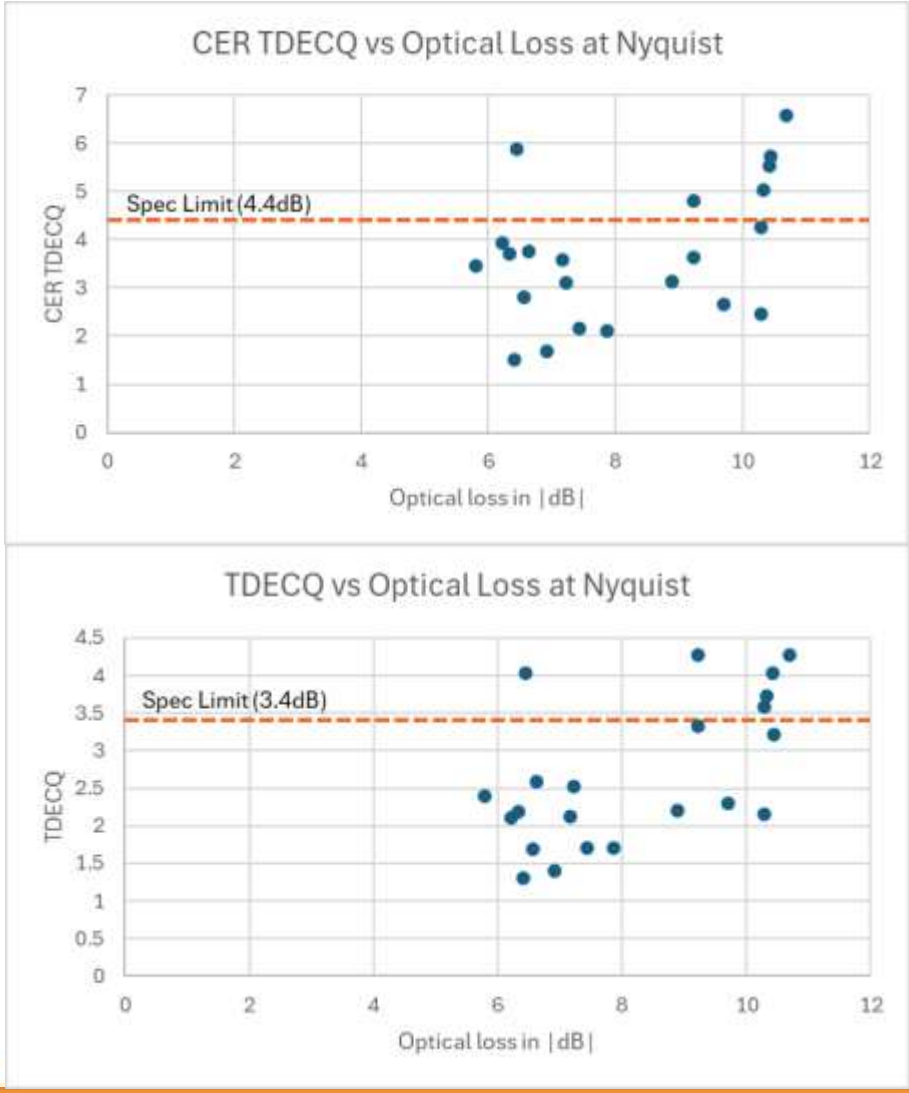


M1 in this case is the **optical signal at TP2** after a 4'th order Bessel Thomson set to 53.125GHz. We then use the FFT operator to extract the signal spectrum.

TDECQ = 3.75dB

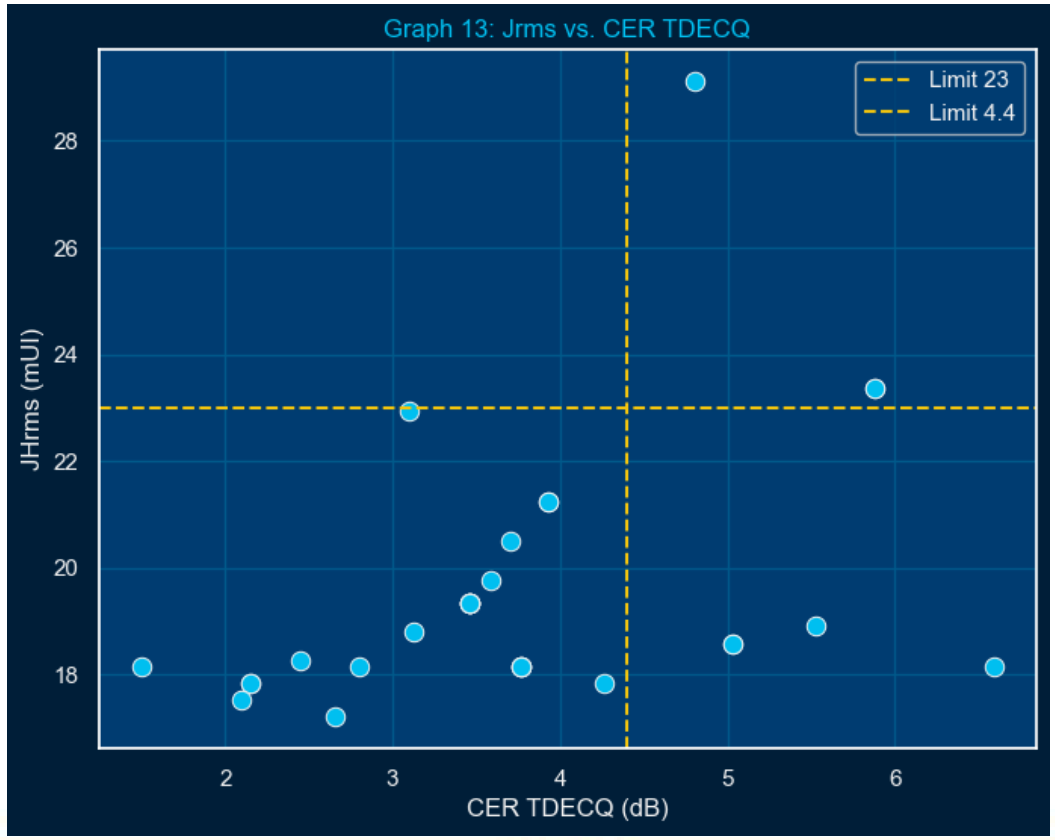
TDECQ and CER TDECQ vs. Optical Module Loss at f(N)

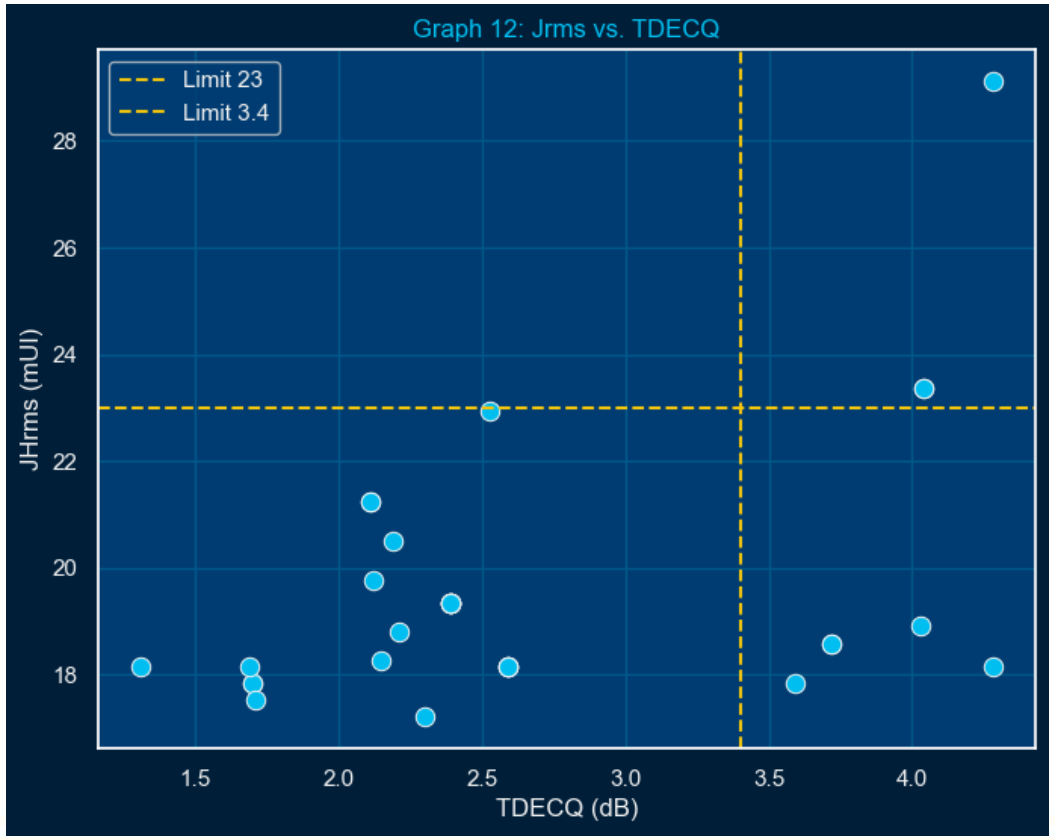
- Per-module assessment comparing TDECQ and TDECQ CER measured at TP2 to the measured loss within the optical module
- Minor correlation between failing TDECQ and higher optical module loss f(N)
  - "Higher" loss is not a guarantee of TDECQ failure



TDECQ and CER TDECQ vs JHrms

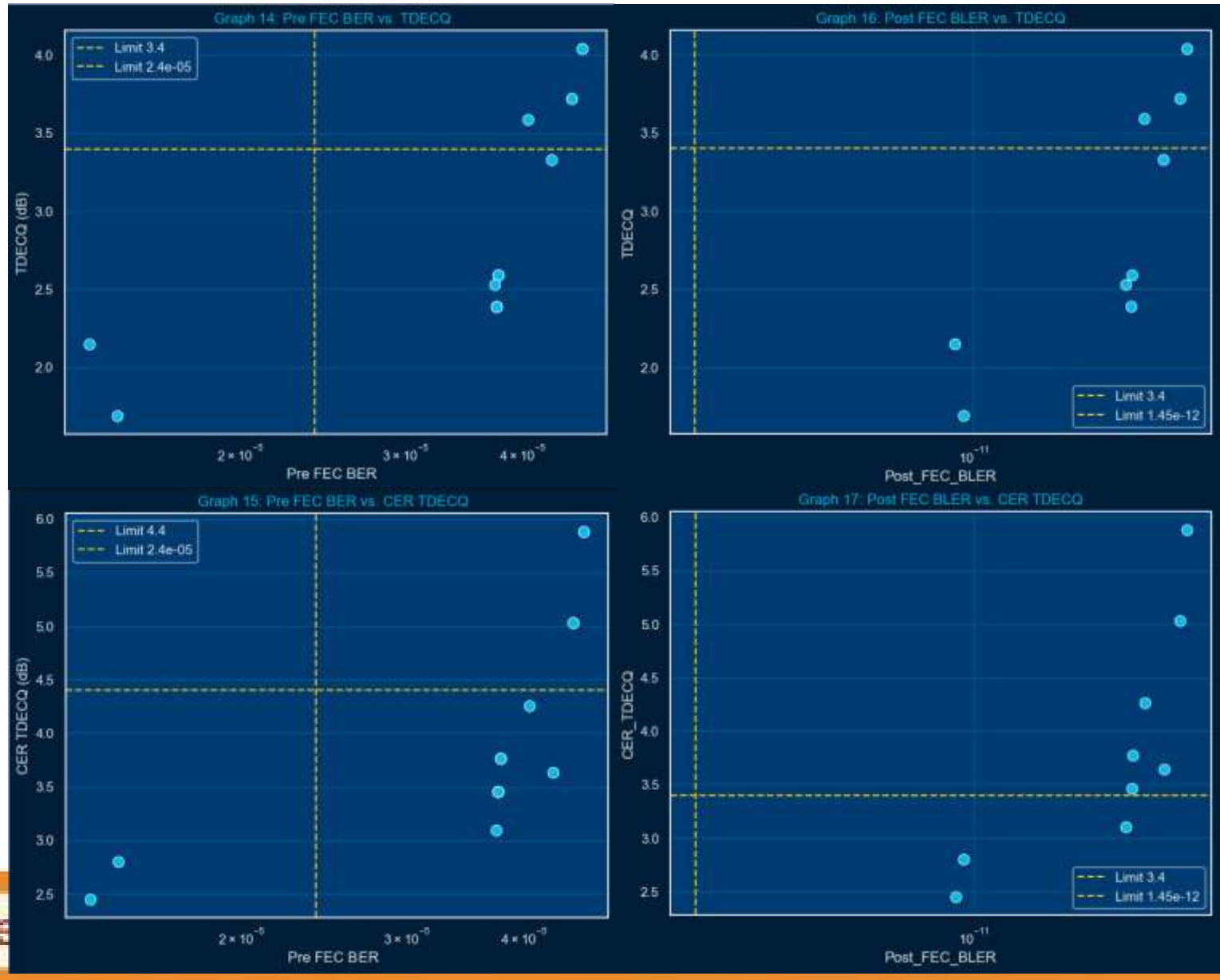
- Per-module comparison of TDECQ/TDECQ CER and JHrms
- Passing TDECQ correlated to passing JHrms, but failing TDECQ not correlated to failing JHrms





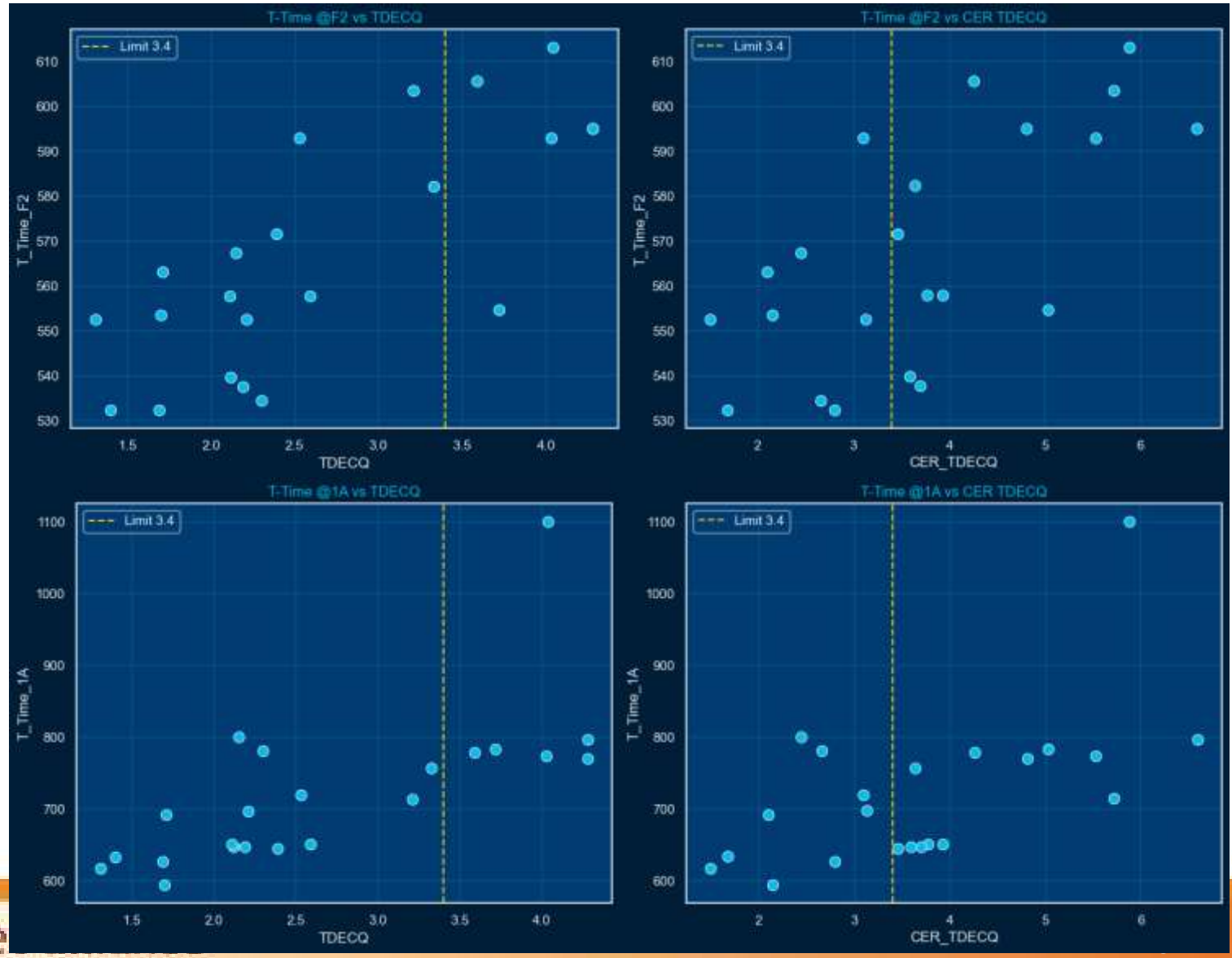
Pre-FEC BER and Post-FEC BLER vs. TDECQ and CER TDECQ

- Pre-FEC BER and Post FEC BLER (802.3dj 174A.9.7) measured on a subset of modules, comparison to TDECQ shown here
- TDECQ and BLER trend alignment, but not pass/fail correlation
- Limited passing Post-FEC BLER results captured



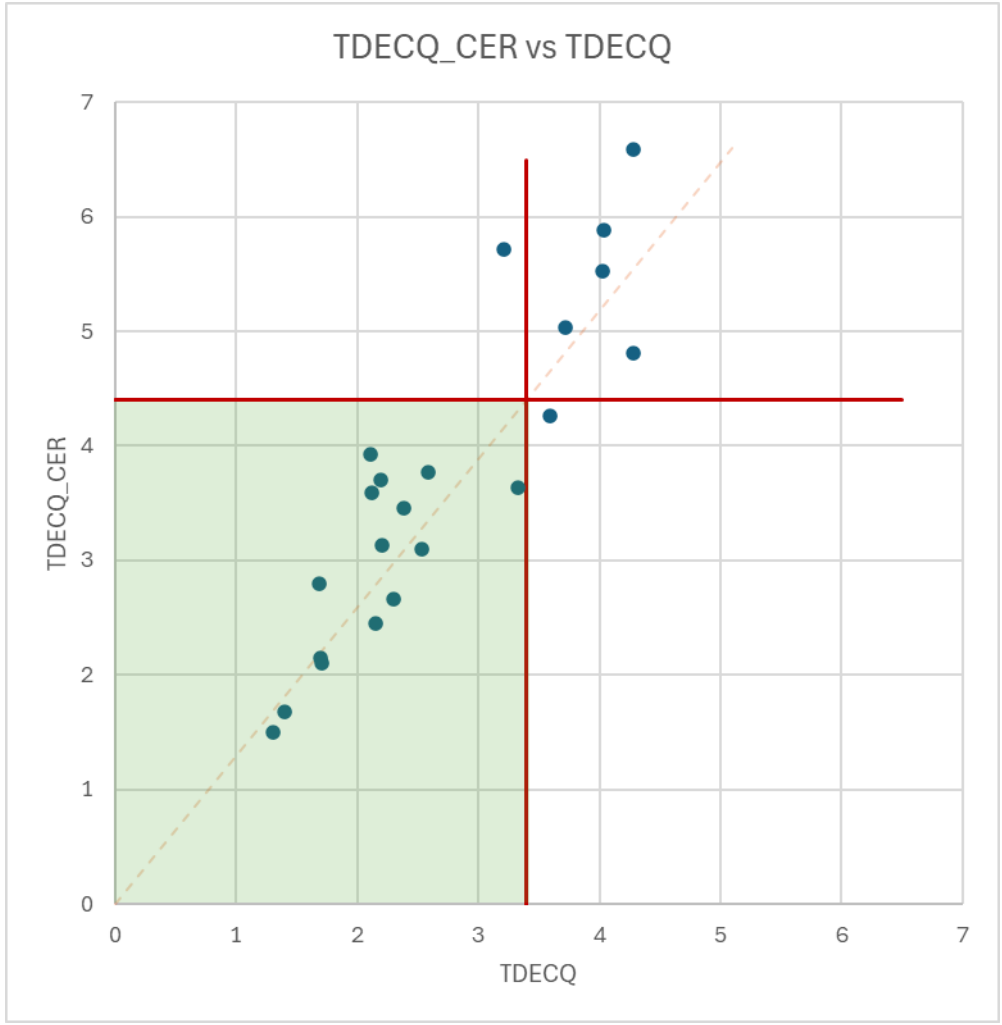
Transition Time vs TDECQ and CER TDECQ

- Notable trend lines between TDECQ and transition time
- Low TDECQ aligned to low transition time



TDECQ vs. CER TDECQ

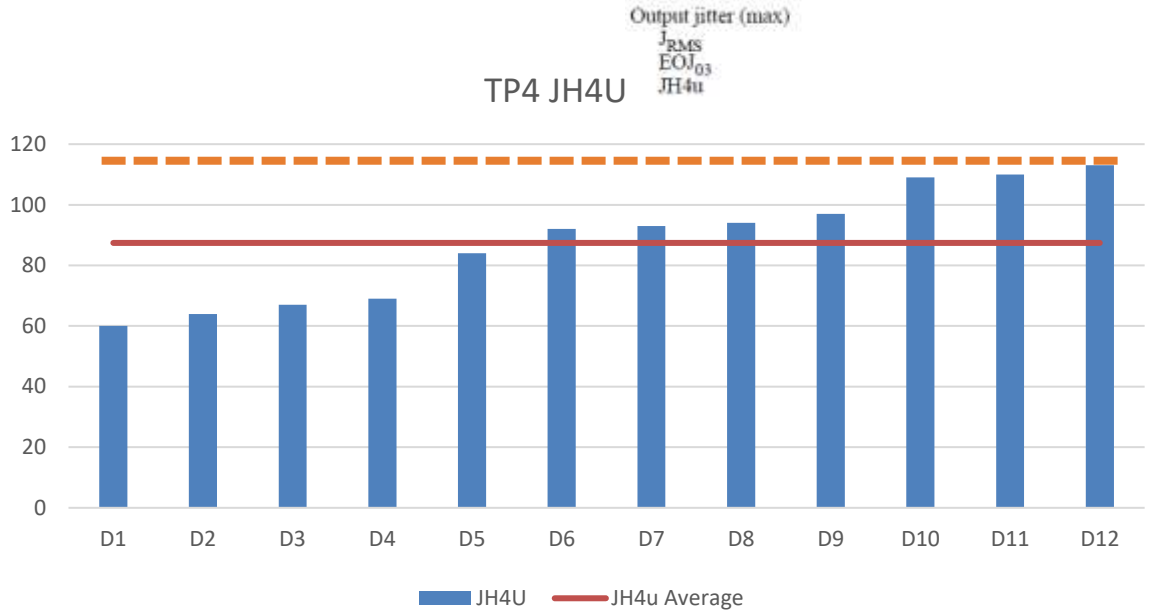
- TDECQ and CER TDECQ generally well-correlated
- Results:
  - 15 passed both specs
  - 5 failed both
  - 1 failed TDECQ, passed TDECQ CER
  - 1 passed TDECQ, failed TDECQ CER

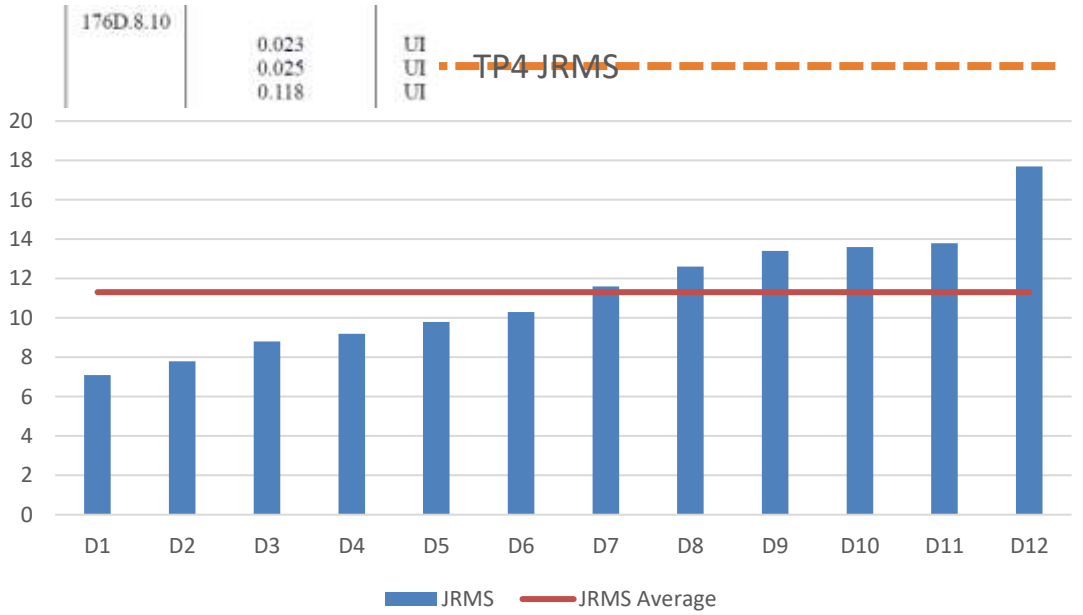


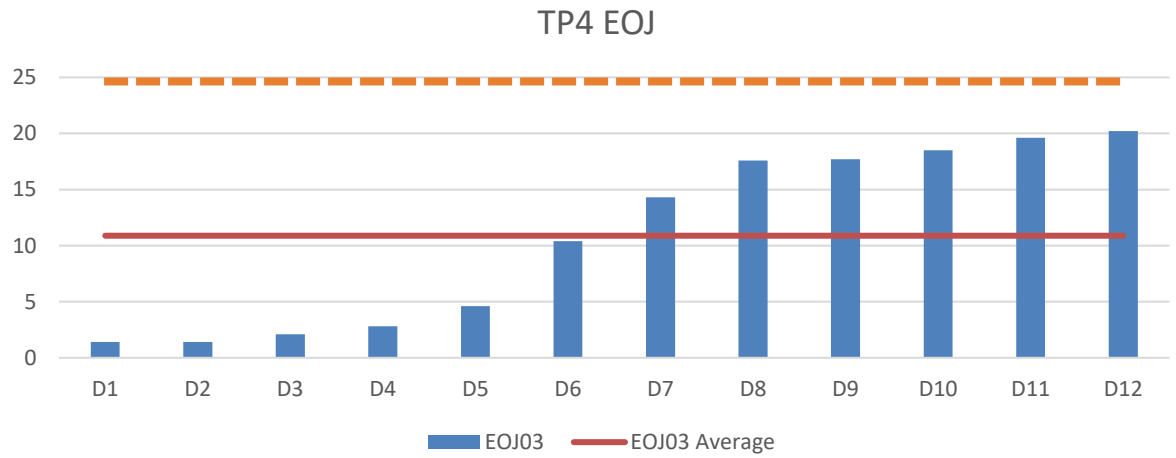
Additional Results Showing No Correlation

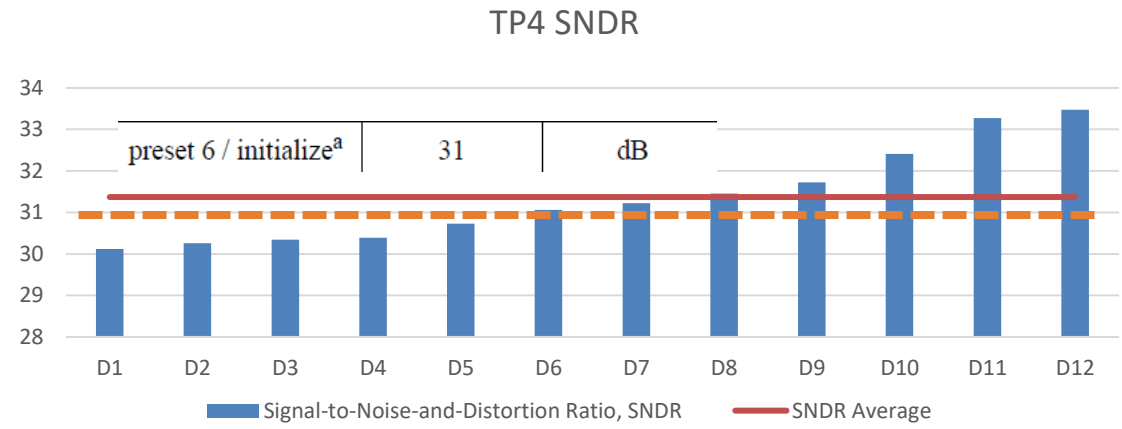
- The following data was assessed to look for any other correlations between measurements, with none being found:
  - Host-reported Pre-FEC BER estimation vs. link partner module TDECQ and TDECQ CER
  - Host-reported Pre-FEC BER estimation vs. link partner module TX jitter (EOJ, JHrms, JH4u)
  - Transition time vs. jitter (EOJ, JHrms, JH4u)
  - Module insertion loss vs. jitter (EOJ, JHrms, JH4u)
  - Overshoot vs. jitter (EOJ, JHrms, JH4u)
  - Overshoot vs. TDECQ and TDECQ CER
- Takeaways:
  - Neither link partner module TX Jitter nor TDECQ were predictors of received signal quality, based on host reported estimate of pre-FEC BER (not a specified measurement).
    - Additional measurements required to predict RX health, such as host insertion losses, local module optical RX quality, link partner TX conformance, etc. Further assessment required.
  - TX parameters largely uncorrelated, suggesting measurements are not redundant

Module TP4 electrical Jitter and Signal to Noise Distortion Ratio data





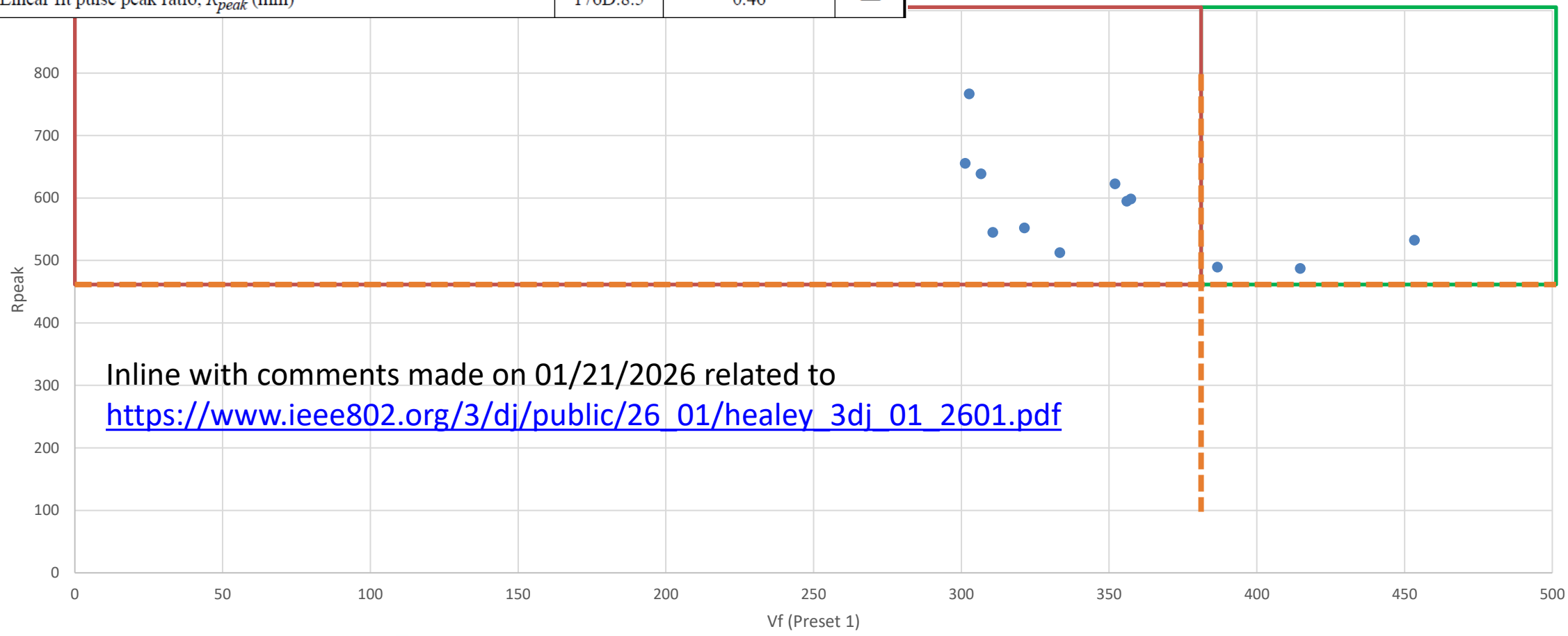




Vf (Preset 1) –vs- Rpeak

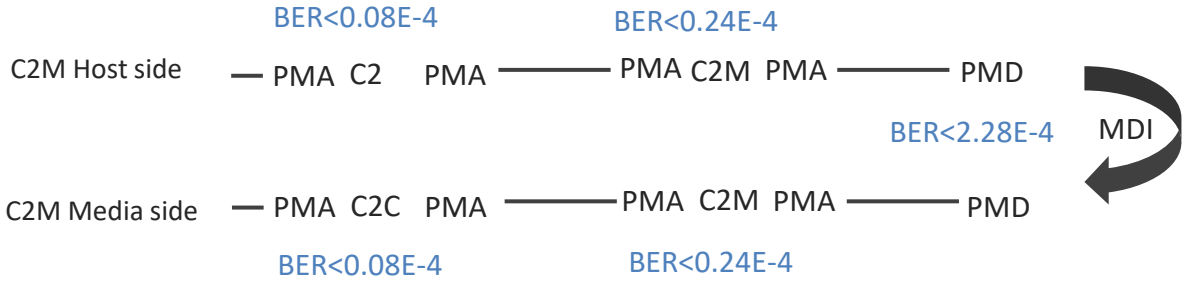
Steady-state voltage (*vf*) and linear fit pulse peak ratio (*Rpeak*)

Transmitter steady-state voltage, v_f (range)	176D.8.5	0.389 to 0.5	V
Linear fit pulse peak ratio, R_{peak} (min)	176D.8.5	0.46	—



Inline with comments made on 01/21/2026 related to
https://www.ieee802.org/3/dj/public/26_01/healey_3dj_01_2601.pdf

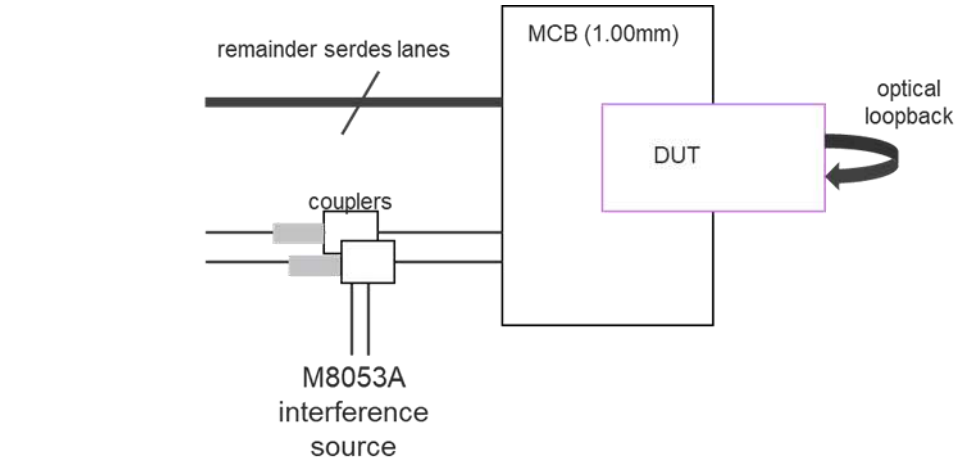
BLER Prelimanry Setup



	BER		multipler	
pmd	2.28E-04		1	2.28E-04
c2m	2.40E-05		2	4.80E-05
c2c	8.00E-06		2	1.60E-05
total	2.60E-04		2.92E-04	

Table 176D–9—Error ratio parameters

Parameter name	Value
p 200GAUI-1 400GAUI-2 800GAUI-4 1.6TAUI-8	 1 2 4 8
BLER limit	1.45×10^{-11}
BER_{total}	2.921×10^{-4}
BER_{added}	2.681×10^{-4}
BER max	2.4×10^{-5}



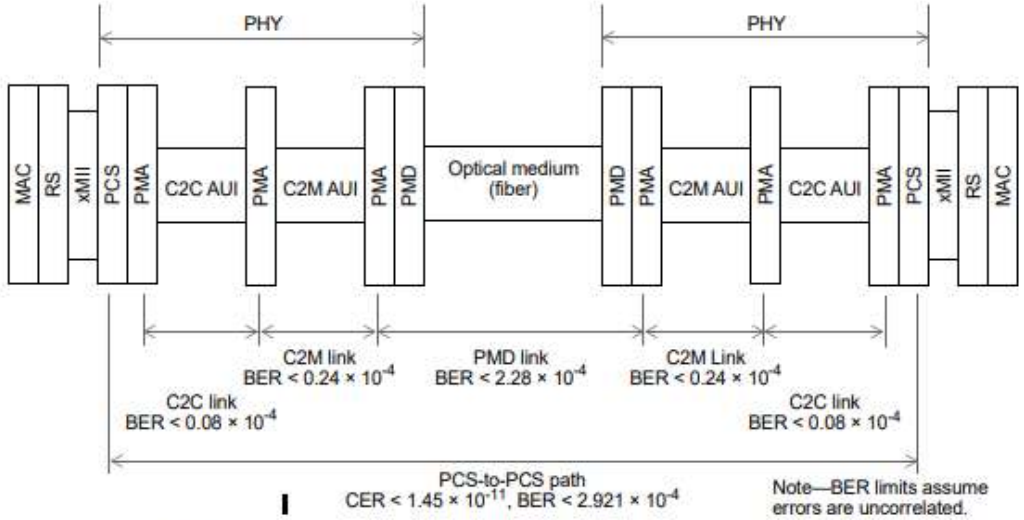


Figure 174A–9—Error allocations for optical PHY types with no FEC sublayer

Failing BLER (174A.9.7)

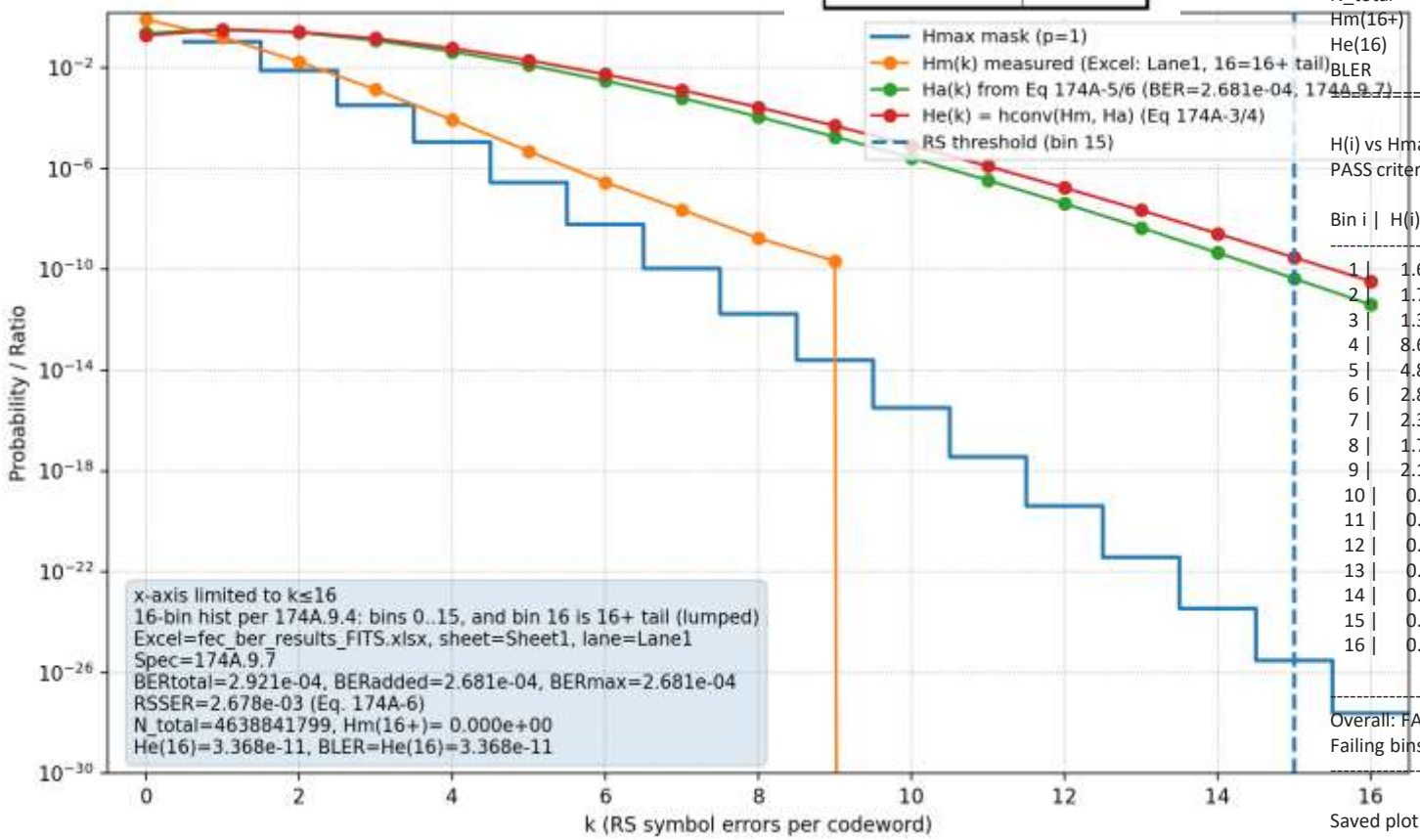
KEYSIGHT

FEC BER Measurement Results

Metric	Lane 1	
	Count	Rate
Pre-FEC BER	3.874E-005	-
Post-FEC BER	0.000E+000	-
FEC Frame Loss Ratio (FLR)	0.000E+000	-
FEC Max Symbol Error Bin	9	-
FEC Margin	40.0%	-
Received Bits	25,235,299,386,560	210,100,677,120
Total Bit Errors	977,738,902	8,162,291
Total Symbol Errors	923,814,921	7,714,158
Corrected Codewords	829,564,089	6,926,654
Total Received Codewords	4,638,841,799	38,621,448
Codewords with 0 Symbol Errors	3,809,277,710	31,694,794
Codewords with 1 Symbol Errors	742,466,834	6,198,748
Codewords with 2 Symbol Errors	80,393,050	671,998
Codewords with 3 Symbol Errors	6,280,565	52,424
Codewords with 4 Symbol Errors	399,476	3,291
Codewords with 5 Symbol Errors	22,722	181
Codewords with 6 Symbol Errors	1,326	11
Codewords with 7 Symbol Errors	107	1
Codewords with 8 Symbol Errors	8	0
Codewords with 9 Symbol Errors	1	0
Codewords with 10 Symbol Errors	0	0
Codewords with 11 Symbol Errors	0	0
Codewords with 12 Symbol Errors	0	0
Codewords with 13 Symbol Errors	0	0
Codewords with 14 Symbol Errors	0	0
Codewords with 15 Symbol Errors	0	0
Uncorrectable Codewords	0	0

Table 176D–9—Error ratio parameters

Parameter name	Value
p	
200GAUI-1	1
400GAUI-2	2
800GAUI-4	4
1.6TAUI-8	8
BLER limit	1.45×10^{-11}
BER_{total}	2.921×10^{-4}
BER_{added}	2.681×10^{-4}
BER	2.4×10^{-5}

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---------- Keysight Technologies (2025) ----------

==================== FEC Overlay Summary ====================
Excel file     : fec_ber_results_FITS.xlsx
Sheet / Lane   : Sheet1 / Lane1
Spec mode      : 174A.9.7
Histogram bins : 0..15 explicit, 16 = 16+ tail lumped
n_symbols      : 544

Pre-FEC BER    : 3.874e-05
BER_total      : 2.921e-04
BER_added      : 2.681e-04
BER_max        : 2.681e-04
RSSER          : 2.678e-03   (Eq. 174A-6)

N_total        : 4638841799
Hm(16+)        : 0.000e+00
He(16)         : 3.368e-11
BLER           : 3.368e-11   (BLER = He(16))
=============================================================

H(i) vs Hmax mask (p=1) for bins i=1..16
PASS criterion: H(i) <= Mask(i)   (blank when H(i) == 0)

Bin i |  H(i) measured |     Mask(i) |  Ratio H/Mask | Pass/Fail
-------------------------------------------------------------------
    1 |    1.601e-01 |    1.100e-01 |    1.455e+00 |     FAIL
    2 |    1.733e-02 |    7.500e-03 |    2.311e+00 |     FAIL
    3 |    1.354e-03 |    3.200e-04 |    4.231e+00 |     FAIL
    4 |    8.612e-05 |    1.100e-05 |    7.829e+00 |     FAIL
    5 |    4.898e-06 |    2.700e-07 |    1.814e+01 |     FAIL
    6 |    2.858e-07 |    5.900e-09 |    4.845e+01 |     FAIL
    7 |    2.307e-08 |    1.100e-10 |    2.097e+02 |     FAIL
    8 |    1.725e-09 |    1.700e-12 |    1.014e+03 |     FAIL
    9 |    2.156e-10 |    2.500e-14 |    8.623e+03 |     FAIL
   10 |    0.000e+00 |    3.200e-16 |              |
   11 |    0.000e+00 |    3.700e-18 |              |
   12 |    0.000e+00 |    4.000e-20 |              |
   13 |    0.000e+00 |    3.900e-22 |              |
   14 |    0.000e+00 |    3.600e-24 |              |
   15 |    0.000e+00 |    3.000e-26 |              |
   16 |    0.000e+00 |    2.400e-28 |              |

---------- Overall Mask Result ----------
Overall: FAIL
Failing bins: 1, 2, 3, 4, 5, 6, 7, 8, 9
-----------------------------------------------------------
Saved plot: fec_overlay_174A.9.7.png
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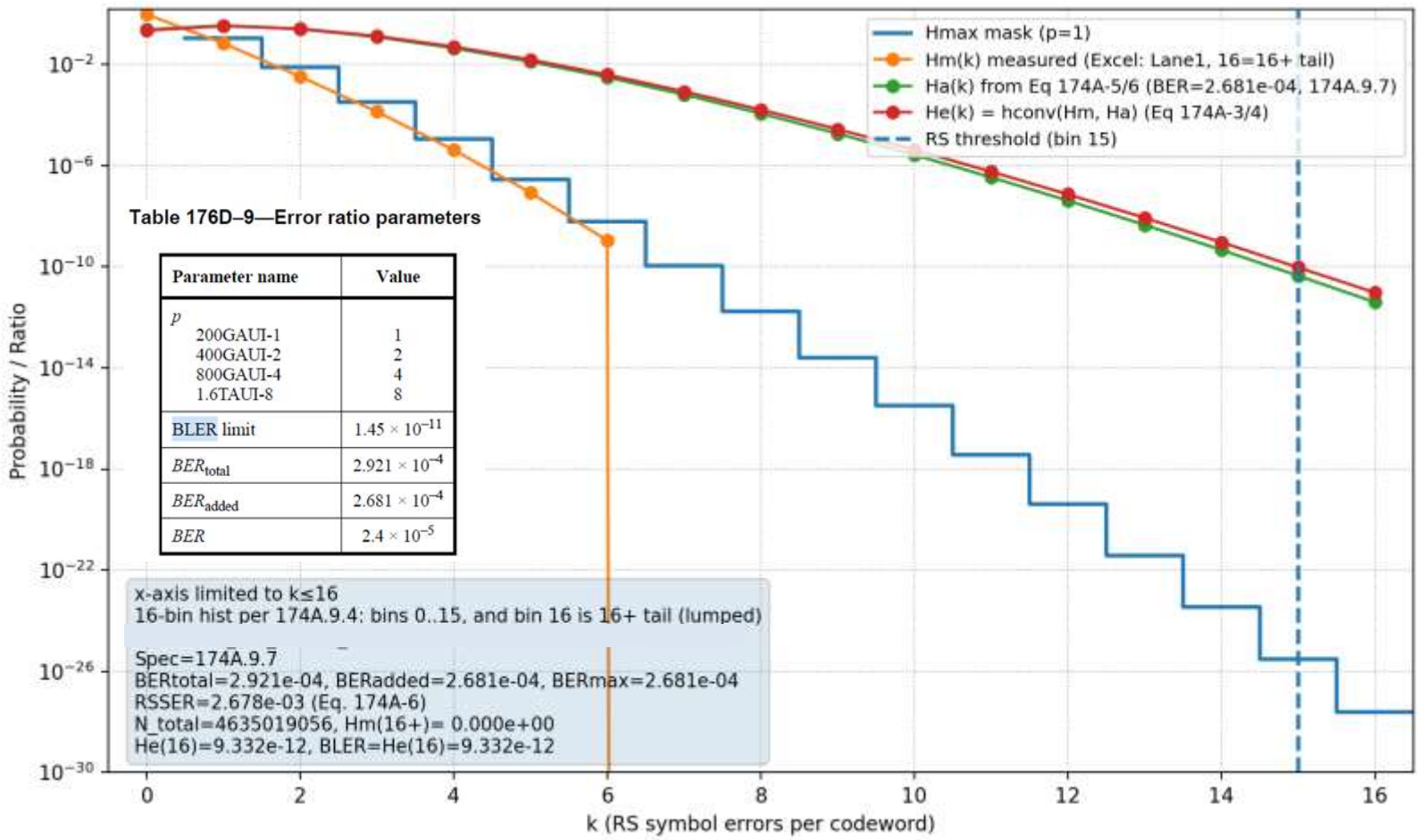
Passing BLER (174A.9.7)

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==================== FEC Overlay Summary ====================

Sheet / Lane    : Sheet1 / Lane1
Spec mode       : 174A.9.7
Histogram bins  : 0..15 explicit, 16 = 16+ tail lumped
n_symbols       : 544

Pre-FEC BER     : 1.477e-05
BER_total       : 2.921e-04
BER_added       : 2.681e-04
BER_max         : 2.681e-04
RSSER           : 2.678e-03   (Eq. 174A-6)

N_total         : 4635019056
Hm(16+)         : 0.000e+00
He(16)          : 9.332e-12
BLER            : 9.332e-12   (BLER = He(16))
============================================================

H(i) vs Hmax mask (p=1) for bins i=1..16
PASS criterion: H(i) <= Mask(i)   (blank when H(i) == 0)

Bin i |  H(i) measured |     Mask(i) |  Ratio H/Mask | Pass/Fail
------------------------------------------------------------------
   1 |    6.735e-02 |   1.100e-01 |   6.122e-01 |     PASS
   2 |    3.291e-03 |   7.500e-03 |   4.388e-01 |     PASS
   3 |    1.330e-04 |   3.200e-04 |   4.156e-01 |     PASS
   4 |    4.109e-06 |   1.100e-05 |   3.735e-01 |     PASS
   5 |    8.393e-08 |   2.700e-07 |   3.108e-01 |     PASS
   6 |    1.079e-09 |   5.900e-09 |   1.828e-01 |     PASS
   7 |    0.000e+00 |   1.100e-10 |             |
   8 |    0.000e+00 |   1.700e-12 |             |
   9 |    0.000e+00 |   2.500e-14 |             |
  10 |    0.000e+00 |   3.200e-16 |             |
  11 |    0.000e+00 |   3.700e-18 |             |
  12 |    0.000e+00 |   4.000e-20 |             |
  13 |    0.000e+00 |   3.900e-22 |             |
  14 |    0.000e+00 |   3.600e-24 |             |
  15 |    0.000e+00 |   3.000e-26 |             |
  16 |    0.000e+00 |   2.400e-28 |             |

---------- Overall Mask Result ----------
Overall: PASS (all nonzero bins satisfy H(i) <= Mask(i))
------------------------------------------------------------

Saved plot: fec_overlay_174A.9.7.png
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