CASE STUDY

BENCHMARKING HIGH-SPEED CABLES

How Amphenol's high-speed IO cables business benchmarked their Active Cables using Xena Ethernet Traffic Generators

June 2026

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Background

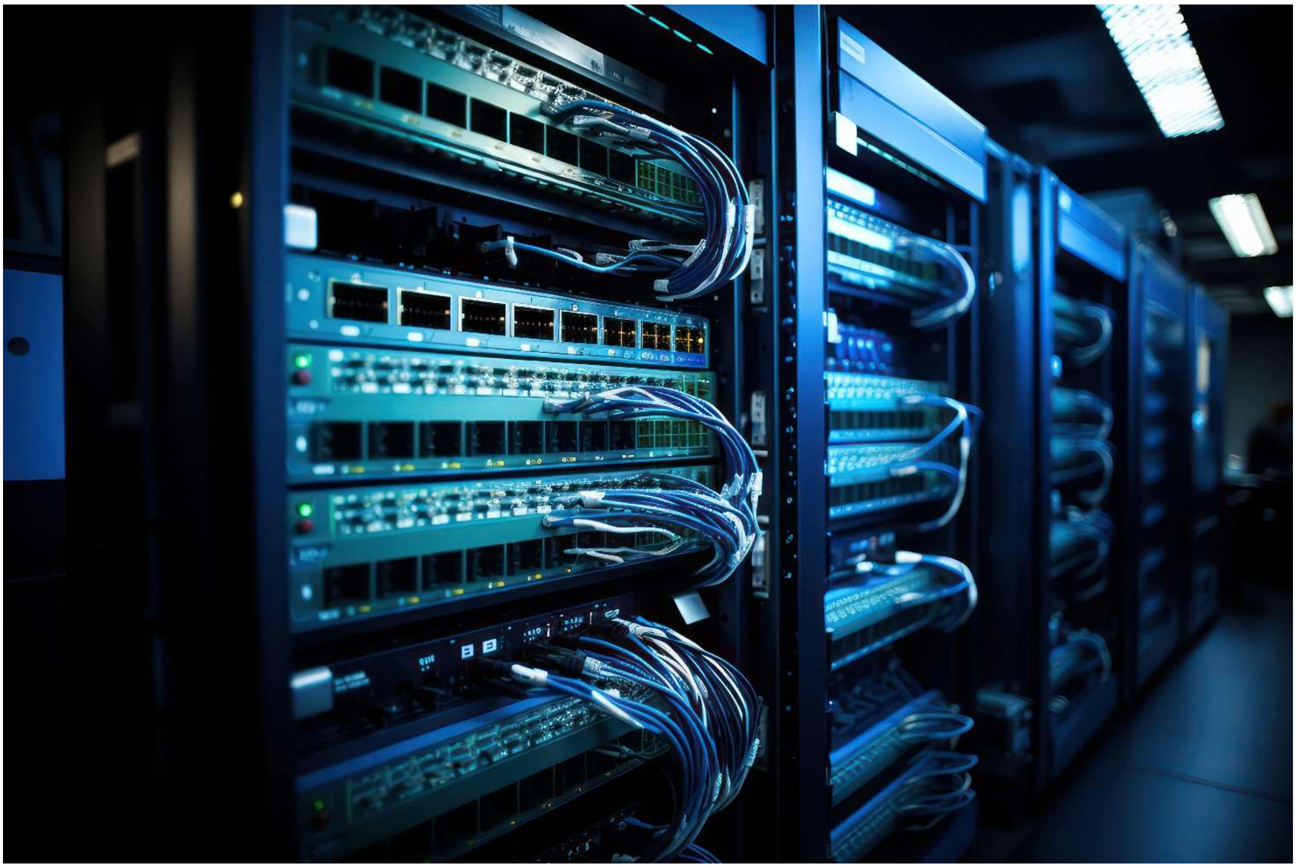


Figure 1: High speed cable connections in data center.

As the demand for bandwidth increases in data centers, high speed, reliable, and cost-effective connectivity solutions become increasingly critical. With the move to 400G, 800G and eventually 1.6T connections, traditional passive copper cables (also known as Direct Attach Cables, DACs) find themselves challenged by the need to transmit 112Gbps PAM4 signals over distances up to 3 meters, from the bottom to the top of the racks. Optical solutions offer the required reach, but they are expensive and consume a lot of power. Moreover, many data centers transition towards 800G switch ports being connected to several Network Interface Card (NIC) 100/200/400G ports via break-out cables, adding further complexity to the scenario.

In response to this demand and the highlighted challenges, Active Copper Cables (ACCs) featuring linear equalizers positioned at one or both ends of the cable, and Active Electrical Cables (AECs) with DSPs at one or both ends, emerged as cabling solutions helping to extend the copper-based ecosystem.

Per lane speed	28G NRZ	56G PAM4	112G PAM4
Typical reach	3m (No FEC) 5m (RS-FEC)	2m	2m

Table 1: Typical reach for passive cobber cables for 28G to 112G.

Amphenol Communications Solutions is one of the world's largest developers and manufacturers of connectors and interconnect systems. With advanced cabled solutions supporting data rates up to 224Gbps per lane and beyond, Amphenol is well positioned to meet the demand in data centers. By providing reliable and consistent high-speed connectivity between racks, Amphenol facilitates the seamless transfer of data across the expansive infrastructure of modern data centers and hyperscale data centers

Amphenol's Octal Small Form-factor Pluggable (OSFP) and Quad Small Form-factor Pluggable, Double Density (QSFP-DD) copper cable assemblies are designed to meet the needs of data center, networking and high-performance computing applications for high-density cabling interconnect systems capable of data rates from 10Gpbs per lane to 224Gbps per lane transmission rates.

Figure 2: OSFP and QSF-DD assemblies from Amphenol Communications Solutions.

This case study describes how Amphenol used Teledyne LeCroy test solutions to measure the performance differences between different passive and active cables to present a more consistent message to customers about relative performance for each type of solution. A large range of DAC, ACC, and AEC cables up to three meters in length were evaluated.

The Challenge

Being a cable vendor, Amphenol naturally needs to test and document the performance differences between different ACC or AEC and DAC interconnect. Additionally, they must investigate the performance in real installations with tightly bent, densely packed cables which could result in varying intra-pair skews across different lanes.

After conducting numerous interoperability tests, Amphenol determined that the absolute Bit Error Rate (BER) measurements can vary across different ports and lanes. Consequently, to accurately assess the performance of one cable relative to another cable or a previous test, it was essential to conduct measurements using the same SerDes implementation. Furthermore, the test module must allow tuning of its TX equalizer to optimize the BER for each type of cable and cable length.

For DACs and even ACCs, it is typical to employ Vector Network Analyzers (VNAs) for analyzing the performance of a cable in the frequency domain. “Meeting the industry standard specifications is the benchmark for shipping to customers, however, when customers report field issues, the differences in the frequency spectrum are often so minor, that it is a bit like finding a needle in a haystack,” says Samuel Kocsis, Director of Standards and Technology at Amphenol Communications Solutions. “For this reason, customers are requesting improved methods for quantifying cable performance, with as close to an *in-situ* test as possible in a way that is both time and cost effective.” Amphenol aims to find the optimal approach that balances the testing effort with the insights gained.

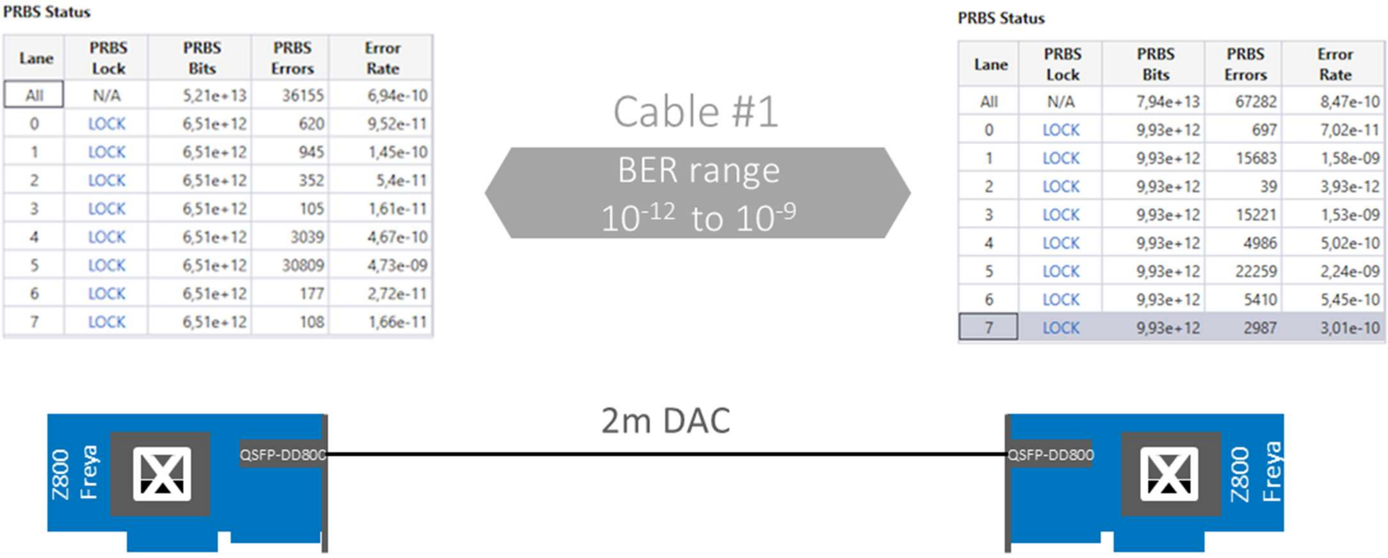
Pseudo-Random Binary Sequence (PRBS) represents a natural progression from VNAs to enable BER measurements relative to a benchmark. However, sometimes PRBS alone is insufficient – for instance, rigid cable bends can lead to divergent skew patterns across lanes, necessitating the use of AN/LT or measuring packet drops at Layer 2.

The Solution

Figure 3: Z800 Freya traffic generator.

Amphenol set out to determine whether the Teledyne LeCroy Z800 Freya traffic generator could be used to test the compliance of both active and passive cables. The Z800 Freya supports testing at speeds ranging from 10Gbps to 800Gbps, using 10/25G NRZ or 56G/112G PAM4 SerDes. The test modules are available with either OSFP or QSFP-DD interfaces, allowing cables with both interface types to be tested within the same rack setup. With its in-house PHY design, the Z800 Freya offers a comprehensive feature set for Layer 1 testing, along with full Layer 2-3 testing capabilities.

The XenaManager software simplifies the configuration and monitoring of per-port and per-lane statistics and facilitates the setup and execution of packet streams at wire-speed. For example, Figure 4 shows the pre-FEC BER measured at both ends of a 2-meter-long DAC. Moreover, Xena OpenAutomation (XOA), a free open-source automation and Python API scripting framework, allows customers to automate and integrate Z800 Freya with their own test scripts. By automating cable testing with the Z800 Freya and XOA, days of cumbersome manual testing using a VNA can often be reduced to a few hours of testing.



PRBS Status

Lane	PRBS Lock	PRBS Bits	PRBS Errors	Error Rate
All	N/A	5,21e+13	36155	6,94e-10
0	LOCK	6,51e+12	620	9,52e-11
1	LOCK	6,51e+12	945	1,45e-10
2	LOCK	6,51e+12	352	5,4e-11
3	LOCK	6,51e+12	105	1,61e-11
4	LOCK	6,51e+12	3039	4,67e-10
5	LOCK	6,51e+12	30809	4,73e-09
6	LOCK	6,51e+12	177	2,72e-11
7	LOCK	6,51e+12	108	1,66e-11

PRBS Status

Lane	PRBS Lock	PRBS Bits	PRBS Errors	Error Rate
All	N/A	7,94e+13	67282	8,47e-10
0	LOCK	9,93e+12	697	7,02e-11
1	LOCK	9,93e+12	15683	1,58e-09
2	LOCK	9,93e+12	39	3,93e-12
3	LOCK	9,93e+12	15221	1,53e-09
4	LOCK	9,93e+12	4986	5,02e-10
5	LOCK	9,93e+12	22259	2,24e-09
6	LOCK	9,93e+12	5410	5,45e-10
7	LOCK	9,93e+12	2987	3,01e-10

Figure 4: Pre-FEC BER measured using PRBS31Q on 2m QSFP-DD800 DACs.

Initially, Amphenol used Z800 Freya to transmit PRBS streams and measure BER performance differences among various cables and test scenarios. By employing a traffic generator, Amphenol was able to detect subtle differences in post-FEC system performance degradation that were not discernible through frequency domain analysis alone. For more advanced testing, such as minor skew differences between different lanes on a cable, Amphenol utilized both Link Training and L2 packet streams to monitor per-lane performance.

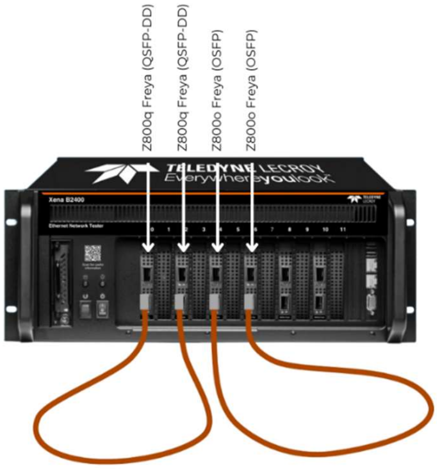


Figure 5: Example of two cables being tested in the same Xena B2400 chassis.

A wide range of DAC, ACC, and AEC cables of varying lengths were tested at 800Gbps using the Teledyne LeCroy Z800 Freya traffic generator. For a comprehensive list of all test results, see the Appendix at the end of this document. Both OSFP and QSFP-DD transceivers were included in the tests, and cables with different gauges ranging from 25 AWG to 32 AWG were evaluated.

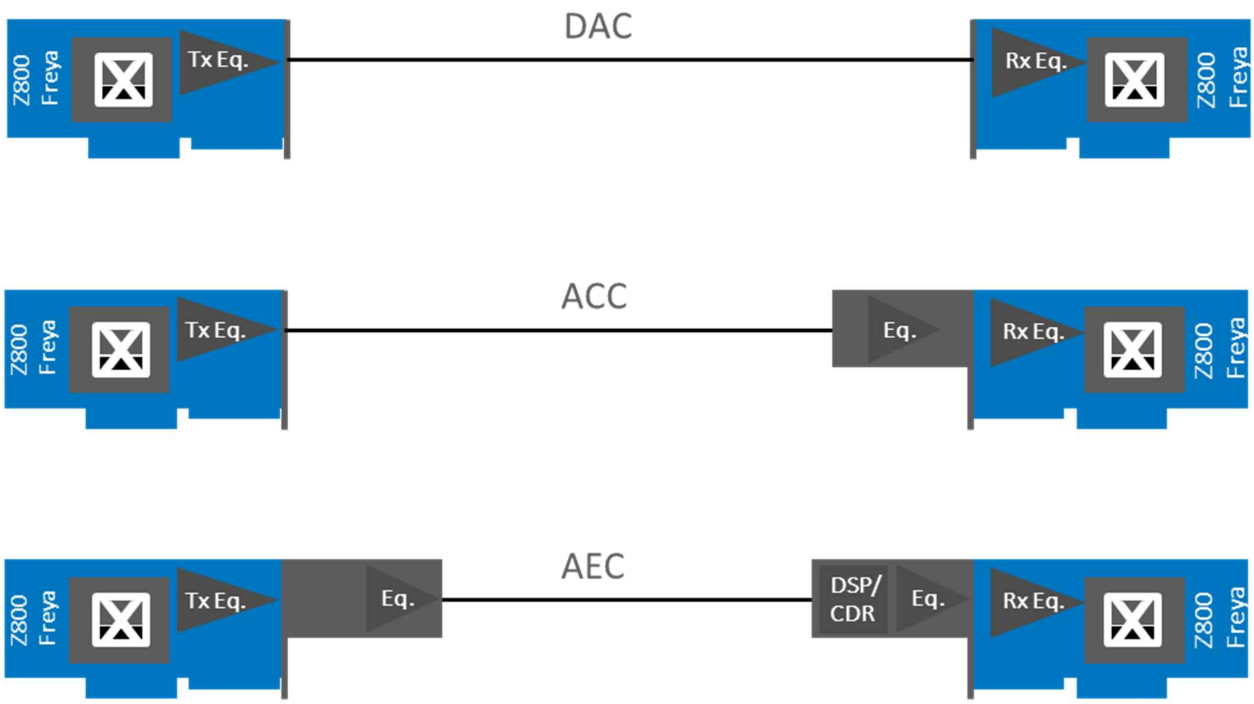


Figure 6: Illustration of equalizers in both transceivers and active cables.

As shown in Figure 6, high-speed Ethernet connections involve multiple equalizers – at the transmitter, the receiver, and, in the case of active cables, within the cable itself. To ensure a fair comparison between the various cable types, it was important to tune the transmitter equalizer taps of the test module transceiver for optimal performance based on each cable's type, gauge, and length. Figure 7 presents an example of the relative BER improvements obtained on ACC cables using two different transmitter equalizer settings.

In one case, the same equalizer setting was applied across all three cable lengths (labeled w/o tuning), while in the other case, the settings were manually optimized for the best possible BER at each length (labeled w tuning). As shown, proper tuning improved BER in this specific example by up to two orders of magnitude.

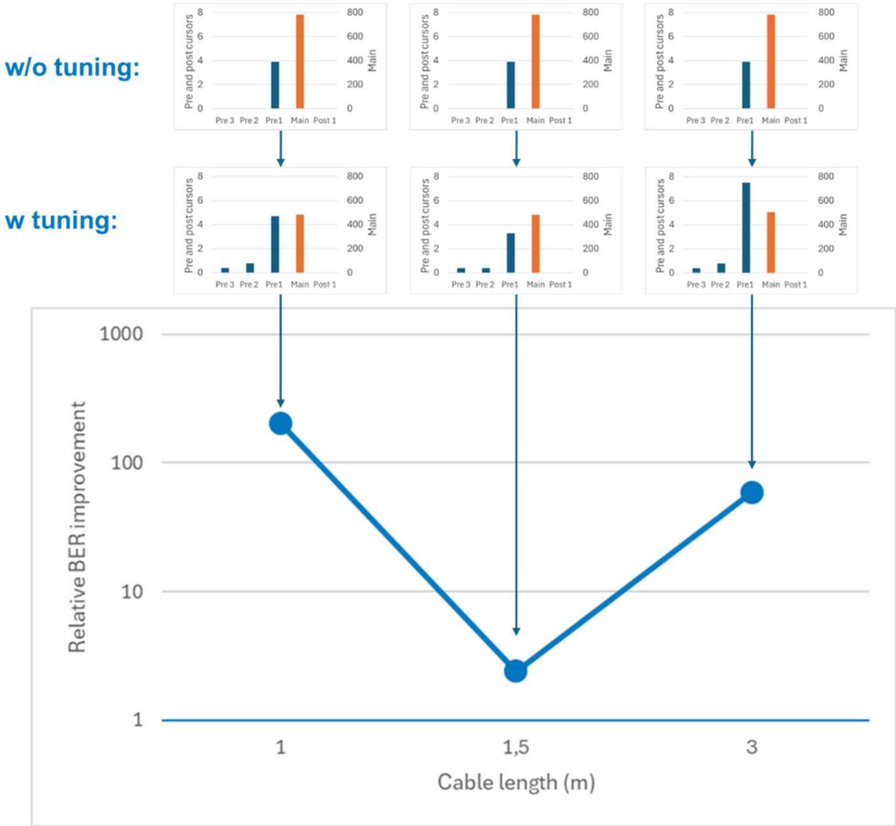


Figure 7: Example of relative BER improvement obtained for three ACCs of lengths 1, 1.5 and 3 meters by tuning of the Tx equalizer of the test module. The insets show the used settings for the Tx equalizer.

In general, it is beneficial to implement a lookup table in the host network equipment that stores the optimal equalizer settings for all cable types and lengths used in the network. In some cases, a test module like the Z800 Freya can be used as a link partner to automatically tune the host's transmitter equalizer through Link Training.

Figure 8 illustrates a benchmarking test conducted on a subset of DAC, ACC, and AEC cables using PRBS to measure pre-FEC BER across different cable lengths and gauge values. The transmitter equalizer taps were adjusted for each measurement. The dotted lines indicate the expected performance trends for DAC, ACC, and AEC cables. The results show that DAC cables perform quite well at lengths below 1.5–2 meters, whereas at longer lengths, ACC and AEC cables exhibit nearly identical performance.

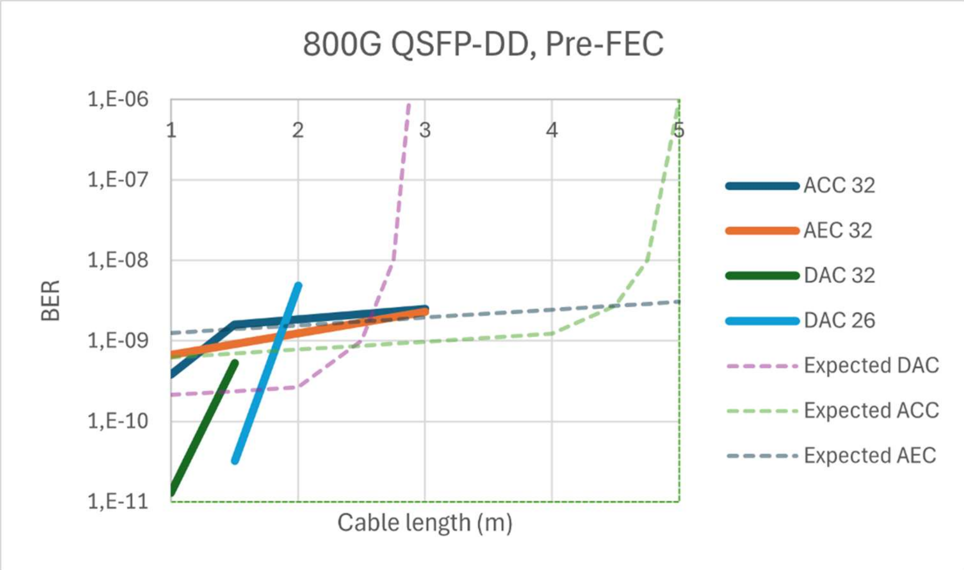


Figure 8: Pre-FEC BER for DAC, ACC, and AECs of lengths varying from 1 to 3 meters. Dotted lines indicate how the performance of the various cables is expected to behave ideally.

The BER measured for an 800Gbps link can vary due to differences in BER across the individual 8 lanes. The Z800 Freya Signal Integrity View (SIV) provides a quick way to identify whether one or more lanes are experiencing poorer PAM4 signal quality compared to the others. Figure 9 shows an example where lanes 0, 1, and 4 are performing well, while the remaining lanes exhibit poor performance.

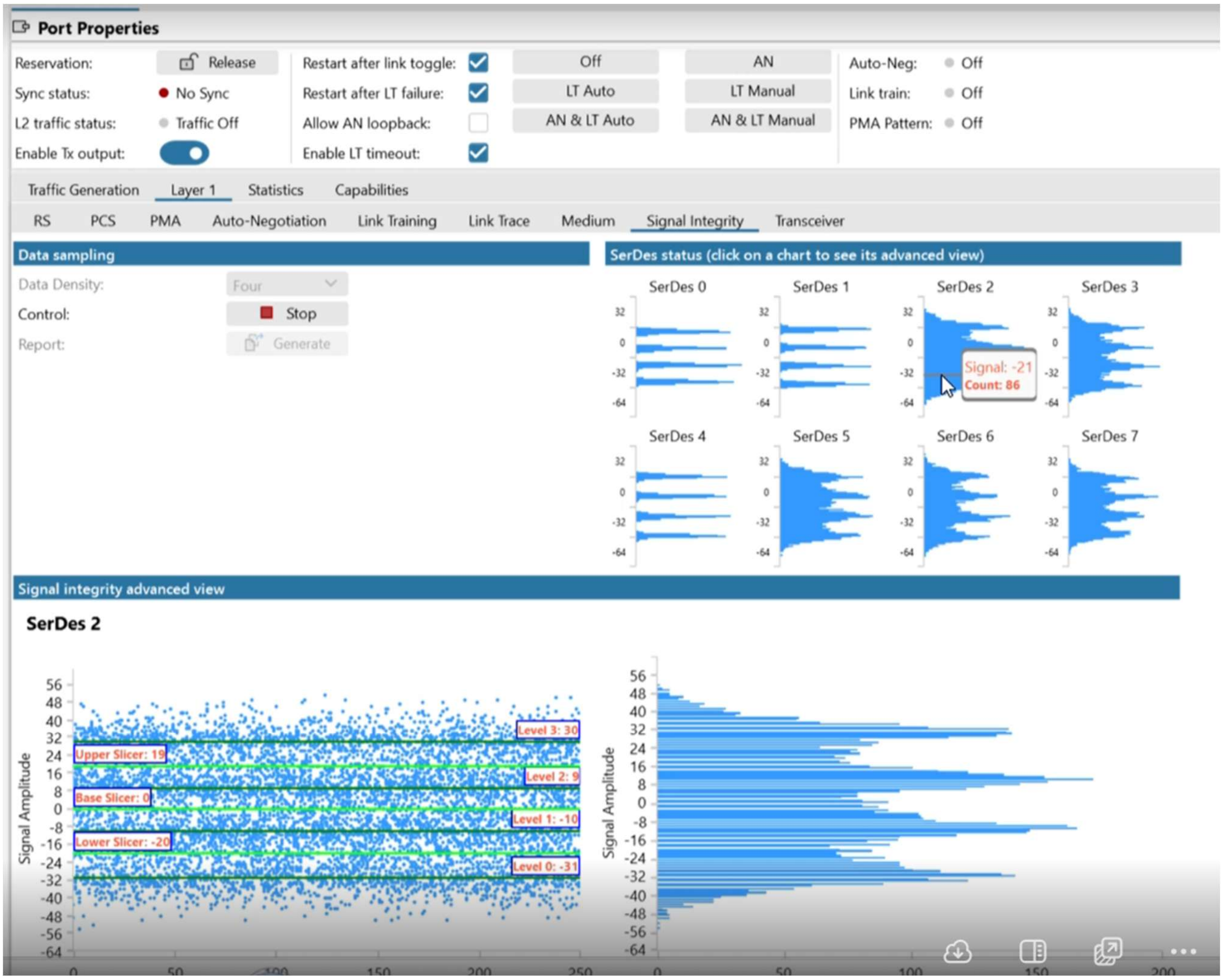


Figure 9: Signal Integrity View showing example of performance of each of the 8 lanes of an 800G PAM4 link.

On top of the BER measurement Ethernet packets of 64 bytes and 1588 bytes were also tested. The packet loss was 0 in all measurements indicating that the aceived BER was adequate. The Z800 Freya test module also enable measurement of the end-to-end latency for all cables.

“Freya enabled us to quickly quantify the performance variances among our different cabling solutions by emulating real-world systems," explains Samuel Kocsis. He further adds, "The platform is highly attractive from the standpoint that we can plug in different test modules in the same chassis mainframe, so we can test a mix of OSFP and QSFP-style ports."

Using Z800 Freya made it easy for Amphenol to compare their various active and passive cable solutions against a well-functioning 112Gbps SerDes implementation. This capability proved valuable in both the development and promotion of new cable types, as well as analyzing cable issues reported by customers. Samuel Kocsis anticipates that Amphenol will utilize the Teledyne LeCroy XOA Python API to further integrate Z800 Freya into their test environment.

Looking ahead, Amphenol envisions the use of Freya in their production processes. Whenever new processes or materials are implemented, it is imperative to prove that these changes have not altered the product's performance.

Summary

Amphenol is one of the world’s largest developers and manufacturers of connectors and interconnect systems including advanced passive and active solutions supporting data rates of 112G, 224G, and beyond. They are always in need of market leading metrology equipment to evaluate the performance differences between various passive and active cable types.

The Teledyne LeCroy Z800 Freya traffic generator, with extensive L1, L2, and L3 test capabilities enabled Amphenol to perform the kind of testing needed for this task.

A key capability of the Z800 Freya is the ability to precisely tune the equalizers in the test equipment to achieve optimal performance for each cable type and length.

Using the Z800 Freya, Amphenol was able to quantitatively compare BER versus length across a wide range of DACs, ACCs, and AECs. The results clearly demonstrated that ACCs and AECs significantly extend the maximum usable transmission distance compared with passive DACs.

Appendix Data

Below, you will find the data collected for the various cables for reference.

The latency is measured as last bit out to first bit in which effectively measures the PHY-to-PHY datapath latency independent of the packet length and FEC but sensitive to cable type and direction-dependent retimer delays.

The same Tx equalizer setting was used for all 8 lanes of each cable type test.

Cables					PRBS					Xena TX Tap Settings					Packet Loss		Latency (ns)	
Cable TYPE	Gauge (AWG)	Length (m)	Name	PreFEC BER (all 8 Lanes)	Overall (8 Lanes)6	Best lane	Lane # (B)	Worst Lane	Lane # (W)	Pre 3	Pre 2	Pre1	Main	Post 1	64Byte/ packet	1518Bytes/ packet	64B (ns)	1518B (ns)
ACC	30	1	OSFP800G ACC	4,40E-09	2,40E-09	1,90E-11	0	1,10E-08	7	0,4	0,8	4,7	483	0	0	0	48	48
ACC	30	1	QSFPDD800G ACC	6,00E-09	5,40E-09	2,80E-11	1	1,40E-08	6	0	0,8	4,5	494	0	0	0	48	48
ACC	32	1	OSFP800G ACC	8,60E-09	1,50E-08	5,00E-11	6	5,10E-08	7	0,4	0,4	3,3	483	0	0	0	50	50
ACC	32	1	QSFPDD800G ACC	3,80E-10	1,90E-10	5,40E-12	3	8,10E-10	6	0	0,8	8,8	494	0	0	0	48	48
ACC	30	1,5	OSFP800G ACC	8,90E-09	3,70E-09	1,10E-11	6	1,20E-08	7	0,4	0,4	3,3	483	0	0	0	50	50
ACC	32	1,5	OSFP800G ACC	2,40E-10	2,00E-10	6,60E-12	6	6,40E-10	3	0	0	4,2	483	0	0	0	51	51
ACC	32	1,5	QSFPDD800G ACC	1,60E-09	9,80E-10	3,90E-12	3	3,70E-09	6	0	3,5	9,1	575	0	0	0	51	51
ACC	30	3	OSFP800G ACC	6,80E-10	8.3r-10	1,10E-11	6	3,20E-09	3	0,4	0,8	7,5	506	0	0	0	59	59
ACC	32	3	OSFP800G ACC	2,60E-09	3,10E-09	1,40E-10	0	1,80E-08	3	0,4	0,8	6,6	506	0	0	0	62	62
ACC	32	3	QSFPDD800G ACC	2,50E-09	1,10E-08	7,60E-10	3	4,80E-08	6	0,3	0,9	6,8	678	0,6	0	0	57	57
AEC	32	1	OSFP800G AEC	2,65E-11	2,20E-10	4,80E-13	1	1,80E-09	4	0	0	*2,2*	*552*	0	0	0	148	148
AEC	32	1	QSFPDD800G AEC	6,70E-10	7,60E-10	4,60E-12	0	3,00E-09	6	0	0,7	5,4	575	0	0	0	84	84
AEC	32	1,5	OSFP800G AEC	4,40E-10	8,40E-10	1,80E-12	2	1,80E-09	3	0	0	*2,2*	*552*	0	0	0	148	148
AEC	32	1,5	OSFP800G AEC	4,80E-10	5,30E-10	1,60E-12	0	1,70E-09	7	0	0,7	5,4	575	0	0	0	85	85
AEC	32	3	OSFP800G AEC	8,70E-10	2,70E-09	2,70E-11	1	1,30E-08	5	0	0	3,5	690	0	0	0	157	157
AEC	32	3	QSFPDD800G AEC	2,30E-09	3,50E-09	8,70E-10	0	8,50E-09	6	0	0,7	5,4	575	0	0	0	94	94
DAC	25	1	OSFP800G DAC	1,70E-11	2,00E-11	1,00E-13	5	2,80E-10	4	0	0	3,9	782	0	0	0	48	48
DAC	25	1	QSFPDD800G DAC	1,30E-10	9,50E-11	2,90E-13	3	2,50E-10	5	0	0	4,6	713	0,6	0	0	46	46
DAC	26	1	O-QDD DAC 800G	4,30E-11	2,50E-11	4,00E-13	1	1,00E-10	6	0	0	4,6	713	0,6	0	0	46	46
DAC	30	1	OSFP800G DAC	8,00E-10	1,30E-09	3,70E-13	6	9,70E-09	3	0	0	3,9	782	0	0	0	49	49
DAC	30	1	O-QDD DAC 800G	3,00E-12	7,30E-12	3,30E-13	6	2..6e-10	3	0	0	4.7 - (0)	782	0	0	0	52	52
DAC	30	1	QSFPDD800G DAC	4,20E-11	7,00E-11	2,00E-12	1	5,60E-10	5	0	0	6,4	713	0,6	0	0	48	48
DAC	32	1	OSFP800G DAC	3,90E-12	1,60E-11	2,80E-13	5	1,30E-10	3	0	0	3,9	782	0	0	0	49	49
DAC	32	1	QSFPDD800G DAC	1,30E-11	1,74E-11	1,10E-12	1	4,40E-11	4	0	0	6,4	713	0,6	0	0	46	46
DAC	26	1,5	QSFPDD800G DAC	3,22E-11	3,80E-11	2,80E-13	1	1,36E-10	5	0	0	5	655	0	0	0	53	53
DAC	27	1,5	OSFP800G DAC	2,80E-12	4,40E-12	2,60E-13	0	2,00E-11	3	0	0	3,9	782	0	0	0	53	53
DAC	32	1,5	OSFP800G DAC	8,90E-11	3,00E-11	2,00E-13	2	1,20E-10	3	0	0	3,9	782	0	0	0	53	53
DAC	32	1,5	QSFPDD800G DAC	5,30E-10	4,80E-10	4,50E-11	0	1,22E-09	1	0	0	1,4	736	1,1	0	0	53	53
DAC	26	2	O-QDD DAC 800G	1,77E-10	1,50E-10	1,60E-12	0	7,60E-10	3	0	0	4.7 - (0)	783	0	0	0	52	52
DAC	26	2	QSFPDD800G DAC	4,60E-09	4,90E-09	4,50E-09	2	2,10E-08	5	0	0	7,2	586	5,3	0	0	56	56
DAC	27	2	OSFP800G DAC	2,73E-11	3,50E-12	1,88E-13	7	1,30E-11	4	0	0	4,7	782	0	0	0	56	56
DAC	30	2	O-QDD DAC 800G	5,10E-10	6,60E-10	9,00E-13	6	6,70E-10	5	0	0	4.7 - (0)	782	0	0	0	56	56
DAC	30	2	OSFP800G DAC	3,00E-10	1,90E-10	2,20E-13	1	5,40E-10	2	0	0	4,7	782	0	0	0	56	56
DAC	30	2	QSFPDD800G DAC	9,30E-11	7,00E-11	4,80E-11	3	5,00E-10	5	0,8	0,3	4,3	759	0	0	0	56	56
DAC	25	2,5	OSFP800G DAC	1,10E-12	3,70E-12	5,00E-13	1	3,40E-11	3	0	0	3,9	782	0	0	0	56	56
DAC	25	2,5	QSFPDD800G DAC	1,50E-10	1,90E-10	6,20E-12	2	7,40E-10	5	0	0	4,8	724	0,6	0	0	56	56