



**AH15199B/AH15203A Wideband Linear Amplifier
For 448 Gbps High-Speed Transmissions**

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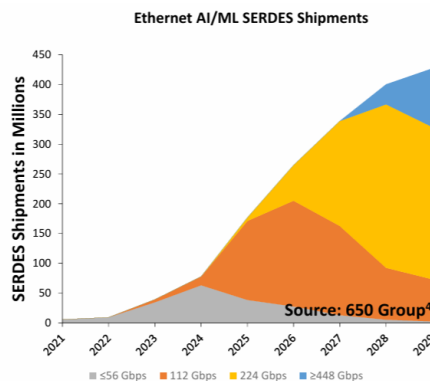
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1 Introduction

The rapid deployment of artificial intelligence (AI) tools and technologies is driving the need for high-bandwidth AI cluster networks. As current 800 Gbps link speeds become inadequate to meet the performance requirements of next-generation AI clusters, 1.6 Tbps and 3.2 Tbps (448 Gbps/lane) technologies are urgently needed. To meet this need, the IEEE 802.3 400 Gbps per Lane PHYs and Interface Study Group has started discussing standardization. The OIF (Optical Internetworking Forum) is also investigating how promote next-generation 448 Gbps systems within the Next Generation CEI-448G Framework. Although PAM6 and PAM8 offer higher data throughput per symbol, making them attractive candidates for achieving 448 Gbps without doubling the symbol rate, they are more susceptible to noise and require signals with a high signal-to-noise ratio (SNR). This application note introduces an example of evaluating a 488 Gbps optical device based on PAM4 technology, which has a proven IEEE 802.3ck/dj and PCIe Gen6/7 track record.

2 Market Trends

The extraordinary growth of artificial intelligence (AI) and machine learning (ML) is placing unprecedented demand on system interconnects and bandwidth expansion. Data-center operators are rapidly scaling their AI networks, and Ethernet at 448 Gbps per lane is expected to see widespread deployment driven by the need for greater bandwidth and increased use of optical interconnects. Market demand for 448 Gbps signal transmission is projected to start in 2027 (Fig. 1).



Source: 650 Group 4Q24 AI Networking (Ethernet and InfiniBand) Report

Fig. 1 Ethernet AI/ML SERDES Shipments

3 Optical Device Evaluation (1) – EML

Verifying the quality of the signal-source waveform is a key challenge for the device under test; before the signal is transmitted to the DUT, the effects of frequency characteristics (loss) in external equipment, such as cables, causing signal distortion must be compensated (calibrated), by using the AWG (DAC) de-embedding function. Particularly, high-speed signals such as 224 Gbaud PAM4 from a signal source have an insufficient output level, necessitating use of an external amplifier. The critical point is whether the amplifier's S21 characteristic assures sufficient gain at the Nyquist frequency of the transmitted signal. When amplifying 224G PAM4 signals, transmission characteristics at or above the Nyquist frequency of 112 GHz are critical. If the bandwidth characteristics are narrow, waveform distortion occurs in the skew direction due to group delay characteristics. Therefore, a bandwidth of at least 112 GHz is required. Figure 2 shows an example of a commercially available 224 Gbaud PAM4 signal source connected to an external AH15203A wideband linear amplifier with a built-in bias tee (see Fig. 3 for S21 and S11/S22 characteristics). Figure 4 shows typical output waveforms. In the single-ended case, the output

amplitude is 0.58 Vpp and the TDECQ is 2.95 dB (9.7E-3). However, the signal from a dual-lane differential configuration has an output amplitude of 1.15 Vpp and TDECQ of 1.78 dB (9.7E-3). Using differential signaling improves the SNR, so the TDECQ value is also improved compared to single-ended signaling (2.95 dB → 1.78 dB) when measured under the same conditions.

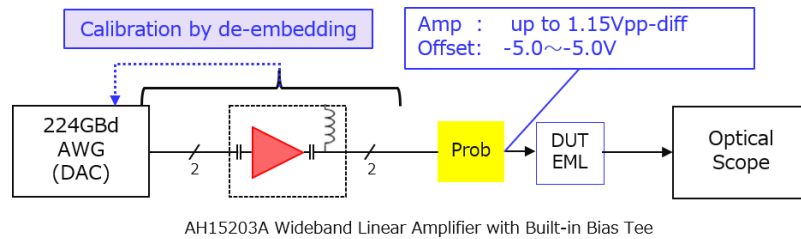


Fig. 2 Example of 224 GBaud PAM4 Optical Device Evaluation Setup (Differential)

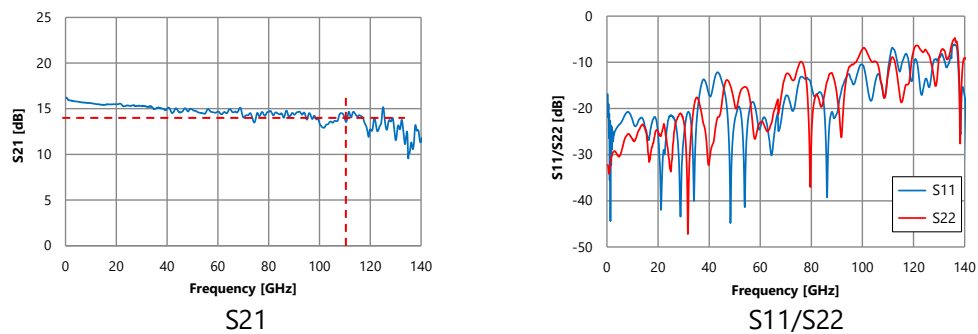


Figure 3 Frequency Response Characteristics (AH15203A)

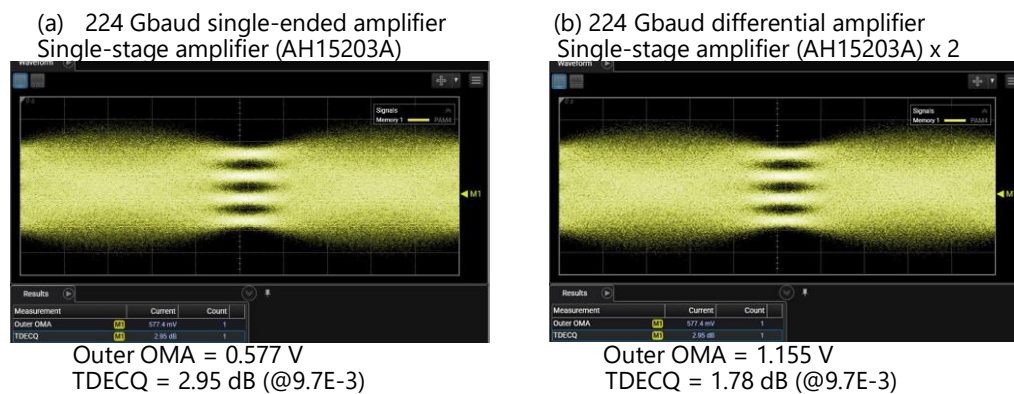


Fig. 4 Typical Output Waveforms (When Connected to AH15203A)

4 Optical Device Evaluation (2) – MZM

Driving an MZ modulator used for medium- to long-distance transmission requires a high-amplitude signal of 2.0 Vpp. Amplifying the output level (about 100 mVpp) of a 224 Gbaud PAM4 signal source (such as an AWG or DAC) to obtain an output signal of 2.0 Vpp or higher, requires a high gain of 23.5 dB or more. Figure 5 shows an example of cascading two AH15199B and AH15203A wideband linear amplifier stages (see Fig. 6 for S21 and S11/S22 characteristics) to obtain a gain of 23.5 dB. Figure 7 shows typical output waveforms; while the single-ended output amplitude is 1.00 Vpp, the differential configuration has an output amplitude of 2.00 Vpp-diff.

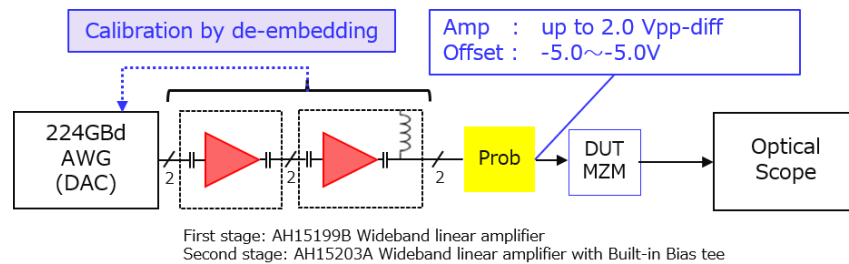


Fig. 5 Example of 2-stage External Amplifier Configuration for 224 Gbaud (differential)

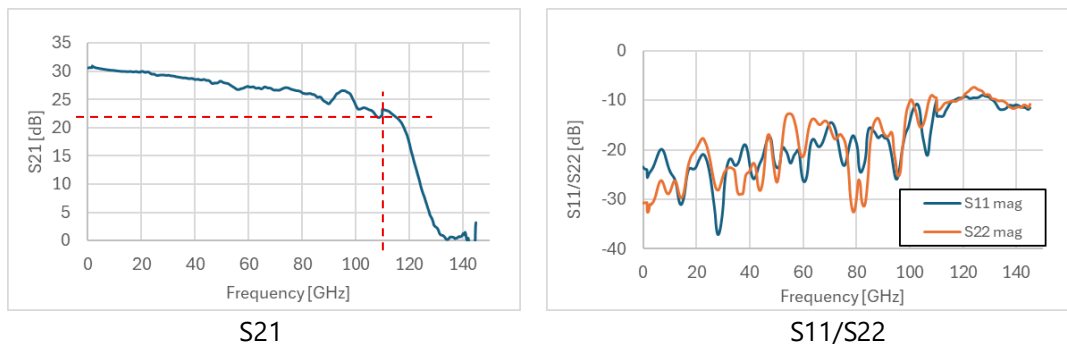
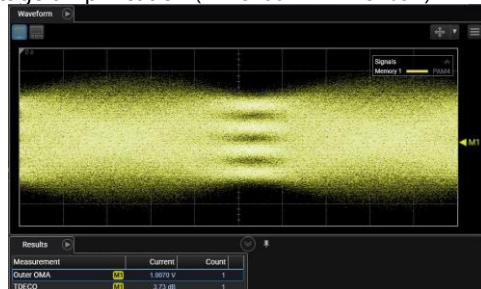


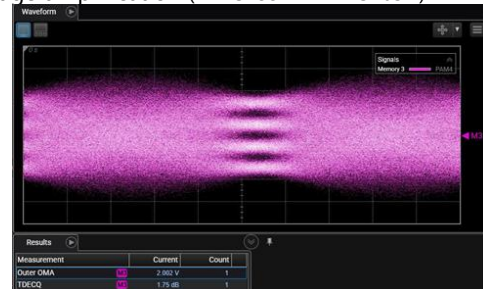
Fig. 6 Frequency Response Characteristics (AH15199B + AH15203A)

(a) 224 Gbaud single-ended
2-stage amplification (AH15199B + AH15203A)



Outer OMA = 1.00 V
TDECQ = 3.73 dB (@5.0E-2)

(b) 224 Gbaud differential
2-stage amplification (AH15199B + AH15203A) x 2



Outer OMA = 2.00 V
TDECQ = 1.75 dB (@5.0E-2)

Fig. 7 Typical Output Waveforms (AH15199B + AH15203A)

5 224 Gbaud PAM4 Optical Device Evaluation

As shown in Fig. 8, a 224 Gbaud PAM4 signal can be amplified to 1.0 Vpp by two wideband linear amplifiers configured as a cascade. Furthermore, a signal can be amplified to 2.0 Vpp-diff by using two 224 Gbaud PAM4 signal sources configured for differential signaling. Using a differential (2-line) configuration also improves TDECQ due to the improved SNR.

While both the AH15199B and AH15203A wideband linear amplifiers can be connected in a cascade, connecting the wideband linear amplifier (AH15203A) with built-in bias tee at the second stage is ideal for evaluating devices requiring output signal offset adjustment.

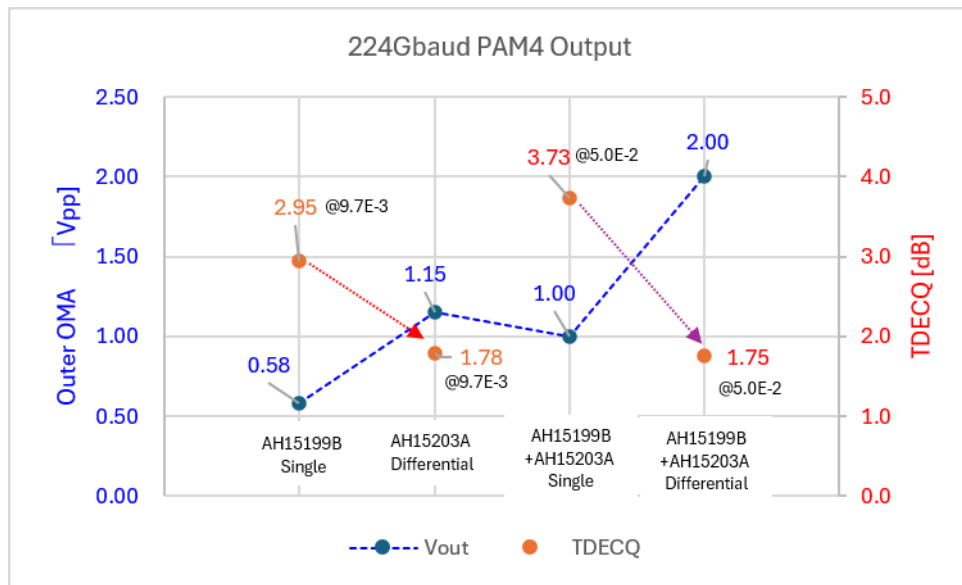


Fig. 8 224 Gbaud PAM4 Output

6 Summary

Evaluating optical devices for next-generation 448 Gbps (224 Gbaud PAM4) transmission entails meeting various requirements, such as high-amplitude signals of 2.0 Vpp. Anritsu's wideband linear amplifiers are ideal signal sources for evaluating optical devices exceeding 140 Gbaud. Anritsu state-of-the-art solutions continue to support customers' testing and evaluation needs.

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