OIF 400ZR and 800ZR Transmitter Quality Metric Measurements White Paper
OFC 2025 Plugfest

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ABSTRACT: The Optical Internetworking Forum (OIF) has standardized coherent optics at the physical layer, notably with the implementation agreements for 400ZR[11] and 800ZR[12]. A missing piece in the specifications is yet a standardized overall transmitter quality metric (TQM). While compliant receivers could easily handle all individual transmitter impairments within their respective specification limits, the combination of several impairments at their worst-case values poses an excessive penalty that may cause link failures. The development of a penalty-based metric called extended transmitter constellation closure (ETCC) is underway. This white paper describes a collective effort to capture a broad range of actual 400ZR and 800ZR waveforms intended to be used for validation and refinement of the ETCC methodology and the associated definition of a reference receiver.

1 Introduction

The Optical Internetworking Forum (OIF) drives the standardization of electrical, optical and management interfaces that enable efficient and reliable optical networks. It plays a crucial role in standardizing coherent optics at the physical layer. The 400ZR implementation agreement 11 is a key milestone for building an interoperable 400G ecosystem using dual-polarization (DP) 16QAM at approximately 60 Gbaud. With the 800ZR implementation agreement 12, the OIF made significant advancements, including a doubling of the symbol rate, creating interoperable 800G solutions. At OFC 2025, multi-vendor interoperability has been demonstrated for both 400ZR and 800ZR and further interoperability tests have been performed at a preceding plugfest, the results of which are discussed in 13 and 14.

In parallel to the OFC 2025 and the 400ZR/800ZR interoperability plugfest, additional measurements were made aiming to support work on a standardized transmitter quality metric (TQM). These measurements comprise waveform captures at the transmitter (Tx) output using an optical modulation analyzer (OMA). Similar 400ZR and 400ZR+ waveform captures from previous pre-OFC and pre-ECOC measurement plugfests garnered significant interest from the community and are utilized by OIF, IEEE and ITU-T for the development of a new TQM methodology called extended transmitter constellation closure (ETCC). This white paper details the test setup and procedure for a new set of waveform captures intended to support validation and refinement of the ETCC test methodology and the associated definition of a reference receiver. For the first time this includes 800ZR waveform captures. The complete dataset is available for downloading along with this white paper.

Overall, the goal is to provide confidence to network operators that multi-vendor ZR environments continue to exist, and high efficiency and high channel density can be achieved on their network.

2 Test Setup

The waveform captures are taken directly from the Tx output connected via a short fiber patchcord to the OMA, see Figure 1. The 400ZR and 800ZR modules respectively were inserted into a G800GE or AresONE Test System for module bring-up and configuration. Besides setting the transmission mode to the standard 400ZR or 800ZR modes, the Tx output power and channel frequency were set to -10 dBm and 193.7 THz for 400ZR and -2 dBm and 193.775 THz for 800ZR respectively. In addition, the 800ZR modules were set to transmit a framed PRBS31 data sequence using MediaSideGenerator enabled by CMIS configuration using Page 13h, byte 152, bit 0 to 1 and byte 156, bits 0 to 3 to 1.

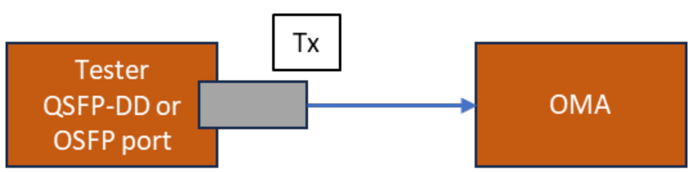

Figure 1: Test setup for direct Tx output captures with an optical modulation analyzer (OMA).

Two different OMA systems were used, the Keysight M8290A with an integrated coherent receiver (ICR) and CMOS-based analog-to-digital converter (ADC) chip for 400ZR, and the Keysight N4391C, a real-time oscilloscope (RTO) based OMA. Both systems are calibrated to minimize coherent receiver front-end impairments such as IQ angle, skews and gain imbalances.

To ensure calibration, test set-up, and measurement repeatability a pair of 800ZR transceivers was used as a control set. The control set units were independently measured and later retested to verify using two individual RTO-based OMA systems. The test system, and the setup was repeatable, and the calibration residuals were low enough to ensure reproducible test results.

For each transmitter under test (TUT), a total of 100,000 symbols were captured and stored as .mat file. The samples are stored in two complex vectors called "Y1" and "Y2", where the respective real and imaginary parts correspond to the I and Q paths of the dual-polarization coherent receiver connected to a pair of digitizers after applying the front-end correction factors and resampling. The variable "XDelta" gives the time difference between the samples and thus 1/XDelta corresponds to the sampling rate.

3 <u>Initial evaluation and consistency check</u>

A preliminary evaluation and data consistency check is performed using different methods. First, the waveforms were analyzed using the error vector magnitude (EVM) script available to OIF members via contribution oif2018.391.04 with different configurations and second using the Keysight OMA software that is running on both used OMA systems and can also be used standalone on a laptop. In the following sections the detailed settings and configurations and resulting EVM numbers are discussed and compared to the average rOSNR for each TUT reported in 13 and 14.

Initially, the settings of the EVM script from oif208.391.04 are following the description in Appendix C of Ref. [1] for 400ZR except for increasing the number of symbols to process from 50,000 to 100,000 to analyze the complete recording taken. For a second try, the noise loading is turned off by setting OSNR = Inf and as a third test, the number of equalizer taps is increased to numTaps = 45 and additionally, a receive filter is applied by setting receiveFilter = 'RootRaisedCosine' and receiveBt = 0.2. For 800ZR only the latter settings are used.

Symbol rates are set respectively to 59.84375 GBd for 400ZR and 118.20335 GBd for 800ZR. The reported EVM number corresponds to the average over 100 blocks, which each comprises 1,000 Symbols and both polarizations. Hence the full length of the recorded 100,000 symbols is taken into account. The normalization reference for EVM used is the maximum reference constellation point, hence it is demoted as EVM_{MAX}.

Using the Keysight OMA software, the following settings were used:

- Pre-processing algorithms:
    - Transmitter Phase Response Equalizer ***(used for 800ZR only)***
    - PolStokesAlign
    - Frequency Offset Compensation
- Custom IQ demodulator
    - Constellation: 16QAM
    - Result Length: 1000 Symbols
    - Measurement Filter: Root Raised Cosine
    - Reference Filter: Raised Cosine
    - Alpha/BT: 0.2

- Filter Length: 45
- Convergence: 5E-07
- Frequency Estimation: Normal

In case of 800ZR, it was found that for most of the TUT, the standard equalizer of the custom IQ demodulator does not converge and hence an additional "Transmitter Phase Response Equalizer" was added in the pre-processing. This equalizer was trained before any other processing steps and kept fixed for the remaining processing steps. For custom IQ equalizer training with the OMA software, the waveform recording was played back in loopback mode for approximately 1 min, then it was set to hold. Afterwards, the full recording was played back once from beginning to end for taking the average EVM over 100 blocks of 1000 Symbols.

4 Test results

Results for 400ZR TUT are shown in Table 1. It can be noted that all captured waveforms can be demodulated, which serves as a preliminary proof of the validity of the recording. Furthermore, it gives a good indication of the relative transmitter signal quality. Using the EVM script, the demodulation fails for several TUT (indicated in the tables as "No"), which is attributed to the equalizer implementation, the development of which has stopped end of 2019 before any 400ZR transmitter implementations became available.

Table 1: 400ZR TUT waveform validation using the EVM script (from oif2018.391.04) and the OMA SW for demodulation and EVM_{MAX} evaluation. For reference the Avg rOSNR from Ref. 13 is shown for the same TUT. "No" indicates demodulation failed.

400ZR TUT from Vendor	A	B	C	D	E	F	G	H	I	J
EVM_{MAX} [%] using EVM script according to Appendix C, Ref [1]	11.3	11.6	10.3	10.3	No	No	10.7	10.2	11.6	No
EVM_{MAX} [%] using EVM script with OSNR = Inf	10.6	10.9	9.6	9.6	No	No	10.0	9.5	10.9	No
EVM_{MAX} [%] using EVM script with more equalizer taps and RRC filter	8.7	9.2	8.0	7.4	No	No	8.5	7.8	No	No
EVM_{MAX} [%] using OMA SW	8.7	9.3	8.0	7.4	8.7	7.9	8.4	7.8	9.4	8.0
Avg rOSNR [dB] (from Ref. 13)	24.2	23.9	23.5	23.9	24.7	24.7	24.3	23.5	25.4	25.3

Table 2 shows the respective 800ZR TUT results. Analog to 400ZR, all captured waveforms can be demodulated and thus providing preliminary proof of recording validity and indicating relative transmitter signal quality. In this case signal demodulation with EVM script fails for all but one TUT and also with the OMA SW it was found that an additional equalizer step, as described further above, was required to obtain the results reported here. Vendor P was accidently missed during the transmitter measurement session.

Table 2: 800ZR TUT waveform validation using the EVM script (from oif2018.391.04) and the OMA SW for demodulation and EVM_{MAX} evaluation. For reference the Avg rOSNR from Ref. 14 is shown for the same TUT. "No" indicates demodulation failed.

800ZR TUT from Vendor	K	L	M	N	O	P	Q	R
EVM_{MAX} [%] using EVM script	No	8.7	No	No	No	N/A	No	No
EVM_{MAX} [%] using OMA SW	No	8.6	No	No	No	N/A	No	12.2
EVM_{MAX} [%] using OMA SW with additional Tx phase EQ	11.2	8.5	10.1	9.9	11.8	N/A	9.8	10.6
Avg rOSNR [dB] (from Ref. 14)	25.7	26.1	26.4	26.8	26.1	26.0	27.1	27.3

5 Summary

This white paper describes in detail the capturing of 400ZR and 800ZR Tx waveforms from a number of pluggables that participated in the OFC 2025 400ZR/800ZR interoperability plugfest. In addition to explaining the test setup and procedure, an initial evaluation and consistency check of the waveform captures is performed and discussed. This provides preliminary validity proof of the recordings as well as an initial indication of the relative transmitter signal quality.

The recoding files, which are available for download as *400ZR_Tx_Waveforms.zip* and *800ZR_Tx_Waveforms.zip*, are expected to be instrumental for further development, refinement and validation of ETCC methodology and the definition of the associated reference receiver.

6 Acknowledgement

We highly appreciate OIF and all participating module vendors for organization of and participation in the plugfest.

7 Participating Module Vendors

400ZR

Accelink
Ciena
Cisco
Coherent
Eoptolink
HG Genuine
Hisense
Juniper
Marvell
Precision Optical Technologies

800ZR

Accelink
Cisco
Coherent
HG Genuine
Hisense
Juniper
Marvell
Precision Optical Technologies

8 References

1. OIF, "OIF-400ZR-03.0 – Implementation Agreement 400ZR", *October 2024*
2. OIF, "OIF-800ZR-01.0 – Implementation Agreement 800ZR", *October 2024*
3. OIF, "OIF 400ZR Interoperability White Paper OFC 2025 Plugfest", *April 2025*
4. OIF, "OIF 800ZR Interoperability White Paper OFC 2025 Plugfest", *April 2025*

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About the OIF:

For more than 25 years, OIF has accelerated progressive transformation in optical networking by serving as the only global industry forum driving the electrical, optical and control interoperability that enables a more efficient and reliable network. Its active member ecosystem collaborates through a transparent and fast-paced process to develop, validate and publish Implementation Agreements (IAs) and technical white papers that are critical to accelerating market adoption of optical networking technologies.

Based on established methodologies including the documentation of industry requirements, bringing forward member-driven technical solutions, validation testing and free publishing, OIF's interoperability solutions are vital to the global network.

With more than 160 member companies spanning component suppliers to network operators, OIF members strive to identify the industry's needs and requirements and rapidly develop solutions that directly impact and facilitate global connectivity in the open network world.

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