

Development of MU104014B for DCI Coherent Transmission Quality Measurement

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[Summary]

Computationally intensive services such as generative AI are driving the need for larger data centers but limited building space in urban areas as well as the need to spread risk from large-scale disaster favors regionally distributed data center locations. Distributed Data Center Interconnects (DCI) are switching increasingly from conventional high-cost WDM lines to lower-cost 400ZR and OpenZR+ connections. Consequently, we have developed a network tester supporting 400ZR and OpenZR+ optical transmission quality measurements.

1 Introduction

Construction of data centers and metro networks is progressing rapidly, driven by factors such as generative AI, fast adoption of cloud services, and Digital Transformation (DX) promotion. In particular, extant data centers face difficulties in significantly increasing data processing capacity due to constraints on power supply and air-conditioning systems. Consequently, adding distributed data centers is an effective means to scale-up processing capacity, leading to increased demand for Data Center Interconnects (DCI) between different sites (Figure 1).

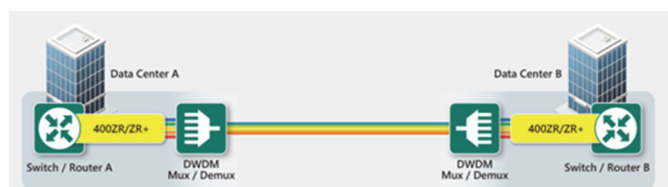


Figure 1 DCI Network

WDM lines owned by major telecommunications carriers have been used widely for DCI, but the high line usage fees are an issue. To cut costs, the OIF standards organization specifies installation of 400ZR-OIF pluggable coherent transceivers in routers and switches. Although 400ZR was intended for applications with transmission distances of less than 120 km, transmission beyond 120 km is achieved using the OpenZR+ standard resulting from combination with OpenROADM specifications (Table 1).

Table 1 400ZR vs OpenZR+

	400ZR	OpenZR+
Application	Edge DCI	Regional/Long-haul DCI
Standard	OIF 400ZR	OpenZR+ MSA
Client interface	400GbE	100 to 400GbE
Reach@400G	<120 km	>120 km
Line interface	400G	100/200/300/400G
SD-FEC	CFEC	OFEC
Maximum power consumption	<20 W	>20 W

Against this background, we developed the updated 400G (QSFP-DD) Multirate Module MU104014B for the MT1040A (Figure 2), which is a measurement instrument for evaluating various networks, including Ethernet, OTN, and CPRI. This module supports 400ZR and OpenZR+ transceivers and can evaluate optical transmission quality and 400 Gbps Ethernet transmissions. The MU104014B is based on the existing MU104014A supporting 400G Ethernet, and adds the following features:

- Effective cooling

Optical transceivers compatible with 400ZR and OpenZR+ have high power consumption and generate significant heat. Therefore, we enhanced the air cooling system and implemented measures to prevent failures caused by the heat generated by the optical transceivers themselves.

- Support for OpenZR+ optical transceivers

We enabled frequency-grid, output-wavelength, and output-power settings. The wavelength can be set by channel, frequency, or wavelength, according to the user's needs.

- Measurement of coherent transmission quality

We enabled reading of optical transmission quality results measured by optical transceivers, allowing time-series

display and storage.

- Evaluation of multiclient transmission qualities

OpenZR+ not only supports 400G Ethernet, but also enables 100G Ethernet multiplexed transmission. Therefore, we developed applications supporting 1×100, 2×100, and 4×100 Gbps.



Figure 2 MT1040A External view

2 MU104014B 400G (QSFP-DD) Multirate Module

In addition to an RJ45 interface, the MU104014B has electrical interfaces for various transceivers meeting SFP28, QSFP28, and QSFP-DD standards. It supports protocol tests for Ethernet (400GbE, 100GbE, 40GbE, 25GbE, 10GbE, 1GbE, 1000MbE, 100MbE, 10MbE), as well as for OTN, FC, and CPRI transport networks. Figure 3 shows the external view.

It also has a Sync Clock Out connector outputting a trigger signal for an external optical waveform sampling oscilloscope to monitor optical waveforms output from optical transceivers connected to various interfaces.

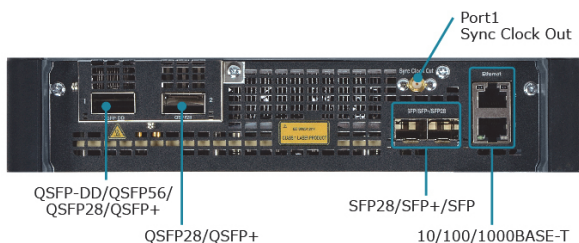


Figure 3 MU104014B External view

Two MU104014B modules can be installed in the MT1040A (Figure 4), for evaluating end-to-end bidirectional communications, and testing Network equipment's performance by connecting client side and line side to the module.

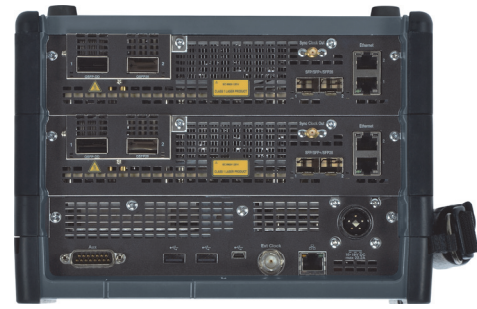


Figure 4 MU104014B Dual-module configuration

3 Hardware

As described earlier, 400GZR and OpenZR+ optical transceivers require high cooling performance due to their significant power consumption and heat generation. At the same time, since the MU104014B is used for on-site measurement targets, it must also be compact and quiet.

3.1 Target Performance

While OpenZR+ optical transceivers can generate more than 20 W of heat as mentioned in the previous section, they are still in the development stage, and the maximum power consumption has not been specified. Therefore, we set 23 W as the target based on datasheets for many OpenZR+ transceiver models and aimed for cooling performance that would not trigger temperature alarms even at an ambient temperature of 40°C.

The operating temperature in environments using OpenZR+, such as data centers, is expected to be 25°C or lower. However, some locations can become hot locally due to heat exhaust from equipment racks and other sources. To ensure sufficient margin in cooling performance even when used in such locations, we designed the system assuming an operating temperature environment of 40°C.

3.2 Increasing Cooling Efficiency

Optical transceiver cooling capacity depends on the QSFP-DD connector housing and the fan airflow volume. Since the MU104014B uses a stacked module configuration, fans cannot be installed on the back side. Therefore, we enlarged the heat sink on the housing upper surface and fan, and increased the fan rotation speed. These improvements, almost tripled the airflow compared to existing products, making it possible to sufficiently cool hotter Open ZR+ module across a wide ambient temperature range. Figure 5 shows the MU104014B cooling configuration.

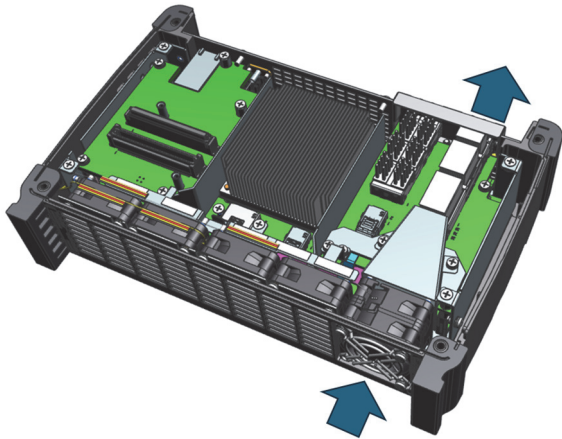


Figure 5 MU104014B Cooling configuration

3.3 Optimizing Fan Control

Increasing the fan maximum rotation speed as described in the previous section, increased the noise compared to existing products. Therefore, it was necessary to control and optimize the fan speed according to the optical transceiver temperature. However, feeding-back the readings from the optical-transceiver built-in temperature sensor to the fan control could destabilize temperature control.

Therefore, we added a dedicated sensor to monitor the MU104014B intake air temperature and achieved stable transceiver temperature and noise reduction by controlling the fan speed based on that temperature.

3.4 Testing Fan rpm and Transceiver Temperature

We investigated OpenZR+ temperature requirements and established the target temperature to 70°C. Controlling the fan speed based on ambient air temperature required investigating ambient air temperature and optical transceiver heat generation. For this purpose, we placed a QSFP-DD heat-generating module in MU104014B and monitored the temperature of the thermometer inside the heat-generating transceiver while in a 25°C constant-temperature chamber (Figure 6).

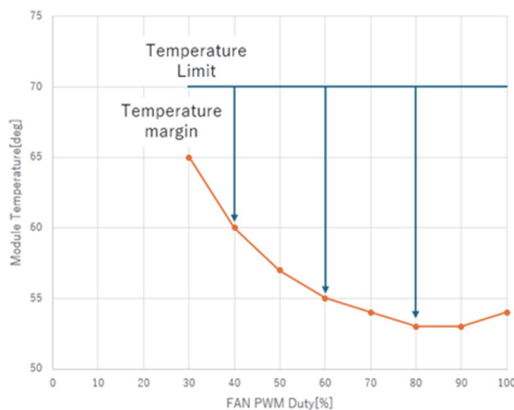


Figure 6 Fan rpm vs temperature margin

When the ambient air temperature rises by $\Delta^{\circ}\text{C}$, the above-described temperature margin decreases by $\Delta^{\circ}\text{C}$. We designed the fan control table so the fan speed is not increased more than necessary while ensuring the temperature margin does not reach zero (Figure 7).

The control table was designed with four fan speed modes: Low, Middle, High, and Extra. Each mode was controlled to change according to an external temperature threshold. We implemented hysteresis for the thresholds, so the higher-speed transition occurs at the temperature threshold $+2^{\circ}\text{C}$ and the lower-speed transition occurs at the temperature threshold -2°C . This prevents oscillations caused by small temperature changes.

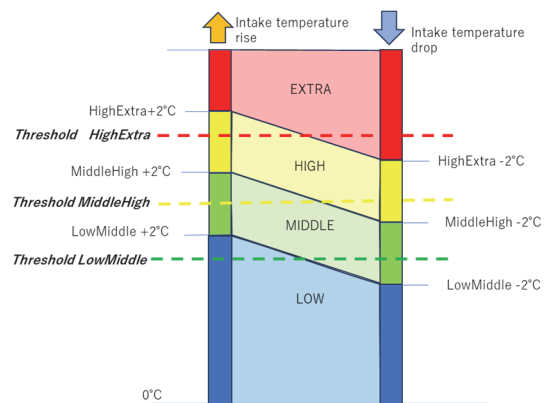


Figure 7 Fan control table

3.5 Safety Measures and Optimum Cooling Settings

Any deviations from the temperature model during the above-described verification risks damaging the optical transceiver due to insufficient cooling. Therefore, we designed a system to: monitor optical transceiver temperature alarms; power-down and shut-down the optical output at an alarm; and display a log of the temperature alarm occurrence.

Furthermore, we designed the system so that excess or deficient cooling caused by differences from the temperature model can be optimized to match the transceiver by providing a mode where users can switch the above-described fan speed modes manually.

3.6 Competitor Comparison

We inserted the QSFP-DD heat-generating transceiver, varied the ambient temperature, and compared the cooling performance using a competitor's measuring instrument. Since the competitor's instrument does not control the fan, the module temperature increased linearly versus outside

air temperature. In comparison, the MU104014B maintained a constant module temperature even in high-temperature environments due to the improved cooling efficiency and optimized fan control.

While current optical transceivers operate at appropriate temperatures using competing test instruments, the MU104014B demonstrate sufficient cooling capacity even with higher-power products.

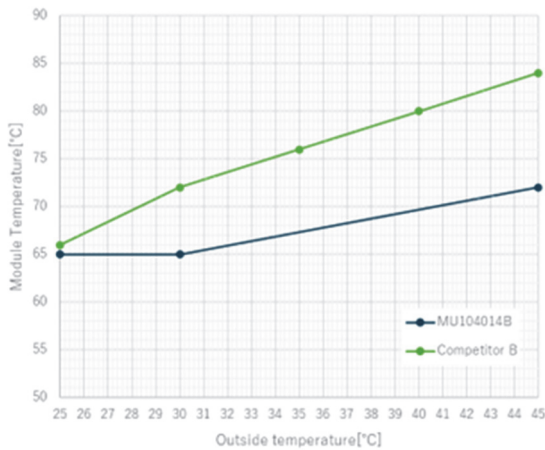


Figure 8 Module temperature vs ambient temperature

4 Additional MU104014B Functions

This section explains functions added to the MU104014B module to support OpenZR+.

4.1 Coherent Mode Setting

OpenZR+ transceivers support multiple applications, including 400ZR DWDM DP16QAM ZR applications, and ZR+ ZR400-OFEC-16QAM applications. When inserting and starting an optical transceiver, a number assigned to each application (APPSEL number) must be assigned to the transceiver. As a result, users must find the APPSEL number to activate up to 15 applications. For user convenience, we added a coherent mode setting allowing direct selection of 400ZR and OpenZR+ applications without knowing the APPSEL number (Figure 9).

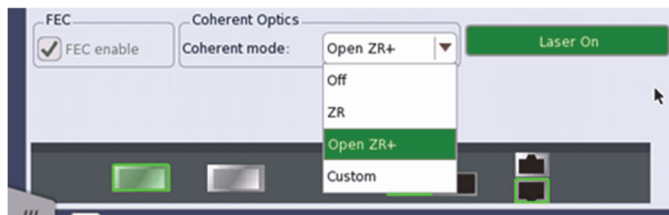


Figure 9 Coherent mode setting screen

Currently, 400ZR and OpenZR+ are the mainstream applications in use, and we have made it possible to select these

directly from a menu. Coherent transmission standards are still in the development stage, and vendor-specific implementations and new standard applications are also emerging, so we added a Custom mode setting to the menu for future-proof support. This Custom mode is designed to allow users to set the application to use while checking the contents of the transceiver applications in a list (Figure 10).

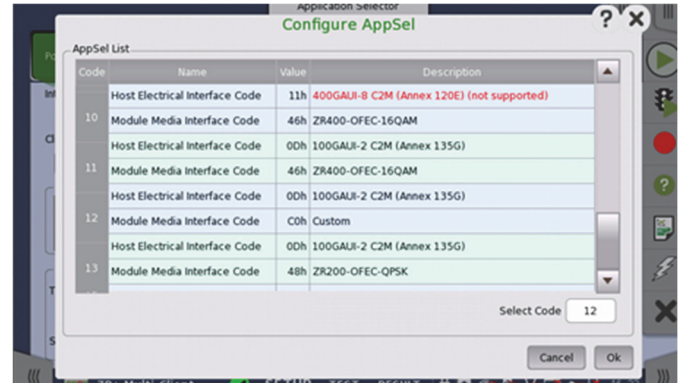


Figure 10 Custom application dialog

4.2 Tunable Settings

400ZR and OpenZR+ are used by setting wavelength and output power for connection to the WDM transmission equipment. The setting method is defined in the Common Management Interface Specification (CMIS), and can be changed by specifying the channel (offset) and grid from the 193.1-THz reference channel.

<Calculation Example (Frequency)>

When Grid = 75 GHz and Channel = 24

$$193.1 + (24 (\text{Channel}) \times 0.025 (\text{Grid})) = 193.7 \text{ THz}$$

On the other hand, since users often specify frequency or wavelength for transmission equipment, we added a screen (Figure 11) for three setting types: frequency, wavelength, and channel:

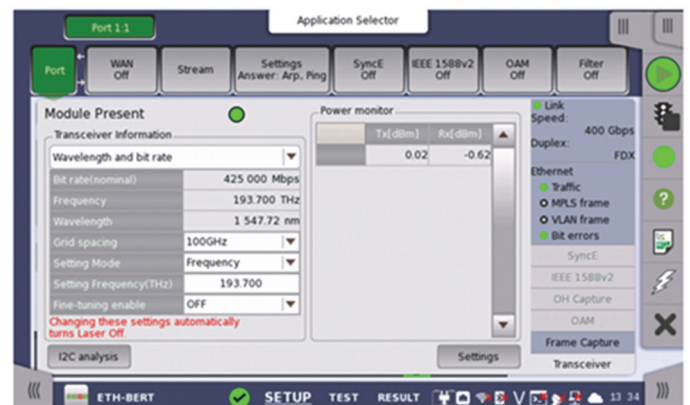


Figure 11 Output frequency (wavelength) setting screen

4.3 Measuring Coherent Transmission Quality

The MU104014B captures the following internal data from 400ZR and OpenZR+ transceivers for on-screen display.

- Rx bits, Rx frames
- Tx power, Rx power
- OSNR (Optical Signal to Noise Ratio)
- PreFEC BER (Uncorr. Frames)

Capturing information from the transceiver at minimum intervals of 1 second and logging it as measurement results confirms the relationship between the throughput of the 400GbE client signal and coherent-signal polarization or power variations. Additionally, exporting results to a CSV file facilitates detailed offline analysis, such as trend analysis.

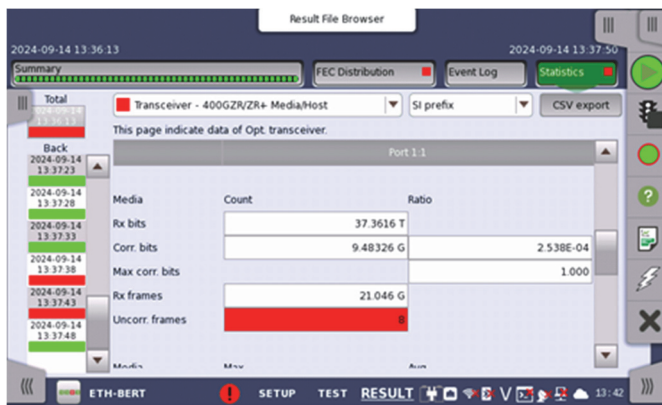


Figure 12 Measurement results screen

4.4 Technical Challenges Supporting 400ZR and OpenZR+

Multiple register operations must be performed in a specific sequence for 400ZR and OpenZR+ startup and tunable settings. Although these should work if configured according to the procedures described in the CMIS specification, the following problems have occurred due to differences between manufacturers and CMIS versions.

- Differences in waiting time after register operations
- Manufacturer-specific additional settings
- Differences in startup procedures depending on CMIS versions

We confirmed the detailed specifications for manufacturer-specific operation with the manufacturers and incorporated them so as not to cause problems with the standard CMIS procedures. For different processes depending on versions, we established a system to switch configuration procedures after reading the transceiver supported version. This

enabled consistent operation even with transceivers from different manufacturers or with different versions.

5 Multi-Client Application Support

In addition to the MT1040A 400G Ethernet application, we developed the OpenZR+ Multi-Client BERT MU104014B-036 option, which evaluates multiplexed 100G Ethernet transmissions by adding a software license. In addition to 400GbE measurements, this application adds client mode settings for selecting 100GbE multiplexing.

While 400ZR transceivers only transmit 400GbE, OpenZR+ transceivers can not only transmit 400GbE but can also multiplex multiple 100GbE signals. Each of these transmitted signals is called a client, and multiple 100GbE clients are independent of each other. The OpenZR+ Multi-Client BERT application can select 4×100 GbE, 2×100 GbE, or 1×100 GbE client modes, and can configure and measure each 100GbE client individually. Displaying the number of client ports corresponding to the selected client mode makes it easier to identify the current configuration.

Also, since the types of supported client modes vary depending on the OpenZR+ transceiver, on-screen indications display which client modes are supported by the currently installed transceiver, making client mode configuration easier.

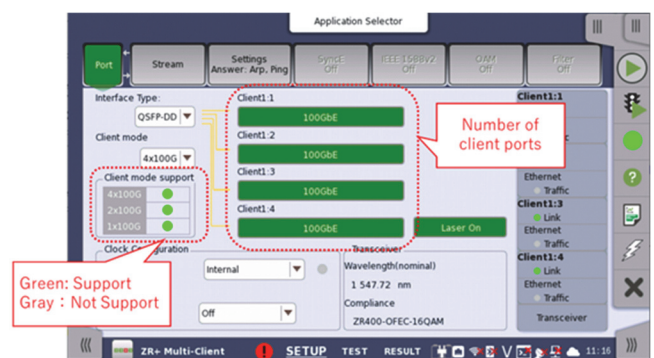


Figure 13 Multi-Client application

6 Automated rOSNR Test System using MU104014B Module and MS9740B

Development of the MU104014B module facilitated configuration of a system to automatically measure the required Optical Signal-to-Noise Ratio (rOSNR) of 400ZR and OpenZR+ transceivers.

This system uses an Amplified Spontaneous Emission (ASE) light source as the noise source, and the amount of

noise is adjusted by a variable optical attenuator. An ASE light source amplifies and emits spontaneously emitted light, and can be used to evaluate how systems and components perform in the presence of noise because it has broadband, low-coherence characteristics.

The rOSNR is measured by monitoring the Pre-FEC BER values of the 400ZR and OpenZR+ transceivers inserted into the MU104014B, and the OSNR values received by the Optical Spectrum Analyzer MS9740. To determine the OSNR precisely, the optical attenuator is adjusted while monitoring the measured values from the MU104014B and MS9740B.

This can be utilized by users examining multi-vendor connections, as well as by users with single-vendor setups, for verifying connectivity between transceivers with different revisions and for quantitative evaluation of transmission resilience for each transmission channel.

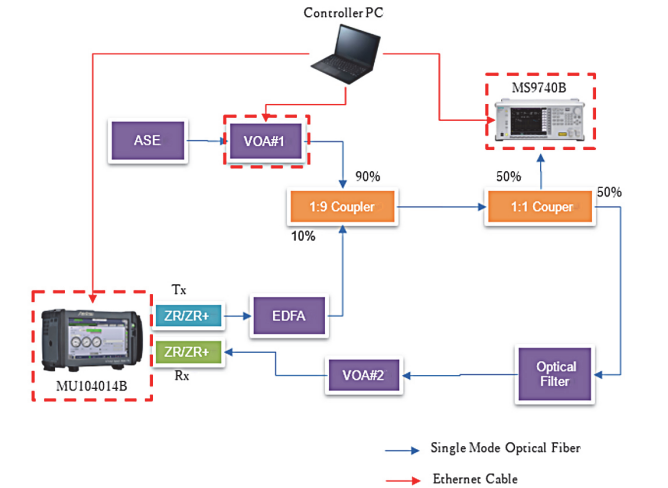


Figure 14 rOSNR Test system setup

7 Conclusions

We have developed test equipment for evaluating 400ZR and OpenZR+ transceivers being adopted for connections between distributed data centers. 400ZR and OpenZR+ are transitioning from the verification to the operational phase, and this test equipment is being utilized by various companies for network deployment and verification.

Anritsu is continuing to contribute to improving the quality of future network evolution.

References

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