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200 Gbit/s OTN Optical Transmission Device with Line Protection Capability

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With the launch of 5G services and AI applications, the amount of data flowing into networks is increasing. While network devices are required to have higher bandwidth, they are also required to be smaller and denser due to limited installation space in urban areas. We have developed a small 200G OTN optical transmission device to improve the accommodation efficiency. This device uses digital coherent optics to achieve long-distance and high-density transmission through wavelength multiplexing. This paper reports the transmission distance and the traffic restoration time in line protection using the device.

Keywords: optical transport network (OTN), optical transmission device, metro network, data center interconnect

1. Introduction

Against the backdrop of the recent proliferation of 5G, use of artificial intelligence (AI), and accelerating digital transformation (DX), network traffic volume is ever increasing. Bandwidth shortage is a challenge to all networks. Networks include metro networks that connect carriers' central offices to business users' buildings and also store data from local subscribers, as well as Data Center Interconnects (DCIs) that mutually connect data centers. These facilities face the need for miniaturization and higher density due to spatial restrictions, as well as for capacity enhancements.

To meet the demand, Sumitomo Electric Industries, Ltd. has developed an optical transmission device, which is small, capable of high-density accommodation, and usable for metro networks and DCIs. This optical transmission device with a small enclosure is in a one rack unit (1 RU) size and has slots, allowing line cards capable of handling up to 200 Gbps to be inserted into two slots. Moreover, the device can be combined with an optical switch module in a 1 RU size, enabling 1.6 Tbps dense wavelength-division multiplexing (DWDM)*1 transmission over long distances to be implemented in a 5 RU size using up to eight wavelengths.

In the present study, the optical transmission device developed by Sumitomo Electric was used to construct line protection predicated on line-segment fiber errors. The transmission performance and traffic restoration time of the line protection were measured and evaluated. The instantaneous interruption of this system at the moment of protection switching was 3 ms long when manually triggered by an operator and 35 to 45 ms when triggered by a fiber error. With the use of an optical amplifier, the optical transmission device proved itself to be able to receive signals at −40.9 dBm when handling 100 Gbps or at −32.0 dBm when handling 200 Gbps and usable for transmission over a distance of 80 km as described in this report.

2. Device Requirements

Figure 1 outlines a present-day network architecture.

Networks are roughly divided into core networks connecting between nationwide urban areas, metro networks that cover areas such as prefectural and urban areas, fiber-to-the-home (FTTH) networks, and leased lines for businesses and other access networks that accommodate subscribers. In recent years, the required bandwidth of DCIs has grown substantially owing to diverse user services, including the use of AI. The volume of the total download traffic on broadband access networks has roughly doubled in two years.(1) Accordingly, metro networks that handle the traffic have been facing the need to enhance the capacity.

In response to this need, the transmission device adopted optical transport network (OTN)*2 widely used on metro networks and was designed to support two modes of transmission rate, 100 Gbps and 200 Gbps. In addition, by employing wavelength-variable digital coherent optics (DCO)*3 at line ports, the transmission device makes long-distance transmission possible for 80 km or more

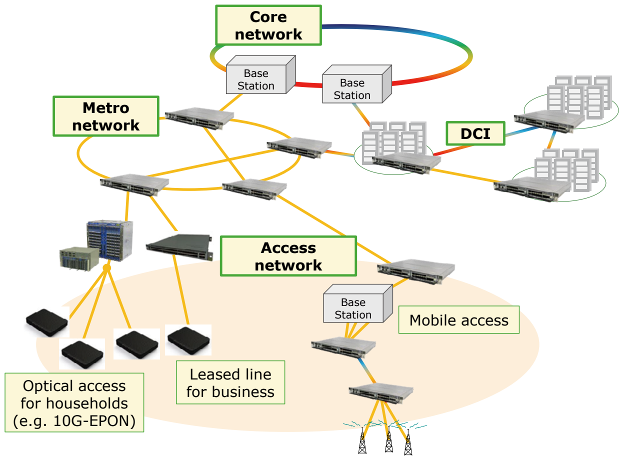

Fig. 1. Outline of network configuration

using wavelength-division multiplexing (WDM) as required on metro networks and DCIs.

Device sizes should desirably be small. Moreover, as the required bandwidth has increased and user services have changed, shorter delivery schedules for system expansion and versatile system configurations are demanded. Therefore, the present optical transmission device adopted a 1 RU slot system. This system enables the operator to cope with the need for different transmission technologies and a quantity of ports simply by installing the required number of enclosures and then replacing units with the enclosures intact. Thus, the optical transmission device will flexibly support future larger-capacity transmission technologies and changes in the services handled.

3. Optical Transmission Device

3-1 Device configuration

Figure 2 illustrates the exterior of the enclosure of Sumitomo Electric's optical transmission device. Table 1 shows the enclosure specifications.

The enclosure of the transmission device has one control slot to mount a control unit and four line slots to mount line units. The enclosure also employs a slot system for its main assembly control block, enabling the control unit to be replaced with one equipped with a device control interface to meet specific purposes. The line slots are configured to mount up to four units. Unit sizes can be selected according to specific line unit size requirements. These features make it possible to flexibly support different optical transceivers and quantities of ports varying with specific applications and communication modes.

Entire enclosure

Front (control unit × 1 and OTN units × 2 mounted)

Fig. 2. Enclosure exterior

Table 1. Enclosure specifications

Parameter	Specification	
Device size	Enclosure (1 RU of 19-inch rack) 440(W) × 450(D) × 44(H) mm † Projections not included	
Slot configuration	Control	One slot
	Line	Four slots
Power supply	48 V DC or 100 V AC Line protection/Unitary type	
Air-cooling method	Forced air cooling with a fan	
Maintenance port	† See the control unit specifications.	

Table 2 lists control unit specifications. This control unit has two management secure shell (SSH) ports for connection to a monitoring and control network and one serial port for direct connection to a control terminal device. Additionally, it has an interface connecting to an external device, i.e., an SD card slot for storage purposes.

Table 2. Control unit specifications

Parameter	Specification	
Unit size	82.6(W) × 200(D) × 37.5(H) mm † Projections not included	
Power supply	DC 48 V	
Maintenance port	Management (SSH)	Two RJ45 ports
	Serial port [command line interface (CLI)]	One RJ45 port
	Storage	One SD card port

Figure 3 shows the exterior of the OTN line unit. Table 3 lists its specifications. The line port of this line unit has a C-form factor pluggable 2 (CFP2) cage installed and allows for the use of leading-edge DCO. The client port has small form factor pluggable plus (SFP+) and quadrature small form factor pluggable 28 (QSFP28) cages installed. To mount these cages, the size of the line unit equals two line slots of the enclosure. Client signals are

Fig. 3. Exterior of OTN line unit

Table 3. Specifications for OTN line unit

Parameter	Specification	
Unit size	175.2(W) × 200(D) × 37.5(H) mm Line slots: Two slots occupied † Projections not included	
Power supply	DC 48 V	
Maximum rate handled	100 Gbps or 200 Gbps	
Line port	Number of ports	One CFP2 port
	Transmission rate	100 Gbps or 200 Gbps
	Interface	OTU4
	Transceiver	Supports DCO, tunable C-band, and 50 GHz ITU-T grid
Client port	Number of ports	10 SFP+ ports
		Two QSFP28 ports
	Transmission rate	SFP+ 10 Gbps
		QSFP28 100 Gbps
	Interface	10GE, 25GE, 100GE CPRI*4, eCPRI
Power consumption	100 W or less	
Delay	25 μs or less (one way during 10GE aggregation)	

merged into OTN signals of the line port. A single unit provides the functionality of a transponder and a muxponder, allowing for merging-pattern settings.

Table 4 presents specifications for the monitoring and maintenance software installed in the optical transmission device. This software has distinctive maintenance and operation functions, such as OpenConfig, in-service software update, and zero-touch provisioning. OpenConfig is a common programmable interface, which is independent of network device manufacturers, with an eye to network virtualization. The in-service software update enables updating software (the operation system and applications) with no impact on main signal services. Zero-touch provisioning, when installing a device, automatically incorporates the device setting data provided in advance by the administrator.

Table 4. Software specifications

Parameter	Specification
Connection method	Telnet, SSH
Management function	CLI, SNMPv2c/v3, NETCONF/YANG, OpenConfig, RMON (Remote networking Monitoring), In-service software update Zero-touch provisioning Log management In-channel remote maintenance
Monitoring function	Link loss forwarding, failure detection, and alarm generation
Maintenance function	Channel test

Figure 4 shows a front view of the optical switch used in combination with the optical transmission device. The 1 RU enclosure of the optical switch can accommodate 0.5 RU units equal to up to eight slots. Units include optical switch, DWDM mux, DWDM demux, and optical amplifier units. It is possible to set up services combining these units according to specific uses.

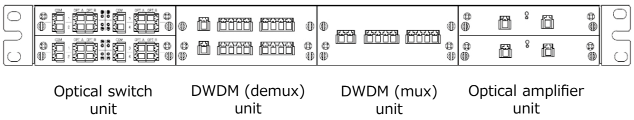

Fig. 4. Optical switch front view

The optical switch unit is a 0.5 RU size unit, which has four ports of two-input/one-output optical switches. By occupying two slots, top and bottom, the optical switch units can be used as an eight-wavelength optical switch. The optical switch supports manual switching by an operator and automatic switching triggered by an interruption of optical input. The DWDM mux unit is an eight-wavelength input/two-output unit, which splits eight-wavelength signals into two and then outputs their respective wavelength-division multiplexed optical signals. Line protection can be achieved by transmitting these signals along different fiber paths as service signals and backup signals. The DWDM demux unit has two sets of one-input/eight-wavelength-output DWDM couplers, which respectively extract WDM signals from the service and backup lines for each wavelength. The 0.5 RU size optical amplifier unit uses one port of erbium-doped fiber amplifier (EDFA).*5

3-2 Example system configuration

Figure 5 illustrates an example system configuration consisting of the optical transmission device and the optical switch.

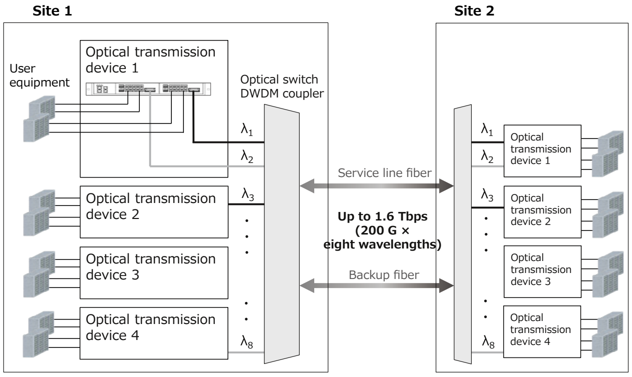

Fig. 5. System configuration

This example configuration shows four optical transmission devices (eight line units in total) and one optical switch installed at each site. The client port of each line unit connects to user equipment, merging client signals into OTN line signals at 200 Gbps at the maximum. Different wavelengths are assigned to the line signals of individual line units. These signals are wavelength-division multiplexed by the DWDM coupler of the optical switch. Wavelength-division multiplexed line signals are transmitted through two transmission paths, i.e., the service and backup lines. Both the optical transmission device and optical switch are of 1 RU size, enabling 1.6 Tbps transmission at the maximum between sites only in a 5 RU space.

The site on the other end receives line signals through both service and backup lines and amplifies the optical signals by an optical amplifier. The amplified line signals are divided by the DWDM coupler into OTN signals for wavelength-specific line units. Regarding the divided line signals, it is possible for all wavelengths to select which signals to receive, the service line or the backup line, using the optical switch. When the power of the signals received through the service line is normal, the service line is selected for reception. If the power of the signals received through the service line is identified to be abnormal due to, for example, an error in the fiber segment between the sites, the optical switch changes over to the backup line for reception. The optical switch can also be manually operated by an operator for reasons such as transmission path work or maintenance.

4. Evaluation

4-1 Transmission distances

Figure 6 shows the configuration of the transmission evaluation system. Table 5 presents a level diagram. The evaluation system consists of four optical transmission devices for DWDM transmission using eight wavelengths (λ1 to λ8 = 1546.92 to 1552.52 nm, 100 GHz grid). The figure depicts only one-way optical lines from the optical transmission device on the left (transmit block) to the optical transmission device on the right (receive block). A CFP2-DCO was used for the transmission between the line ports with a budget of 30 dB in 100G mode and 24 dB in 200G mode. To compensate for loss of 7.7 dB incurred by the optical switch module (on the other end) and a target optical fiber loss of 24 dB, an optical amplifier with a gain of 14.5 dB was used. An optical fiber loss of 24 dB translates to 80 km at a rate of 0.3 dB/km. When the transmitter power of the optical transmission device is 0.0 dBm, the input power of each wavelength at the optical amplifier will be −28.5 dBm, and the receiver power of the optical transmission device on the other end will be −17.2 dBm. It is necessary to receive signals at a reception error ratio of 10^{-2} or less (before error correction). The evaluation assessed the reception error ratio (before error correction) of the receive block while varying the input power to the optical amplifier with a variable optical attenuator (VOA).

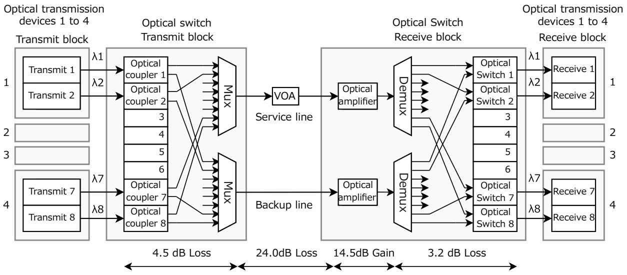

Fig. 6. Transmission evaluation system configuration

Table 5. Optical Power Level Diagram

Parameter	Optical Transmission device Transmit block	Optical Switch Transmit block	Optical fiber	Optical switch Receive block	Optical Transmission device Receive block
Loss (dB)	-	4.5	24.0	−14.5 +3.2	-
Power (dBm)	0.0	−4.5	−28.5	−17.2	−17.2

With optical fibers, 24.0 dB translates to 80 km.
For the receive block of the optical switch, −14.5 dB is the gain of the optical amplifier.

Figures 7 and 8 illustrate reception characteristics in 100G and 200G modes, respectively, depicting the relationships between the input power of the optical amplifier and the reception error ratio (before error correction). At an error ratio of 10^{-2}, the optical amplifier input power was −40.9 dBm in 100G mode and −34.0 dBm in 200G mode. Thus, exhibiting reception characteristics with a wide margin relative to the target of −28.5 dBm, the optical transmission device proved itself to be usable for 80 km transmission. Moreover, in 100G mode, the optical transmission device exhibited a margin of 4.4 dB even against an optical fiber loss of 33 dB (translating to 110 km).

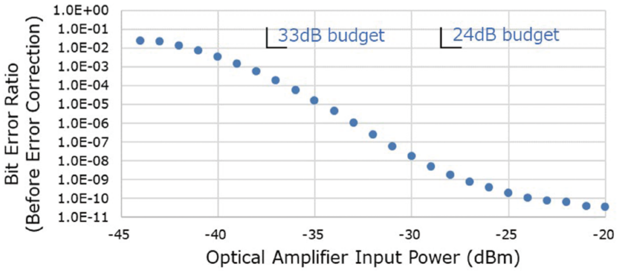

Fig. 7. 100G reception error ratio characteristics (before error correction)

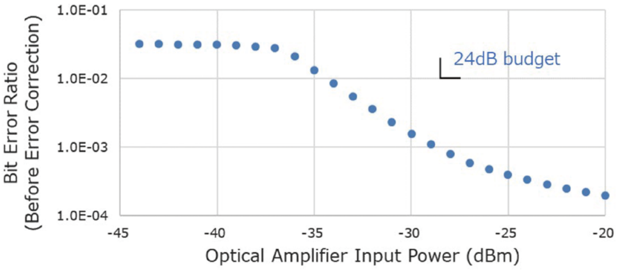

Fig. 8. 200G reception error ratio characteristics (before error correction)

4-2 Line protection performance

Figure 9 shows the configuration used to evaluate line protection performance. One optical transmission device and one optical switch were installed at each site. Using two line units, two-wavelength WDM transmission and a backup line for the line segment were formed. Line signals were transmitted in 100G OTN mode. As client signals, each line unit handled two types of test traffic, 100GE and 10GE. The service line fiber had an optical error generator inserted to simulate fiber errors.

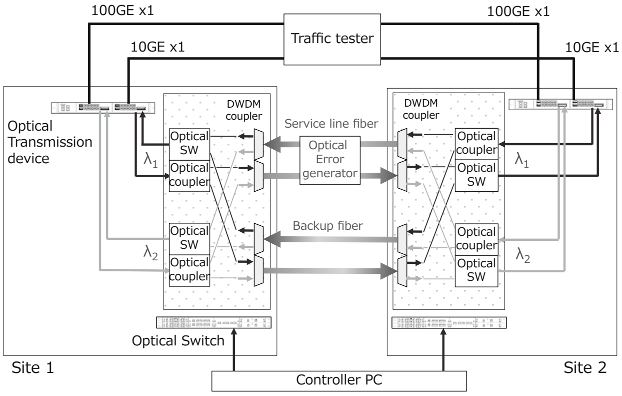

Fig. 9. Measurement system for line protection performance

As a measure of line protection performance, the evaluation used the instantaneous interruption recovery time of the client signal as determined by a traffic tester. For this performance measurement, the target value was set to 50 ms as required by ITU-T G.873.1.(2) Protection switching triggered by a fiber error generated by the optical error generator and those manually triggered by the optical switch via a controller PC were measured.

The measurement results are shown in Table 6. The results of protection switching triggered by a fiber error varied in each test instance, whereas in all test instances, the results remained within the range of 35 to 45 ms. In all test instances of manual switching, switching were completed within 3 ms. Thus, the target value of 50 ms was achieved.

Table 6. Measurement results for instantaneous interruption recovery time

Interruption triggered by fiber error	35~45 ms
Manually triggered interruption	3 ms

5. Conclusion

This report described the development of an optical transmission device with a small enclosure, capable of high-density accommodation by means of WDM for metro networks. In line protection, the optical transmission device was measured for its transmission distances and line protection performance. It proved itself to be usable for long-distance transmission for 80 km or more and able to perform fiber switching with 50 ms or less instantaneous interruption.

The enclosure of the optical transmission device has slots, into which line units designed to various protocols can be mounted according to specific applications. The task ahead is to explore the possibilities of a unit with enhanced capacity and a unit that can handle different client signals to meet future needs.

Technical Terms

*1 Dense wavelength-division multiplexing (DWDM): WDM is the method to send multiple signals with different wavelengths through a single optical fiber. Dense WDM is the method that improves multiplexing by narrowing the wavelength spacing of the light.

*2 Optical transport network (OTN): A transmission protocol that can aggregate client signals to a higher-rate signal by time-division multiplexing. Time-division multiplexing assigns fixed time slots to individual client signals, avoiding congestion and guaranteeing bandwidth and delay on a client-by-client basis.

*3 Digital coherent optics (DCO): Optical transceivers for coherent communications using digital signal processing; DCO carries out digital signal processing to demodulate electrical signals generated from the interference between optical signals and local oscillation light.

*4 Common public radio interface (CPRI): A communication standard used to establish connection between the base band unit and remote radio head of a wireless base station.

*5 Erbium-doped fiber amplifier (EDFA): An EDFA directly amplifies an optical signal by stimulated emission with high amplification efficiency.

References

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(2) Recommendation ITU-T G.873.1 (2017), Optical transport network: Linear protection

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