MESHED SUBMARINE CABLE NETWORK WITH OADM TECHNOLOGY

Takanori Inoue, Ryuji Aida, Yoshiro Sato, Shigehisa Sugiyama, Katsuji Yamaguchi and Takaaki Ogata (NEC Corporation)

Email: <t-inoue@jm.jp.nec.com>
NEC Corporation, 34-6, Shiba 5-chome, Minato-ku, Tokyo, 108-0014, Japan

Abstract: This paper describes our study on meshed submarine networks with the application of the latest OADM technologies in the wet plant, which achieves high-flexibility and high-reliability. We have also demonstrated the non-interrupted transmission under cable failure condition with 6,800 km straight transmission experiment.

1. INTRODUCTION

The OADM (Optical Add/Drop Multiplexing) scheme was first introduced to the 2.5 Gbps WDM (Wavelength Division Multiplexing) submarine systems in mid-1990s, in order to economically branch a few channels for local stations. This scheme has been revived in the last few years for the latest 10 Gbps DWDM system as one of the “wavelength pass-through” methodologies bypassing intermediate local stations, which can also contribute in reducing the latency compared with the non-OADM systems.

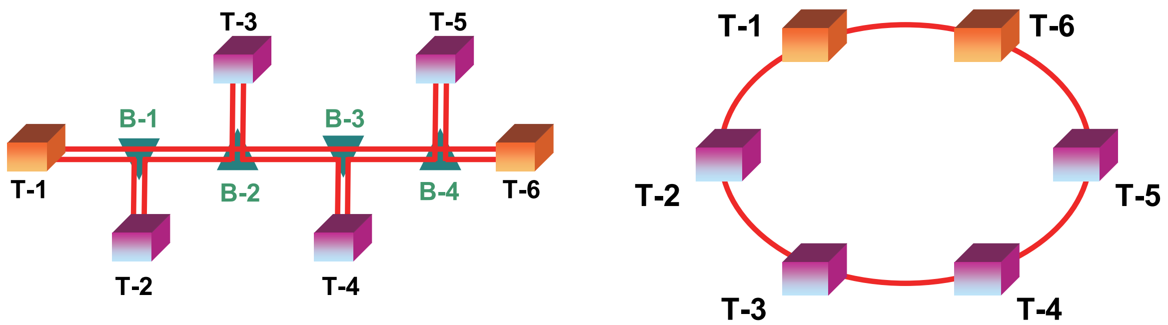
This paper describes our study on meshed submarine networks with the application of the latest OADM technologies, including experimental demonstrations with 6,800 km of straight line. Although some papers have reported the transmission of the OADM system with a re-circulating loop experiment [1], we believe there is a few straight line experiments ever performed.

2. MESHED SUBMARINE NETWORK

The technologies for optical filtering and optical line design have improved significantly as well as the equipment performance since the first OADM system deployed. The incorporation of OADM BUs (Branching Units) into the 10 Gbps DWDM submarine networks has advantages over conventional BUs, because it can offer very cost-effective and flexible network configurations against various traffic demand patterns. This architecture enables us to share the DWDM traffic on the same fiber pair not only between the high capacity trunk nodes, but also between the trunk and branch nodes, or between the intermediate branch nodes.

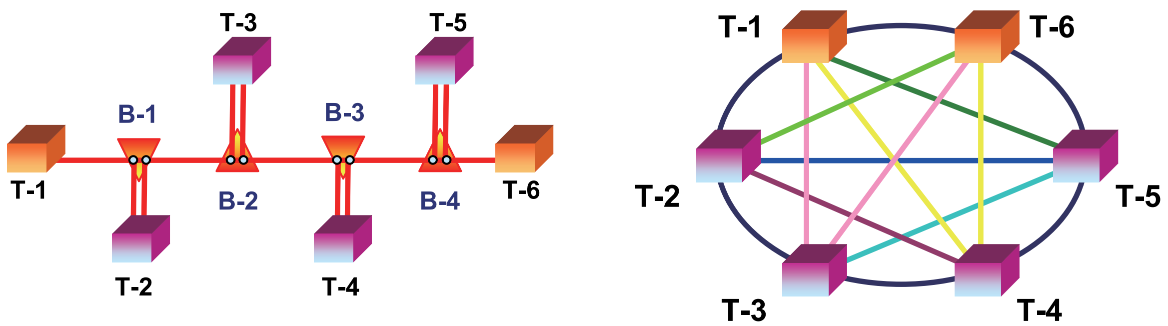
Figure 1 and Figure 2 show typical configurations of a conventional branching system and an OADM branching system respectively. In the conventional branching system, each branching nodes (T2, T3, T4 and T5) communicates to a single neighbouring node only, forming a ring network logically. On the other hand, all nodes are able to communicate among each other in the OADM system, realizing a logical meshed network.

In submarine cable systems, the OADM function is realized not on the wavelength-by-wavelength, but on the sub-band basis. It means that the entire transmission bandwidth is divided into an express sub-band and one or more add/drop sub-bands. For example, two sub-band and four sub-bands are required to achieve fully meshed network with one and two branch nodes respectively. In the same manner, Nx2+α sub-bands are required with N branch nodes.



(a) Physical Path (b) Logical Path

Figure 1: Configuration of a Conventional Branching System



(a) Physical Path (b) Logical Path

Figure 2: Configuration of an OADM Branching System

3. OADM TECHNOLOGIES

3.1. ADD/DROP FUNCTION

Submarine cable systems require extremely high reliability in order to realize 25 years of system life. Because the OADM function is implemented in a submersible BU (Branching Unit) [2], its configuration should be simplified as much as possible.

Our OADM BU design employs optical couplers and band-pass / high-pass / low-pass optical filters, permitting to add/drop a set of wavelengths (sub-band). A typical example of an OADM BU with optical band pass filter is shown in Figure 3.

Incoming signals from the trunk fiber are first split into two by an optical coupler. While the drop side signals are directly connected to the branch fiber, trunk side pass-through signals are selected by an optical filter. Incoming signals from the branch fiber are filtered removing unnecessary sub-band, and then combined with the pass-through traffic.

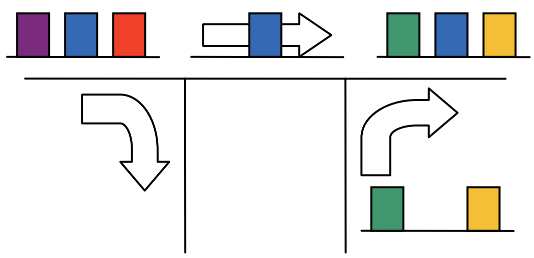


Figure 3: Example of OADM BU

3.2. PROVISION FOR CABLE FAILURE

In the OADM system, a cable failure would affect the transmission performance of survived signals since a single fiber pair is shared by multiple sub-bands carrying traffic signals from different locations. Absence of some sub-bands would induce an increase of the channel power of the survived signals, because the output power of repeaters are constant and the gain flatness is lost due to SHB (Spectral Hole Burning) [3,4].

If some repeaters exist between the BU and failure point, ASE (Amplified Spontaneous Emission) noise generated from repeaters is supplied to the BU and combined with survived signals instead of the missing sub-band, maintaining the channel power and gain flatness of the survived signals. However, if cable failure occurs at the proximity of the BU and no repeater exists between the BU and the failure point, the transmission performance of the survived signals would degrade significantly.

In order to achieve the highest availability under all types of cable failures, we have introduced new functionalities in the system. One is the addition of optical amplifiers in the BU. Since each BU has its own optical amplifier, ASE noise generated by this amplifier contributes to maintain the channel power of the survived signals. The other is the insertion of sub-band CW tones from the SLTE [5]. If a cable failure occurs, all terminals inform of their received signal condition to a centralized management system which analyzes the information and controls the CW tone signals. Then, CW tone signals are inserted at the relevant SLTEs in order to maintain the channel power of the survived signals automatically.

4. DEMONSTRATION OF OADM SYSTEM

We have successfully demonstrated our OADM features with 6,800 km of straight line. Figure 4 shows a demonstration setup. The trunk line consists of 43 km-long NZDSF (Non-Zero Dispersion Shifted Fiber) spans and 158 optical amplifiers, with total fiber length of 6,800 km. The branch line consists of 43 km-long spans and 20 repeaters, with total fiber length of 860 km. The OADM BU functional block is positioned in the middle of the trunk line. In order to simulate a

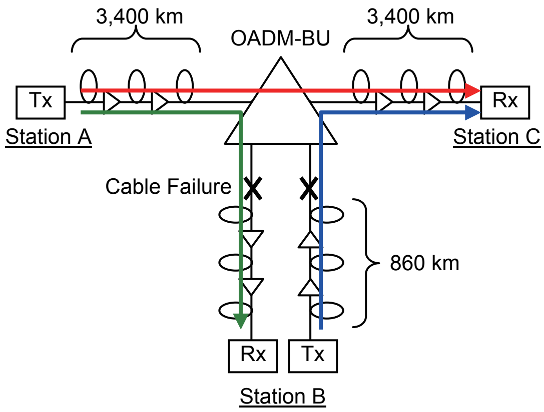
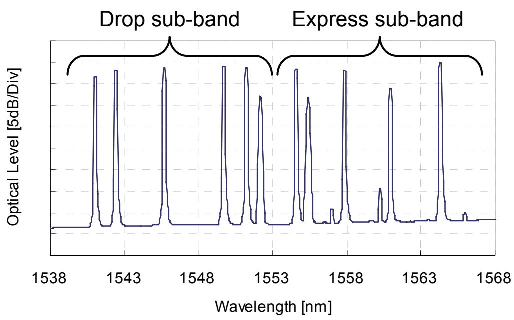


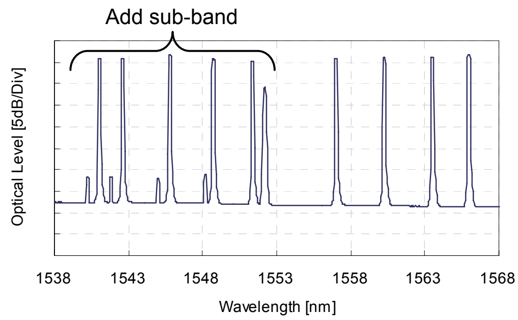
Figure 4: Demonstration Setup

cable failure, optical shutters are inserted between the OADM functional block and a neighbouring repeater in the branch side.

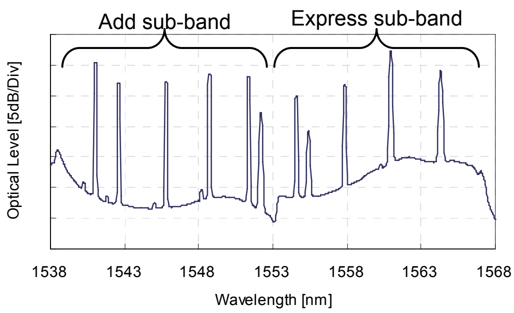
We used the T640SW LTE (Line Terminating Equipment) [5] as transponders. Station A has one RZ-DPSK (Return to Zero Differential Phase Shift Keying) transponder for the express traffic and one RZ transponder for the drop traffic. Also nine channel dummy tones are provided in order to emulate fully loaded system (Figure 5 (a)). When the optical shutters which simulate the branch cable failure are "ON", additional four CW tones are inserted from the SLTE of station A. Station B has one RZ transponder for the add traffic and nine channel dummy tones (Figure 5 (b)). In the OADM functional block, the express sub-band from Station A, longer than 1553 nm, is passed and the drop sub-band, shorter than 1553 nm, is rejected by a high pass filter. The add sub-band transmitted from Station B, shorter than 1553 nm, passes through a low pass filter, then is combined with the express sub-band and received at Station C (Figure 5 (c)).



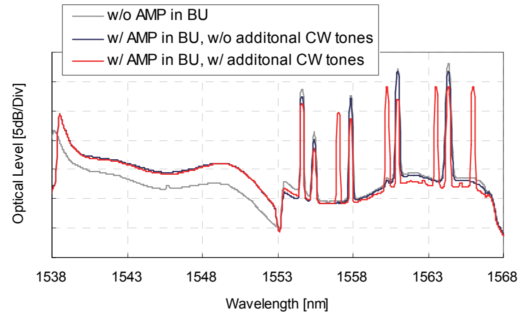
(a) Station A (Tx)



(b) Station B (Tx)



(c) Station C (Rx)



(d) Comparison of Optical Spectrum (Station C (Rx))

Figure 5: Optical Spectrum

Table 1: Q factor comparison of the express signal under cable failure

	Normal	Failure w/o AMP	Failure w/ AMP, w/o additional CW tones	Failure w/ AMP, w/ additional CW tones
Q-factor	14.4 dB	LOS	11.2 dB	12.1 dB

We have compared the transmission performance of the express signal under the normal condition and the cable failure condition.

Figure 5(d) shows the comparison of the received optical spectrum at Station C under the cable failure condition. The amplifier in the BU has reduced the channel power of the express signal. The insertion of the additional CW tones contributes to maintain the channel power of the express signal.

Table 1 shows the Q-factor of the express signal under each condition. While LOS (Loss of Signal), which means interruption of traffic, occurred under a cable failure without amplifier in BU, no interruption was observed with the amplifier in BU (Q-factor: 11.2dB). Moreover, Q-factor was improved to 12.1dB after insertion of the additional CW tone signals. This result indicates that the amplifier in BU and the additional CW tones achieve high-reliability transmission even in case of the cable failure.

5. CONCLUSION

The OADM technology enables flexible connections among multiple stations in an economical way, and our OADM solution offers high reliability even in cable failure. It is expected that the OADM BU technologies will open a new era for advanced submarine cable systems.

6. REFERENCES

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