FULLY FLEXIBLE AND AUTOMATED SUBMARINE LINE TERMINATING EQUIPMENT FOR ADVANCED DWDM SYSTEMS

Tatsuhiro Nakada, Yoshiro Sato, Yasushi Hara, Shigehisa Sugiyama, Takaaki Ogata and Yasuhiro Aoki

Email: <t-nakada@bu.jp.nec.com>

Submarine Network Division, NEC Corporation
34-6, Shiba 5-chome, Minato-Ku, Tokyo, 108-0014, Japan

Abstract: The submarine cable systems have been evolving to support higher capacity and longer distance as well as migration of traffic to the Ethernet. The efficient operation and effective use of wavelength are requested for the development of submarine cable systems. This paper describes newly developed Submarine Line Terminal Equipment (SLTE) meeting with such advancement of the DWDM submarine cable systems.

1. INTRODUCTION

Recent dissemination of the Internet has been promoting rapid expansion of the services for handling large-capacity contents such as audio and video. To provide such services efficiently, it is very important for the SLTE to achieve a high quality transmission, flexible choice of the tributary interface and automated tuning capability along with minimization of the equipment size. The new SLTE satisfies all the requirements described above including the Optical Add and Drop Multiplexing (OADM) function in both the wet plant and dry plant [1].

2. SLTE CONFIGURATION

Figure 1 shows the simplified functional blocks of the SLTE. It is composed of three functional parts. The first part is the Transponder equipment, which provides the FEC encoding & decoding function and the colored optical signal transmitting & receiving function for the long distance transmission. The second part is Wavelength Multiplexing and demultiplexing Equipment (WME), which provides the WDM multiplexing & demultiplexing function. The third part is N:1 Redundant Switching Equipment (RSE), which switches a working transponder to the protection transponder in case of a transponder failure.

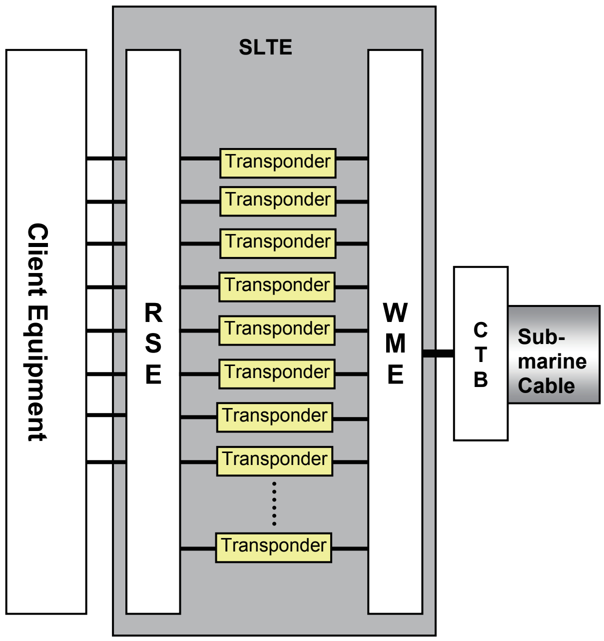

Figure 1: Main function blocks of SLTE

The SLTE rack size is fully compliant to the ETSI standard. The footprint of the rack is 600mm x 300mm and the height is 2200mm. Maximum 32 transponders can be accommodated in one rack. All the operation and the access can be done from the front side so that the racks can be installed back-to-back or back to the wall. The power distribution panel of the rack can be installed at the bottom or top of the rack, while external access can be made either from the bottom or top of the racks. The SLTE adopts the forced air cooling system in order to achieve the stable operation in compact size.

3. LARGE CAPACITY AND LONG DISTANCE TRANSMISSION

To achieve large-capacity transmission, the SLTE can employ various channel spacings from 100GHz up to 25GHz, adopting multi sub-band MULDEX scheme in full C-band. The SLTE can accommodate both the 10Gb/s and 40G/s transponders in the same rack. The maximum transmission capacity of SLTE is 1.8Tb/s (180 x 10Gb/s) in case of 10Gb/s transponders with 25GHz channel spacing, or 3.6Tb/s for the case of 40Gb/s transponders with 50GHz spacing. Further capacity expansion will be achieved in the future by adopting the multi-level modulation format and the polarization multiplexing technique together with the digital coherent technology. The SLTE also enables long-distance transmission over 12,000km [2].

4. OADM SYSTEM SUPPORT

To improve bandwidth utilization of the submarine cable, the OADM network has been put to practical uses. The SLTE supports the OADM function either in the wet plant at the submersible branching unit (BU) [3] or in the dry plant at the SLTE itself. **Figure 2** shows the example of OADM network with the OADM BU. In NEC's OADM system, the WDM signal can be added or dropped on a sub-band basis. The boxes containing numbers in **Figure 2** represent the optical signals divided into sub-bands. The WDM signals are separated for each destination and the signals to the same destination are added at the BU.

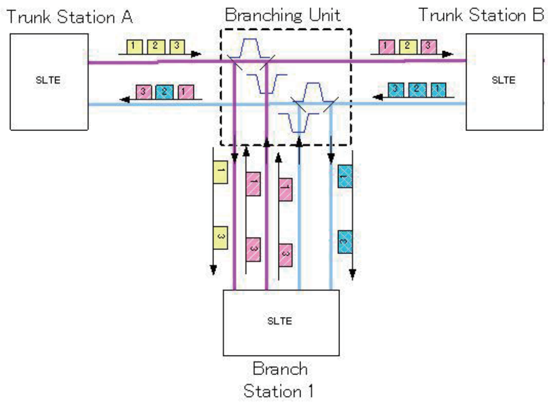

Figure 2: OADM system using submersible BU

In the OADM system, amplified wavelength band is shared among trunk nodes and branch nodes. Therefore, in case of a cable failure, the optical level of survived signals from other nodes changes. This level change could affect the quality of survived signals. In order to maintain the survived signal's quality the SLTE equips the tunable CW light sources that control the optical levels automatically. **Figure 3** shows the example of other OADM system using pass-through scheme in the SLTE. The pass-through function provides the cost effective solution to avoid the back-to-back transponders.

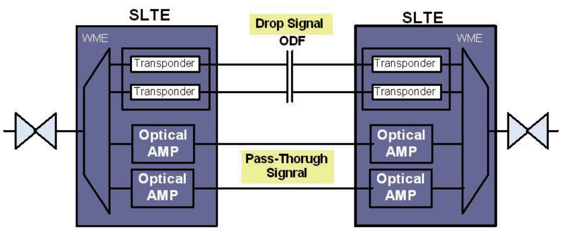

Figure 3: OADM system using pass-through scheme in SLTE

5. SLTE PERFORMANCE AND FUNCTION

The SLTE provides both the enhanced transmission performance and the easy O&M function with flexibility as described below.

5.1. CLIENT INTERFACES

The SLTE supports various client interfaces such as STM16x4, STM64, 10G WAN-PHY and 10G LAN-PHY, provided with the pluggable optical modules (XFP and SFP). The 10Gb/s transponder supports multi-rate client interface that can be configured for either 10GLAN-PHY or STM64 by software switch.

5.2. FOWARD ERROR CORRECTION FUCTION

In order to improve the signal quality for the optical submarine cable systems with a long transmission distance over several thousand kilometers, the SLTE is provided with the enhanced forward error correction (FEC) function compliant to the ITU-T G.975.1. **Figure 4** shows the error correction performance of the enhanced FEC adopted in the SLTE. The FEC can correct a degraded signal with a bit error rate (BER) of 1.2×10^{-2} to an error-free condition with BER below 1×10^{-12}. The coding gain is 10dB. The adoption of enhanced FEC enables to increase the transmission capacity beyond the design capacity for the existing systems, and/or enables to expand the repeater spacing drastically for the new-build system.

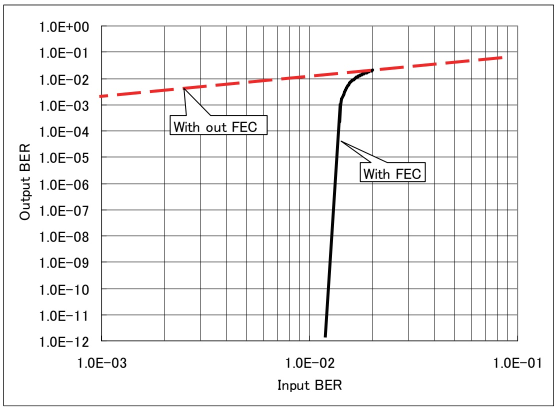

Figure 4: Error correction performance of the FEC function

5.3. MODULATION FORMATS

The modulation format is one of the very important items for the ultra long-distance transmission. The SLTE supports various modulation formats to optimize the SLTE configuration considering the best balance between the performance and the cost. The 10Gb/s transponder can provide three kinds of modulation formats; NRZ, RZ and RZ-DPSK. The RZ-DPSK modulation format provides the best transmission performance among them, and enables the trans-pacific transmission over ten thousands kilometers. The 40Gb/s transponder supports the RZ-DQPSK modulation format, which doubles the transmission capacity compared to the 10Gb/s transponder with 25GHz channel spacing. The SLTE can be flexibly configured adopting various modulation format transponders and/or various line rate transponders.

5.4. CHROMATIC DISPERSION COMPENSATION FUNCTION

The compensation of chromatic dispersion accumulated in the transmission line is an essential function in the SLTE. The SLTE provides two kinds of chromatic dispersion (CD) compensation function. One is based on the dispersion compensation fiber with fixed CD value, and is adopted for all the WDM signals and/or the sub-band WDM signals to roughly cancel the accumulated CD. The other is the tuneable chromatic dispersion compensation function accommodated in each transponder, and is adopted for each optical wavelength to make a precise compensation. The CD value of tunable chromatic dispersion compensation module can be automatically adjusted to achieve the optimum transmission performance per wavelength. The adjustment work in the installation can be greatly reduced thanks to the automated feature.

5.5. PRE-EMPHASIS FUNCTION

The optical submarine repeaters are fabricated and managed with very high accuracy so that the gain characteristic is flat over the signal bandwidth. However,

with long-distance systems over thousands of kilometers, the accumulation of the gain deviation produces an inconsistency in the signal quality depending on the wavelength. As a means of compensating such deviations, the terminal equipment introduced a pre-emphasis function which controls the optical signal levels at the transmitter side. The optimum optical transmission power for each wavelength may thus be adjusted according to the wavelength dependency of each submarine transmission line.
The SLTE achieves automatic pre-emphasis optimization in corporation with the Element Management System (EMS).

5.6. FULLY TUNABLE LIGHT SOURCE

The full-tunable light source is installed in the submarine interface of the transponder so that the output wavelength of the transponder can be set to the exact wavelength within the C band grid (1530-1566nm). A transponder with the tunable light source can also be used as a spare card for all wavelength channels. Tunable light source is also used for CW dummy lights, so the spare cards can be made common as well.

5.7. N:1 WAVELENGTH REDUNDANCY

The SLTE can be configured with redundancy using protection wavelengths according to the availability requirement. This function offers redundancy of N:1, using one protection transponder for N (N = Max. 32) units of working transponders. In the case a fault occurs with one of the working transponders (working wavelengths), it is automatically switched to the protection transponder (protection wavelength). It switches back to the working transponder whenever the fault is recovered.

6. SPECIFICATIONS

The SLTE fundamental features are specified in **Table 1**. The SLTE fully complies with the industry specifications for submarine DWDM applications.

Table 1: SLTE Specification

Item		Specification
Submarine Interface		
	Maximum Wavelength	180
	Channel Spacing	25GHz/33.3GHz/50GHz/100 GHz Grid
	Wavelength	1530-1566nm(Tunable)
	Stability	better or equal to +/-0.02nm
	Transmission Speed	12.4Gb/s(10G) 43Gb/s(40G)
	Modulation	RZ/NRZ/RZ-DPSK(10G) RZ-DQPSK(40G)
Terrestrial interface		STM64/OC-192 STM16/OC-48 10GBASE-R 10GBASE-W STM256/OC-768
Supply voltage		-57.0V to -40.5V
Environmental condition		Temperature 5 to 40degreeC Humidity 5% to 85%
Cooling system		Forced convection air-cooling system with FAN in the shelf
Dimensions		2200mm(H) x 600mm(W) x 300mm(D)
Automatic adjustment function		Dispersion compensation Pre-emphasis control Dummy light power control
Redundancy		N:1 Wavelength redundancy (N=max 32)

7. CONCLUSIONS

This paper describes the newly developed SLTE for the next generation DWDM submarine cable systems. The SLTE provides a high quality transmission, various client interfaces and automated adjustment features. It also supports the OADM function for both the wet plant and the dry plant.

8. REFERENCES

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