HIGH PERFORMANCE AND HIGH FLEXIBILITY SUBMARINE LINE TERMINATING EQUIPMENT FOR NEW BUILD AND CAPACITY UPGRADE APPLICATIONS

Tadashi Koga, Taketo Onuma, Tatsuhiro Nakada, Yoshiro Sato, Yasushi Hara and Takaaki Ogata

Email: t-koga@ab.jp.nec.com

Submarine Network Division, NEC Corporation

29-23, Shiba 5-chome, Minato-ku, Tokyo 108-8420, Japan

Abstract: We describe the features and benefits of newly-developed Submarine Line Terminating Equipment (SLTE) which exploits digital coherent technology to advance the capacity of DWDM submarine cable systems. The SLTE allows the combination of 10Gb/s, 40Gb/s and 100Gb/s line rates and multiple modulation formats to maximize the ultimate capacity of new build systems and the capacity expansion of the existing systems alike. It provides superior spectral efficiency of 2bit/s/Hz in DP-QPSK modulation format to achieve a fiber capacity of 10Tb/s and chromatic dispersion compensation capability well in excess of 100,000ps/nm to cope with the ideal digital coherent transmission line based on uncompensated dispersion maps.

1 INTRODUCTION

Ever-higher bandwidth demand from end users has fed a need for drastic capacity enhancement in submarine cable systems. Digital coherent technology has been instrumental in answering this need by enabling trans-oceanic transmission with line rates of 40Gb/s and 100Gb/s [1][2].

In this paper we describe the features and benefits of newly-developed Submarine Line Terminating Equipment (SLTE) which exploits digital coherent technology to advance the capacity of dense wavelength division multiplexed (DWDM) submarine cable systems.

2 SLTE CONFIGURATIONS

To meet the demands of carrying high capacity signals through the global networks, the SLTE plays very important roles in the connection between the terrestrial networks and the submarine networks.

The SLTE converts the terrestrial traffic signals, which are compliant to the ITU-T standards or IEEE standards, to the ideal DWDM line signals with ultra-long haul transmission capability over transoceanic distance. Figure 1 shows the functional block diagram of the SLTE. It consists of two functional parts. One is the transponder equipment, which provides the conversion function between the client signal and the colored aggregate signal. It also provides the ultra-long haul transmission capability by introducing the forward error correction technology and the advanced optical modulation /detection technologies, such as the multi-level optical modulation and the digital coherent detection. The other is the wavelength multiplexing and demultiplexing equipment, which generates the DWDM signals with a superior spectral efficiency. It also provides the interface function for the wet plant supervisory and control.

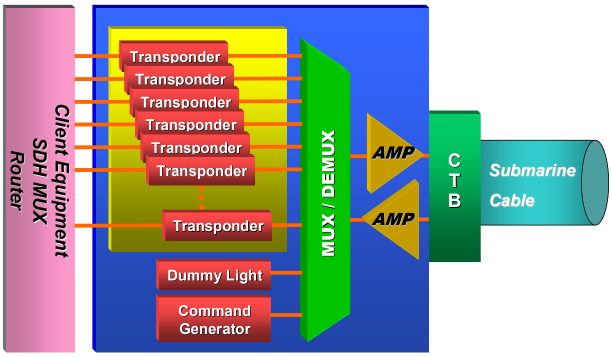

Figure 1: Functional block diagram of SLTE

The SLTE rack size is fully compliant to the ETSI standard. The footprint of the rack is 600mm(W) x 300mm(D) and the height is 2,200mm(H). It provides the high density packaging design to save the floor space, and accommodates maximum 16 transponders per one rack for the case of 40G signal. All the operation and 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 set at the bottom or top of the rack to be compliant to various requirements in various stations. The rack adopts the forced air cooling system in order to achieve the stable operation in the high density packaging.

3 SLTE PERFORMANCE AND FUNCTION

The newly-developed SLTE provides both the high capacity transmission capability over trans-oceanic distance and the flexibility on the operation by introducing following key technologies and key features.

3.1 Optical modulation technology

The optical modulation formats is one of the most important features for the high capacity transmission over trans-oceanic distance. The SLTE supports various modulation formats in order to provide the cost effective solutions with optimum transmission performances. The 10Gb/s transponder can provide three kinds of modulation formats: non return to zero - on off keying (NRZ-OOK), return to zero - on off keying (RZ-OOK), and return to zero differential phase shift keying (RZ-DPSK). The 40Gb/s and 100Gb/s transponder support the multi-level modulation format: dual polarization - quadrature phase shift keying (DP-QPSK). The combination of the dual polarization technology and the quadrature phase shift keying technology contributes an enhancement of the spectral efficiency. In case of 100Gb/s DP-QPSK signal over 50GHz channel spacing, the excellent spectral efficiency of 2bit/s/Hz is achieved. In addition, dual polarization - binary phase shift keying (DP-BPSK) is also available as an option. The DP-BPSK modulation format provides the superior transmission performance especially in the dispersion managed transmission lines that are widely deployed in the legacy systems, thanks to its high nonlinear tolerance and optical signal-to-noise ratio (OSNR) tolerance.

3.2 Digital coherent detection

The digital coherent detection technology is the breakthrough technology in the next generation submarine cable systems with ultra-high speed signal such as 40Gb/s and 100Gb/s or more. It is adapted to the line side receiver of the transponder, and performs the polarization demultiplexing, the chromatic dispersion compensation, the polarization mode dispersion compensation and the frequency/phase tracking between the incoming signal and the local oscillator light in the coherent detection. These features provide the full compensation capability of linear distortion in the transmission line. They also provide the high receiver sensitivity, which overcomes the OSNR degradation in the transmission line.

3.3 Forward error correction

The forward error correction (FEC) technology has already been deployed widely in the submarine cable systems. The newly-developed SLTE introduces the enhanced FEC with a net coding gain (NCG) of more than 10dB.

3.4 Pre-emphasis function

For ultra-long distance transmission over thousands of kilometers, the accumulation of the gain tilt with several hundreds number of submarine repeater amplifiers induces an imbalance of the signal quality among the WDM channels. To reduce such imbalance, the SLTE supports a pre-emphasis function which controls the optical output power of each channel at the transmitter of line side. The SLTE performs pre-emphasis optimization for each channel automatically in collaboration with the Element Management System (EMS).

3.5 Client interfaces

To satisfy the demands for various services, the flexibility of various client interfaces becomes mandatory requirement for the SLTE design. The newly-developed SLTE provides various kinds of client interfaces as follows:

- 10G: STM-64, OC-192, 10GbE LANPHY, 10GbE WANPHY, OTU2, OTU2e
- 40G: STM-256, OC-768, 40GbE, OTU3
- 100G: 100GbE, OTU4

All the 10G, 40G and 100G optical interfaces are provided with small form factor pluggable modules and can be configured by software switch for easy and flexible operation. As an option, the 2.5G interface such as the STM-16 can be provided by adopting the additional interface card.

3.6 Wavelength multiplex/demultiplex function

The SLTE can multiplex and demultiplex maximum 180 optical signals with minimum channel spacing of 25GHz. It can support various channel spacing depending on various modulation formats.

3.7 Dispersion compensation function

The SLTE provides the optical chromatic dispersion compensation function as well as the electrical chromatic dispersion compensation. With the combination of the optical method and the electrical method, the SLTE can perform large chromatic dispersion compensation capabilities in excess of 100,000ps/nm to cope with the ideal digital coherent transmission line based on uncompensated dispersion maps.

3.8 Dummy light insertion function

The SLTE equips the dummy light insertion functionality designed to maintain the power level of the traffic signal adequately in case that the traffic capacity at the initial stage is much smaller than the ultimate design capacity.

3.9 Wet plant control function

The SLTE provides the command generation functions of the power feeding path switching and the reconfigurable optical add drop multiplexing (ROADM) reconfiguration in the branching unit (BU) under the EMS control.

4 TRANSMISSION PERFORMANCE

We have evaluated the transmission performance of 100Gb/s DP-QPSK signal *1) in the SMF transmission line with a trans-oceanic distance of 7,400km. The transmission line was based on the uncompensated dispersion map design. The total cumulated chromatic dispersion was more than 140,000ps/nm.

Figure 2(a) shows the measured pre-FEC Q performances and post-FEC bit error rate (BER) after 7,400km transmission.

The 100Gb/s DP-QPSK signal achieved the Q performances with more than 8dB at pre-FEC and the error free performances at post-FEC over 30nm optical signal range.

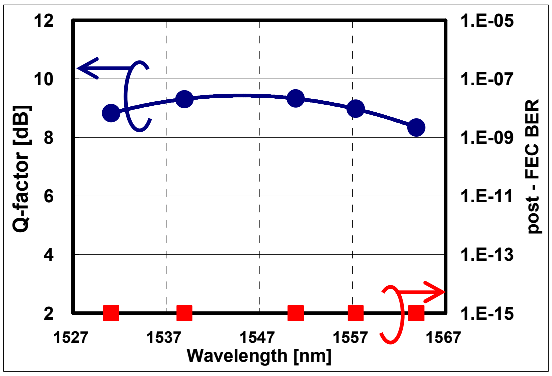

Figure 2(a): 7,400km transmission performance

We have also evaluated the long term Q performance stability. The measured stability is shown in Figure 2(b). The 100Gb/s DP-QPSK signal achieved very stable Q performance with a standard deviation of less than 0.1dB after 7,400km transmission.

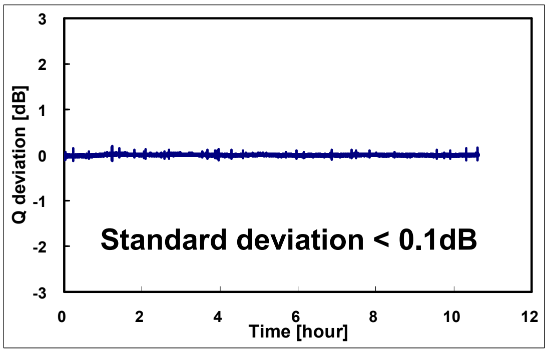

Figure 2(b): Long term Q stability

5 CONCLUSION

This paper describes the newly developed SLTE for the next generation DWDM submarine cable systems. The SLTE provides a high capacity and ultra-long distance transmission with an excellent spectral efficiency, various kinds of client interfaces and user friendly easy operation.

6 REFERENCES

[1] Takanori Inoue, et al., "100G Trans-Pacific Transmission with Extremely High Spectral Efficiency", SubOptic2013, Paris, France

[2] T. Nakano, et al., "Transmission Capacity Enhancement by Higher Bit-rate Signal Upgrades in Legacy Cable Systems", SubOptic2013, Paris, France

*1) partially uses results from "R&D on High Speed Optical Transport System

Technologies (2009)" and "R&D on Ultra-high Speed Optical Edge Node

Technologies (2010-2011)," which are supported by the Ministry of Internal Affairs and Communications of Japan