SUBMARINE LINE TERMINAL EQUIPMENT USING DIGITAL COHERENT TECHNOLOGY

Izumi Yokota, Akira Sugiyama, Yasushi Oikawa

Email: yokota.izumi@jp.fujitsu.com

FUJISTU LIMITED, 1-1 Kamikodanaka 4-chome, Nakahara-ku, Kawasaki, 211-8588, Japan

Abstract: With the rapid growth of digital society, mobile traffic, optical access and communication with data centres for such cloud services are increasing sharply day by day. These demand caused traffic explosion on submarine networks so that an expanding submarine network capacity has become extremely critical in the world. In the above situation, the Digital Coherent Technology [1] which has dramatic effect compared with the existing technology is the best solution for new SLTE. This paper describes the features of new SLTE which applies this technology.

1 INTRODUCTION

In order to expand transmission capacity of submarine cable system, the number of wavelength on a fiber is increasing by using Dense Wavelength Division Multiplex (DWDM) technologies. In SubOptic 2010, we had reported that our SLTE achieves a transmission capacity of 1.8 Tb/s with 10 Gb/s base and 3.6 Tb/s with 40 Gb/s base [2]. However, these solutions are unable to solve the recent traffic explosion on the submarine cable network caused by the rapid growth of digital society. A higher bit-rate per wavelength application by using Digital Coherent Technology is the best solution for the above situation.

2 DIGITAL COHERENT TECHNOLOGY

By using Digital Coherent Technology such as high speed signal processing at receiver side, the following features can be realized in SLTE.

- **Higher bit-rate : 100 Gb/s**

  Digital Coherent Technology breaks the limitation of 10/40 Gb/s using existing technologies such as binary OOK modulation and QPSK modulation, then a bit-rate per wavelength is increased to 100 Gb/s. The reason of achieving such higher line bit-bit-raterate, baud rate can be reduced by 25% such as 25 Gb/s by applying optical polarization multiplex and quaternary level modulation format with digital signal processing at receiver side.

- **Coherent detection**

  In realizing coherent detection, it is essential to precisely control optical signal frequency at transmitter side and local oscillator optical frequency at receiver side. By using digital signal processing at receiver side, the precise control of both transmitter and receiver side can be relaxed. As the result, required Signal Noise ratio (SNR) to obtain transmission performance can be also relaxed by 3 dB. The coherent detection is essential to realize higher line bit-rate.

- **Compensation for Chromatic Dispersion (CD) in electrical**

  Accumulated CD caused by transmission fiber was mainly compensated by using optical fiber and/or optical device at SLTE. The CD compensation value becomes larger, additional optical amplifier which compensates the loss of optical dispersion compensator is required. Therefore, compensation for CD in electrical at receiver side whose value is up to +/-40,000 ps/nm is attractive function in order to reduce cost of CD compensator and required space for equipment.

- **Compensation for differential group delay (DGD) in electrical**

  As a line bit rate increases to 100 Gb/s, DGD caused by transmission fiber and submergible plants such as optical repeater should be managed in order to obtain stable transmission performance. The compensation for DGD at SLTE of receiver side can be relaxed the specification of submersible plants DGD. The compensation for DGD is essential to realize higher line bit-rate.

3 FEATURE FOR SLTE WITH DIGITAL COHERENT TECHNOLOGY

SLTE is applied to two cases below, i.e. one is capacity upgrade for the existing submarine cable system and the other is for a new built.

3.1. Capacity upgrade for the existing system

There are many existing submarine systems which were optimised to transmit DWDM 10 Gb/s signals in '00s. The features to achieve more upgradable capacity and easy operation is required in new SLTE in capacity upgrade compared with original designed capacity.

In the existing system with optimisation of 10 Gb/s signal, new 100 Gb/s signal power per wavelength during fiber transmission is usually higher than the optimal one. The nonlinear effect according to signal power of new 100 Gb/s signal is large, and then CD compensation is required at both transmitter and receiver side of approximate ratio of half-and-half as shown in Figure-1 to achieve large upgradeable capacity, even if it could be one more 100 Gb/s wavelength.

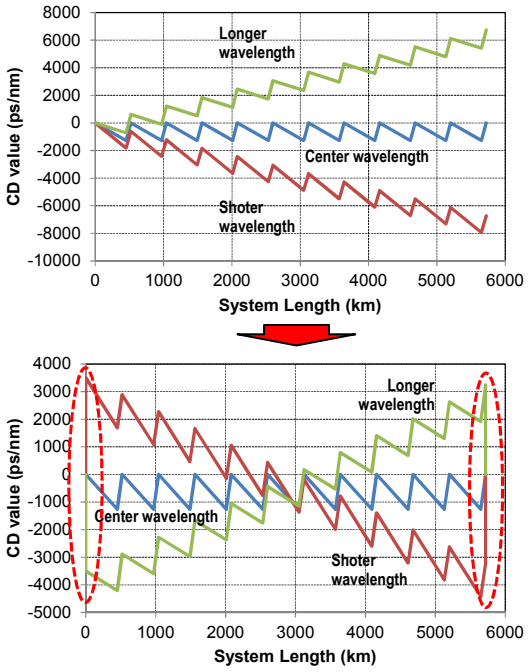

Figure-1 : Dispersion management

At current technology, dispersion compensation function by using digital signal processing at transmitter side is not available. Although digital signal processing will be equipped at transmitter side for CD compensation which is the one of the functions in near future, pre-dispersion compensation is incompatible with RZ (Return Zero) modulation format that is suitable for long-haul transmission system. Therefore, pre-dispersion compensation scheme on optical is required for capacity upgrade of the

existing submarine system. New SLTE has two stage pre-dispersion compensations for cost effective and small size equipment solutions as shown in Figure-2.

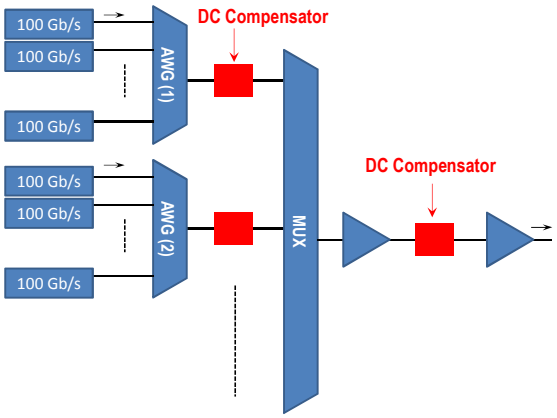

Figure-2: Pre-dispersion compensation scheme

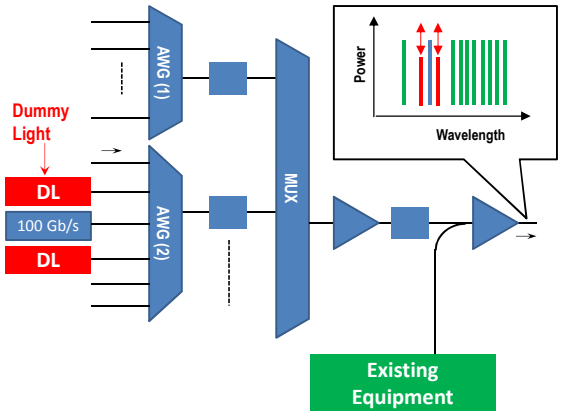

Figure-3: Dummy Light

In submarine system SLTE has a function of Dummy Light (DL) which keeps the signal power per wavelength constant independently from equipped number of wavelength and compensates spectrum hole-burning caused by small number of wavelength at entire gain bandwidth. In case of upgrading for the existing system with almost full original design capacity based on 10 / 40 Gb/s, the existing capacity must migrates to new 100 Gb/s wavelength while installation of new wavelength for capacity upgrade. A full-tuneable DL with 50 GHz grid same as signal wavelength is useful to adjust both the existing signal power and new 100 Gb/s signal power in order to avoid Q value degradation and to compensate spectrum hole-burning as shown in Figure-3.

To get easy adjustment of total power of both existing SLTE and new SLTE, the configuration as shown in Figure-4 is suitable. Furthermore, the risk of the affection to existing signals during installation of new 100 Gb/s signals will be minimized.

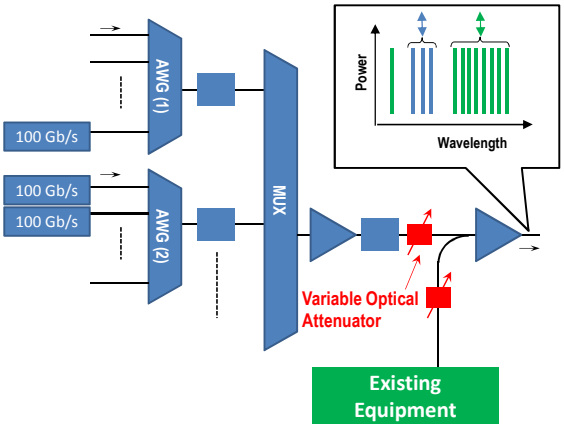

Figure-4: Total power adjustment

3.2. New built submarine cable system

Usually, in case of new submarine cable system the required initial equipage is small number of wavelength compared with design capacity. If the DL as described in 3.1 is allocated to entire bandwidth with high power equal to the power of 6 to 8 signals, Q value degradation will be observed. One of the reasons of this degradation is the Raman gain and Raman depression due to agreement of optical polarization between DL and signal wavelength.

In order to suppress this Q value degradation, another type of DL with non-polarization state is effective. In our SLTE, this type of DL which consists of Amplifier Spontaneous Emission (ASE) noise is equipped to control optimum for signal power per wavelength.

4 BEYOND 100 G

To expand total capacity at a limited bandwidth effectively, spectral efficiency must be increased. There are two solutions which are more multi-level modulation (i.e. 16 QAM) and spectral shaping (i.e. Nyquist filtering) for increasing spectral efficiency. By applying 16QAM and/or Nyquist filtering technology, signal optical spectrum becomes narrower and signal channel spacing also becomes narrower, and then a large number of signal wavelengths with high line bit-rate can be allocated in the entire bandwidth. However, between these technologies and transmission performance at long haul system is relationship of trade-off. On order to achieve beyond 100 Gb/s transmission in submarine cable systems, we believe that not only these technologies but also further technology, which might be non-linear compensation function [3] by Digital Coherent Technology should be implemented in future SLTE.

5 CONCLUSION

In order to resolve the recent traffic explosion on submarine cable network, new SLTE by using Digital Coherent Technology which has effective features for both new built and capacity upgrade of the submarine cable systems is required. Especially, new SLTE achieves easy operation, smart migration of existing capacity and low-risk for degradation of existing signal for capacity upgrade of the existing system by equipped of both the full-tuneable DL and the configuration of total power adjustment.

6 REFERENCES

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