DEVELOPMENT OF NEXT GENERATION SUBMARINE LINE TERMINAL EQUIPMENT

Hiroshi Ogiwara, Hiroshi Oikawa, Izumi Yokota

Email: <ogiwara@jp.fujitsu.com>

FUJITSU LIMITED
1-1 Kamikodanaka 4-chome, Nakahara-ku, Kawasaki, 211-8588, JAPAN

Abstract: To meet the demand for increasing capacity of submarine telecommunication systems, we have developed a Submarine Line Terminal Equipment (SLTE): FLASHWAVE S660 that is appropriate for both new submarine cable construction projects and upgrades to existing systems.
The maximum transmission capacity this SLTE achieves a capacity of 1.8Tb/s at 25GHz spacing of 10G signal and 3.6Tb/s at 50GHz spacing of 40G signal.
Furthermore, the optical MUX/DEMUX method of this SLTE enables a mixture of different wavelength spacing, different modulation formats, and different transmission signal rates. This SLTE can arbitrarily select the best wavelength spacing and modulation format that can achieve the maximum transmission capacity corresponding to the submerged line characteristics. This paper describes the features of FLASHWAVE S660.

1. INTRODUCTION

The key specifications of FLASHWAVE S660, which we have developed, are shown in Table-1. The overall configuration is shown in Figure-1.

Table-1 Key Specifications of FLASHWAVE S660

Items	Specifications
Optical Wavelength	1531 – 1566 nm
Bit-rate / Channel spacing	- 10Gb/s with 25 / 33 / 37.5 GHz spacing - 40Gb/s with 50 GHz spacing - 100Gb/s with 50 GHz spacing (future release)
Line Code	- 10Gb/s: RZ-DPSK,RZ-OOK - 40Gb/s: DP-QPSK
Transmission Capacity	Up to 180w x 10Gb/s Up to 90w x 40Gb/s
Maximum System Length	10,000km
Power Consumptions (32w x 10Gb/s)	2600 W (-48V DC)
Rack size	600mm(W) x 300mm(D) x 2200mm(H)

2. FLEXIBLE CONFIGURATION

2-1. Multi-Grid Line Card

To achieve the optimum transmission performance for the various systems, we have developed Multi Grid Fully Tunable Line cards with an external cavity tunable laser and etalon based Chromatic Dispersion (CD) compensator, which can flexibly set the channel spacing. These technologies enable one line card to cover the entire full C-band wavelength continuously. Moreover the line card realizes up to +/-2,000ps/nm CD tolerance with build-in CD compensation.
A key advantage of the multi-grid line card is presented here:
In the case of an upgrade of an existing system, the system gain bandwidth is limited by the existing submerged line characteristics. In order to obtain large capacity, the channel spacing must be narrow. However, there are large propagation impairments at 10G signal rate. With narrow channel spacing that are allocated around zero dispersion wavelength, due to fiber non-linear effect,

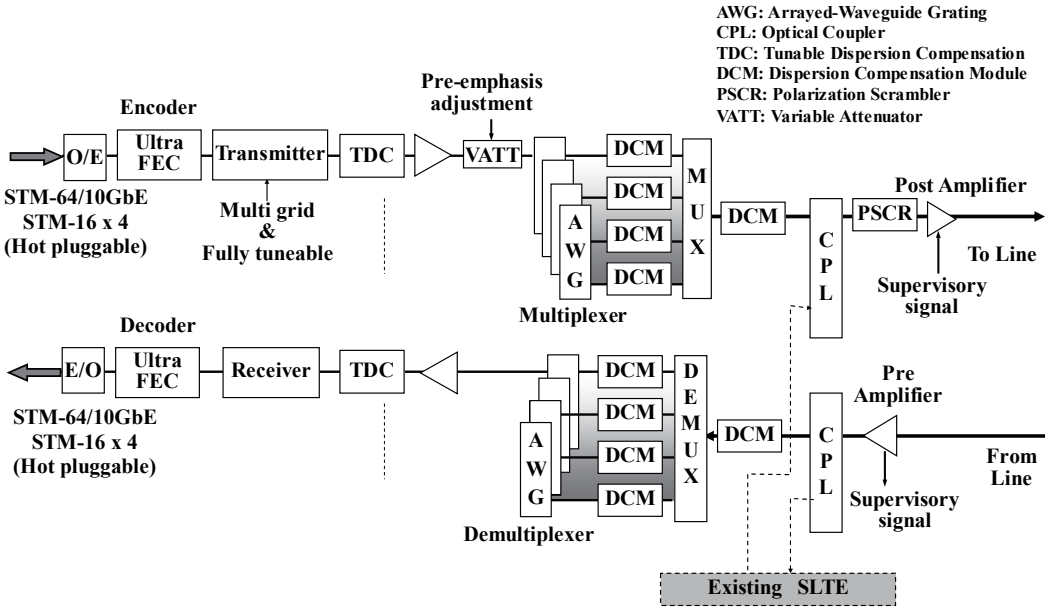

Figure-1 Overview Configuration of FLASHWAVE S660

such as Cross Phase Modulation (XPM) at long system length. Therefore, 33 or 37.5 GHz channel spacing is applied for zero dispersion wavelengths to suppress the large Q penalty. As a result, the maximum number of wavelengths can be achieved by using a mixture of channel spacing (e.g. 25GHZ and 33 GHz) for the upgrade of existing system.

Optical MUX/DEMUX consists of a 300GHz sub-band with "n skip 0" technologies. Then channel spacing can be selected from 25 / 33 / 37.5GHz of 10G signal on every 300GHz bandwidth without any guard band between sub-bands.

2-2. Mixture of Modulation Format and Bit-rate

The line bit-rate of both 10G and 40G signal can be supported in FLASHWAVE S660. There are two modulation formats that are RZ-DPSK (Return to Zero Differential Phase Shift Keying) and RZ-OOK (Return to Zero On-OFF shift Keying) at 10G signals. In generally, RZ-DPSK modulation format can achieve an improvement of 2 - 3dB on the sensitivity of the receiver against RZ-OOK. RZ-DPSK has a nonlinearity advantage on the transmission performance over RZ-OOK. However, RZ-DPSK is known to be influenced by phase noise by accumulated ASE (Amplifier Spontaneous Emission) noise, and the receiver sensitivity deteriorates, particularly in the zero dispersion regions. Therefore, RZ-OOK is more suitable to allocate for zero dispersion regions than RZ-DPSK [1]. Moreover, RZ-OOK is the cost effective solution for regional system short haul system.

For 40G signal, we have plans to adapt the digital coherent technologies, as follows;

1) Improvement of receiver sensitivity (~3 dB)
2) Improvement of chromatic dispersion compensation range
3) Realize multi-level modulation and polarization division multiplexing

With this new SLTE, it is possible to select not only the modulation format but also the line bit-rate in order to achieve the optimal transmission performance.

2-3. OADM configuration

FLASHWAVE S660 has a function of OADM configuration for client interface as shown in Figure-2. In OADM configuration, equipage of a tributary card is not required for a wavelength that can be transmitted through station B for both of station A and C sides. For such a

wavelength, a new card that has a function of optical level control for pre-emphasis adjustment is only necessary at station B. There are the following merits by using this simple OADM configuration.

- Cost effective
- Low latency
- Wavelength independency retained in case of card failure

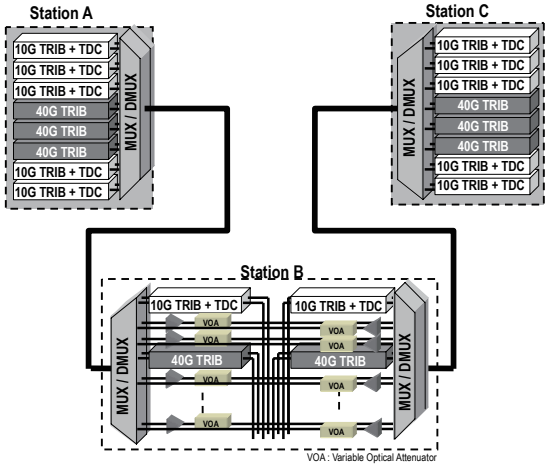

Figure-2 Wavelength Pass Through configuration

2-4. Compact Size

In case of a small capacity system (up to 10G x 16 waves), the required cards for all functions of the system can be accommodated in only one ETSI rack. is the footprint is reduced by 66% compared with existing equipment (of the same capacity). At initial equipage, even if only one ETSI rack is required (i.e. up to 16 wavelengths), then it is still possible to house all of the functions for the system within this single rack.

To realize a compact size SLTE, a new fixed Chromatic Dispersion device, using FBG (Fiber Bragg Grating) technology, is applied for common / block DC. In addition, a new fixed CD device has some merits compared with the conventional DC fiber (DCF) as below;

- Low insertion loss
- Free of fiber non-linear effect

Our ETSI rack for FLASHWAVE S660 complies with Telcordia GR-63-CORE Earthquake Risk ZONE-4 with bottom fixing only.

If a system upgrade is to be achieved while retaining the original SLTE, then FLASHWAVE S660 can be connected using optical couplers on both the transmitter and receiver sides. Fujitsu has significant experience of this type of upgrade by using conventional SLTE with less than 15 minutes traffic interruption [1].

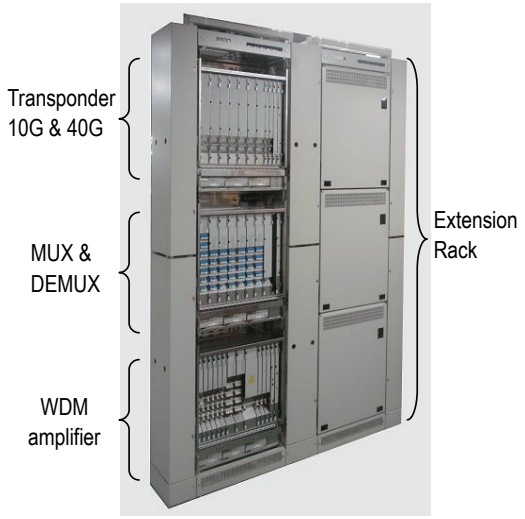

Figure-3 Overview of FLASHWAVE S660

3. EASY COMMISSIONING & MAINTENANCE

3-1. Automatic Functions

In order to easily achieve the optimized transmission performance, there are two major automatic functions employed in FLASHWAVE S660.

- Pre-emphasis control
- DC control at each wavelength

The above automatic functions are available in the case of a mixture of channel spacing, modulation format and line bit-rate. This can be performed in-service, without traffic interruption.

Accordingly, it provides easier operation and maintenance for the system.

3-2. Simple Operation

The tributary of FLASHWAVE S660 supports a pluggable module for client interface with dual-rate (SDH and GbE). In addition, the replacement of the pluggable module is available during powering of a tributary.
The general situation is that initial equipped capacity is less than the design capacity of the system and the capability of the existing system repeaters. In this situation, increased signal power at the repeater output can generate spectral hole burning creating propagation impairments to the transmitted signal. It is therefore essential to activate dummy lights to keep the repeater output power constant and to suppress spectral hole burning. The full band tunable LD is also adapted to this dummy light card.
The type of spare cards can be reduced by the above design and all FLASHWAVE S660 cards can be managed automatically by our system surveillance equipment (SSE).

4. 100G TECHNOLOGIES

In future, higher bit-rates such as 100Gb/s at a single wavelength will be applied for submarine networks that demanda large capacity. For 100Gb/s, digital coherent technologies are essential and DP-QPSK modulation format will be adapted with 50 – 100 GHz channel spacing, the same as 40G signal [2]. However, high performance FEC should be required in order to suppress the propagation impairments due to fiber non-linear effect and to obtain the required SNR.
In future, 100G tributaries can be accommodated by FLASHWAVE S660, also with a mixture of both 40G and 10G tributaries.
As an example of our development, we have demonstrated 100G optical signal transmission over 3,400 km with conventional NZ-DSF [3].

5. CONCLUSION

We have developed FLASHWAVE S660 which can achieve a maximum transmission capacity of 1.8Tb/s at 10Gb/s with 25GHz channel spacing and 3.6Tb/s at 40Gb/s with 50GHz channel spacing. The most suitable line bit-rate, channel spacing and modulation format for submarine networks can be selected with FLASHWAVE S660 in order to achieve optimum transmission performance. Furthermore, easy commissioning & maintenance and flexible configuration can be obtained with a very compact size. In future, 100G tributary will be also available with FLASHWAVE S660.

6. REFERENCES

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[3] H. Nakamoto et al., SubOptic’10, 2010

