T640SW LTE Terminal Equipment for Optical Submarine Cable Systems

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Abstract

The global growth of IP data traffic has been driving the need for increasing the capacities and transmission distances of optical submarine cable systems year by year.

This paper introduces the features and configurations of the T640SW LTE optical submarine cable system terminals. This equipment features an ultra-large transmission capacity of 1.32 Tbps (10 Gbps transmission speed × 132 waves) and an ultra-long transmission distance of over 9,000 km.

Keywords

optical submarine cable system, terminal equipment
high-density DWDM (Dense Wavelength Division Multiplexing), large capacity, long distance

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. Based on the increase in IP data traffic, the optical submarine cable systems forming its backbone network are encountering increasing demands to accommodate the number of circuits that are growing year by year.

In order to meet the market needs of optical submarine systems, NEC has developed the T640SW LTE terminal equipment that features an ultralarge-capacity/ultralong-distance transmission capability. This equipment is introduced below.

2. Outline of the T640SW LTE

The T640SW LTE is a terminal equipment for optical submarine cable systems that features an ultralarge-capacity/ultralong-distance transmission capability with a total transmission capacity of 1.32 Tbps (10 Gbps transmission speed × 132 waves) and a transmission distance of over 9,000 km. The terminal equipment includes the transmitter section, which performs coding of the error correction codes for the tributary optical signals from the land networks, wavelength conversions into modulation codes suitable for long-distance transmissions, wavelength dispersion compensations and wavelength-division multiplexing. It also has a receiver section that performs the reception processing operations. When very high circuit reliability is required, the terminal equipment can apply a redundancy configuration using protection wavelengths.

3. Features of the T640SW LTE

The T640SW LTE applies various technologies for achieving ultralarge-capacity/ultralong-distance transmissions, some of which are described in the following subsections.

3.1 Technologies for Ultra-large Capacity/Ultra-long Distance Transmissions

(1) DWDM (Dense Wavelength Division Multiplexing) Technology

Since the optical submarine cable system limits the number of optical fibers per cable to 16, the DWDM technology is very important from the viewpoint of increasing the capacity. NEC has developed a DWDM technology with a channel spacing of 25 GHz (0.2 nm) that makes it possible to multiplex up to 132 optical signals at 10 Gbps in the 28 nm optical amplification band. This technology allows our terminal equipment for optical submarine cable systems to achieve DWDM transmissions at the world's highest level. In order to maintain the high wavelength stability that is suitable for DWDM, wavelength stabilization control is applied using a high-accuracy wavelength locker.

(2) Optical Signal Modulation Technology

Optical communication systems usually use NRZ modulation method as an optical modulation coding method. On the other hand, because the application of a modulation code with a high OSNR tolerance is effective for increasing the transmission distance, optical submarine cable systems also use RZ modulation method just as widely as the NRZ modulation method. At NEC, we have newly implemented the RZ-DPSK modulation method for use in addition to the above modulation methods in order to improve the quality of long-distance transmissions.

Theoretically, the RZ-DPSK modulation method offers the capability of improving the OSNR tolerance by 3 dB compared to the RZ modulation method. It is therefore expected to be capable of achieving an excellent performance in ultra-long distance transmissions over thousands of kilometers.

(3) Code Error Correction Technology

To attenuate the signal quality degradation of optical submarine cable systems that results from increases in the distance and transmission capacity, NEC has developed a high-gain code error correction FSI compliant to the ITU-T G.975.1 (Advanced FEC LSI) and has installed it in the transponder block. Advanced FEC has a code error correction capability as shown in **Fig. 1** .

By applying the concatenated BCH code, Advanced FEC can correct a signal with a bit error rate (BER) of 3.3×10^{-3} to an error-free signal with BER below 1×10^{-12} , thus achieving an error correction gain of about 8.5 dB.

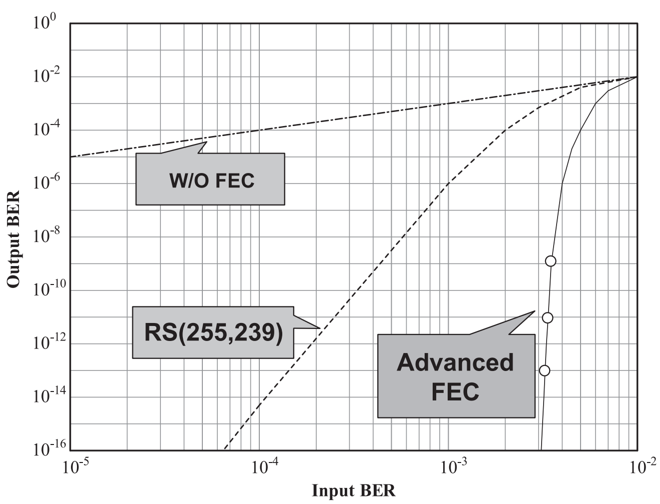

Fig. 1 Code error correction capability of advanced FEC.

3.2 Variable Wavelength Dispersion Compensation

When an optical signal is propagated via an optical fiber, its waveform is distorted by wavelength dispersion and the signal quality is deteriorated after transmission. As the waveform distortion due to wavelength dispersion is more noticeable when the optical fiber distance is long, an optical submarine cable system that transmits a large capacity of signals over a long distance must compensate for the accumulated wavelength dispersion in both the submarine transmission line and the terminal equipment. The terminal equipment introduced here has a variable wavelength dispersion compensation function so that it can adjust the optimum dispersion compensation amount per wavelength according to the wavelength dispersion characteristic of a particular submarine transmission line.

3.3 Pre-emphasis

The optical submarine repeaters used with optical submarine cable systems are fabricated and managed with very high accuracy so that the gain characteristic is flat within the signal bandwidth. However, with long-distance systems over thousands of kilometers, the accumulation of the gain deviation produces a deviation in the signal quality of each wavelength. As a means of unifying the signal quality by compensating for the deviations, the terminal equipment introduced here features a pre-emphasis function for adjusting 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.

3.4 OADM (Optical Add/Drop Multiplexing)

The need to apply OADM to optical submarine systems arises in order to deal with the flexibility of network configurations.

The terminal equipment introduced here has the wavelength management function required for OADM. When this is combined with the submarine branching units equipped with the multiplexer/demultiplexer function, it becomes possible to build an OADM network in which branching and insertion are possible on a per-wavelength basis.

3.5 N:1 Wavelength Redundancy

The terminal equipment introduced here can configure redundancy using protection wavelengths according to the circuit reliability requirement. This function offers redundancy of N:1 waveforms using N (N = Max. 32) units of working transponders and one protection transponder. In the case of a fault occurring with a working transponder (working wavelength), it is switched automatically to the protection transponder (protection wavelength), which is switched to the working transponder (working wavelength) whenever the fault is recovered.

4. Configuration of T640SW LTE

The T640SW LTE is composed of three function blocks. The first of these is the transponder block that transmits and receives the 10 Gbps optical signal. The second is the optical wavelength-division multiplexer/demultiplexer that multiplexes and demultiplexes the 10 Gbps optical signal at channel spacing of 25 GHz. The third is the N:1 redundancy switch block that switches a working transponder to the protection transponder in the case of a fault. Optimum equipment configuration can be built flexibly according to the system requirements, including the number of wavelengths, transmission distances and the need for wavelength redundancy.

4.1 Main Function Blocks and Specifications

Fig. 2 shows the main function blocks of the T640SW LTE and **Table** shows the main specifications. The following paragraphs separately describe the transponder, optical wavelength-division multiplexer/demultiplexer and N:1 redundancy switch blocks.

(1) Transponder Block

On the transmitting side, this block inputs the STM-64/OC-192 or 10 GbE optical signals from the tributary input, performs optical-to-electrical conversion of the input signal, accommodates this in the FEC frames and applies an error correction coding. It then performs an electrical-to-optical conversion to these signals in order to render them suitable for optical wavelength division transmission and to then output the obtained signal to the optical wavelength-division multiplexer/demultiplexer block. It selects the optimum optical signal modulation method from NRZ, RZ or RZ-DPSK according to the system. On the receiving side, this block processes the optical signal from the submarine transmission line by a reverse process to the above and outputs the signal as the tributary signal. The transponder block features a pre-emphasis and variable wavelength dispersion compensation function so that it can adjust the signal in order to obtain optimum quality after transmission.

A 2.488 Gbps × 4 multiple transponder is also available in the menu for use in asynchronous multiplexing/demultiplexing of the four STM-16/OC-48 optical signals used as tributary signals.

(2) Optical Wavelength-Division Multiplexer/De-multiplexer Block

The optical wavelength-division multiplexer block is composed of function blocks including; wavelength-division

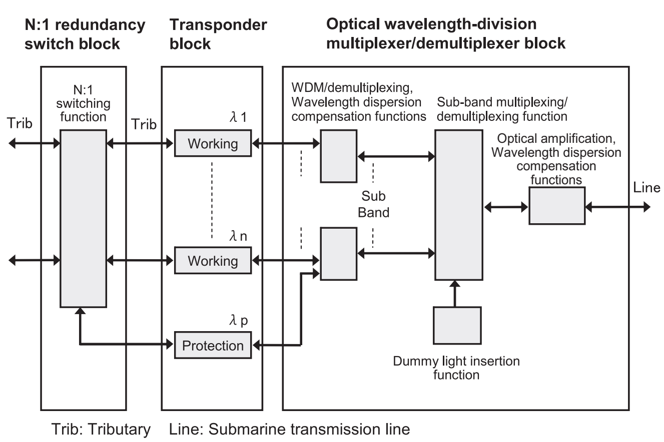

Fig. 2 Main function blocks of the T640SW LTE.

Table Main specifications of the T640SW LTE.

Item		Specification
Submarine line side interface		
	Maximum number of wavelengths	132 waves
	Channel spacing	25 GHz/33.3 GHz/50 GHz/100 GHz
	Wavelength range	1,538 to 1,566 nm
	Wavelength stability	≦ ±0.02 nm
	Transmission speed	10.7092 Gbps, 11.0957 Gbps (10 GbE)
	Modulation method	RZ-DPSK/RZ/NRZ
Tributary side interface		STM-64/OC-192 (ITU-T G.691) 10 GbE (IEEE802.3ae) STM-16/OC-48 (ITU-T G.957)
Supply voltage		-48 V DC
Operating environmental conditions		Temperature: +5 to +40°C Humidity: 5% to 85%

multiplexing/de-multiplexing, sub-band multiplexing/de-multiplexing, dummy light insertion, optical amplification and wavelength dispersion compensation functions.

The wavelength-division multiplexing/de-multiplexing function is connected to each transponder and multiplexes or demultiplexes the signal wavelength at channel spacing of 25 GHz at minimum. The sub-band multiplexing/demultiplexing function is connected to the wavelength-division multiplexing/demultiplexing function and multiplexes or demultiplexes signals on a per sub-band basis. When the number of transponders is less than specified, for example in the initial stage after the start of an operation, the dummy light insertion function inserts dummy optical signals in order to maintain a certain level of optical signal in the submarine transmission line. The optical amplification function amplifies the optical wavelength-division multiplexed signal before outputting it to the submarine transmission line and also amplifies the attenuated optical wavelength-division multiplexed signal received from the submarine transmission line. Finally, the dispersion compensation function compensates the wavelength-division multiplexed signals against wavelength dispersion accumulated in the submarine transmission line, either simultaneously for all wavelengths or on a per-sub-band basis.

(3) N:1 Redundancy Switch Block

The redundancy switch block is composed basically of a combination of optical switches, and is used to switch between a working transponder and a protection transponder. A single protection transponder can support up to 32 working transponders.

If a fault occurs with a working transponder, it is switched automatically to the protection transponder, which is switched automatically to the working transponder when it has recovered from a fault. In addition to the auto switching mode described above, forced switching and manual switching modes may also be selected.

4.2 Wavelength Extension

It is important for the wavelength-division multiplexing system that the wavelengths can be extended as required according to the demand for circuits. The terminal equipment introduced here can extend the wavelengths by adding the wavelength-division multiplexing/demultiplexing function for each combination of transponder and sub-band. **Fig. 3** shows an example of how to extend wavelengths. In the initial configuration, wavelengths can be extended using the transponders and wavelength-division multiplexing function in sub-band 1. When all of the wavelengths in sub-band 1 have been extended, subsequent wavelengths are extended by adding

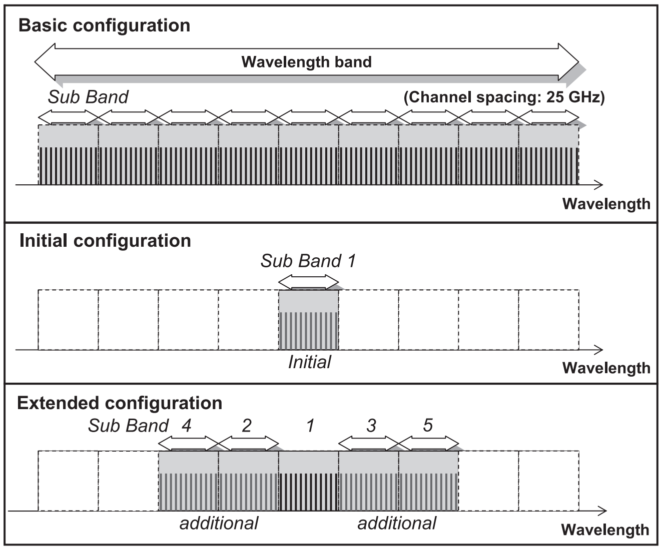

Fig. 3 Example of wavelength extension.

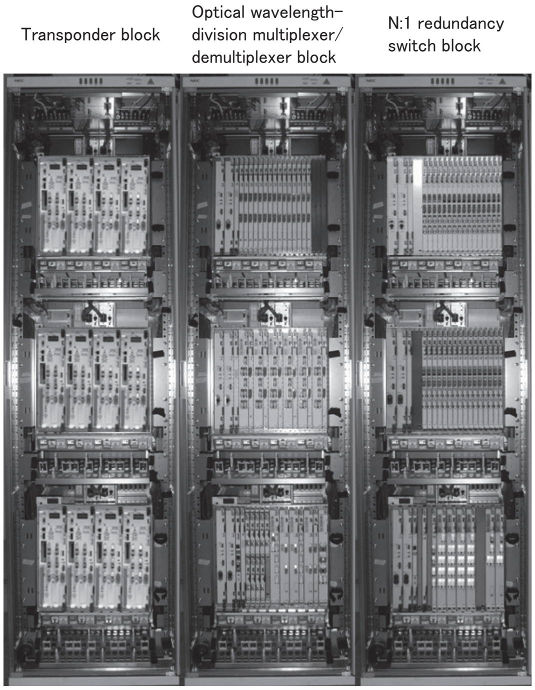

Photo External view of the T640SW LTE.

transponders and wavelength-division multiplexing functions of new sub-bands (sub-bands 2 to 5 in the example of the figure). As a result of the flexible extendibility of this function, the configuration shown will be able to deal with wavelength extensions accompanying the future introduction of 40 Gbps transponders.

4.3 External View of the Product

Photo shows an external view of the T640SW LTE. At the left of the photo is the rack accommodating the transponders, at the center is the rack accommodating the optical wavelength-division multiplexer/demultiplexer blocks and at the right is the rack accommodating the N:1 redundancy switch blocks. Each rack can accommodate three shelves and a power distributor panel that distributes the station power to each shelf. If the system is of a small scale it is also possible to mount the shelf of transponders, the optical wavelength-division multiplexer/demultiplexer block and the N:1 switch block in a single rack.

5. Conclusion

The T640SW LTE terminal equipment for the optical submarine cable system introduced above has already been applied and operated in support of many optical submarine cable systems, from large-scale international networks to relatively small-scale regional networks. In order to meet the current increased demand for international circuits, NEC are already developing innovative technologies aimed at increasing capacity and distance, as well as marketing products applying our previously developed technologies. The demand for improved circuit performance is expected to grow even more rapidly in the future.

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