FIELD PMD MEASUREMENTS OF A NEW 900-KM REPEATERED SUBMARINE SYSTEM DESIGNED FOR 43 G WDM TRANSMISSION

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Abstract: We develop and deploy a new 900-km submarine WDM system that offers 30 ch x 43-G transmission between Kyushu and Okinawa-Island in southwestern Japan. We use the results of computer simulations and transmission experiments to design the transmission line consisting of 9 spans of NZ-DSF with two spans of SMF in the middle. We set the allowable mean DGD at 2.6 ps considering statistical DGD variations over the 25-year system life. We measure the PMD of the system after installation and verify that the maximum measured mean DGD = 2.5 ps.

1. INTRODUCTION

40-Gbps based WDM transmission services [1], which will cost effectively support the rapidly increasing IP traffic, have become commercially available in the last few years. This is raises demands for 40 G submarine transmission services. Single channel 40 G transmission experiments [2] have been conducted on commercially-installed 10 G-based undersea facilities, but no report has examined commercial 40 G submarine systems after installation.

The main factor limiting the transmission capacity in high-speed long-haul transmission is PMD (Polarization Mode Dispersion) [3] [4]. PMD measurements in submarine systems were reported in [5][6][7][8][9][10]. None of them, however, assessed the impact of PMD on 40 G transmission performance in detail.

In this paper, we report the transmission system design of a newly installed 40 G oriented repeatered submarine system and the PMD measurements made on the system. We designed 30 ch x 40-G, 900 km undersea facilities and installed them for consumer use. Its design was confirmed by measuring the PMD of the installed fibers with high accuracy over a wide wavelength range.

2. 40 G SYSTEM DESIGN

The route of the submarine system is between Kyushu and Okinawa-Island in southwestern Japan. The route length is about 900 km including 15 km of land route. Though the transmission line facilities were designed to support 43-G transmission, it was initially operated as a 10-G based DWDM system. The initial capacity was 80 ch x 10G. The final capacity was to be 30 ch x 40 G.

First, after considering commercial technologies and our previous research results, we adopted the RZ-DPSK modulation format and 100-GHz channel spacing. The required optical amplifier bandwidth for 30 ch x 40 G was calculated to be 24 nm.

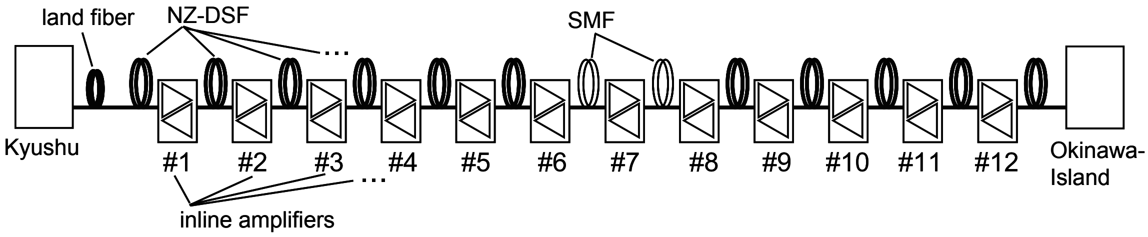


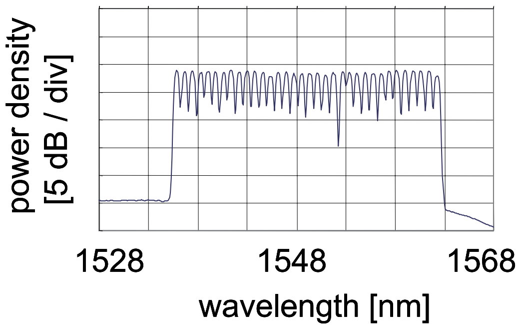
Figure 1: 900-km submarine transmission facilities

Next, theoretical OSNR calculations indicated 74-km mean repeater spacing. Accordingly, the 900 km submarine transmission line consists of 12 repeaters (13 spans). We set the fiber input power optimum considering total output power of inline amplifiers for the initial 10-G based system and their range of power adjustment.

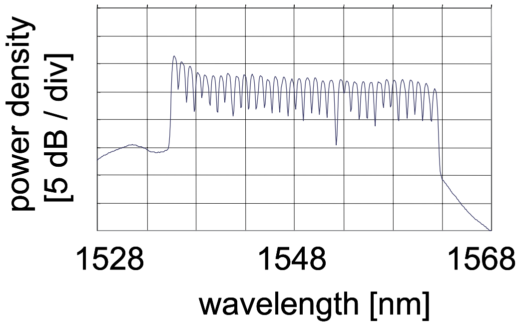
We then elucidated the fiber type and dispersion management by computer simulations on GVD (Group Velocity Dispersion) - nonlinear penalties. We settled on using 11 spans of NZ-DSF with two spans of SMF in the middle of the transmission line to compensate cumulated chromatic dispersion. Figure 1 shows the composition of the transmission line facilities as designed. We calculated that its nonlinear penalty would be 1 dB.

Our previous research results indicated that the PMD penalty of RZ-DPSK modulation format would be 2 dB at DGD (Differential Group Delay) = 9.2 ps. Considering DGD distributions, we specified the PMD of the entire transmission line to be not more than 2.6 ps, which ensures that the out-of-order time is shorter than one hour in the 25-year system life.

To complete the system design, we conducted 30 ch x 43 G transmission experiments. We constructed a 900-km straight line transmission system with transmission fibers and inline amplifiers in our laboratory. They had the same specifications as the consumer machines that were to be installed. The PMD value of the whole transmission line was about 0.3 ps, which was small enough to meet our specifications. The correctness of the design was confirmed by the measured values of 17.6-dB for mean received OSNR (at 43 GHz optical bandwidth) and 1 dB for nonlinear penalty. Figure 2 shows the optical spectrum of the experiments. (a) is the transmitted spectrum, and (b) is the received spectrum. Though the number of channels of the installed 40 G system was 30, we transmitted 33 ch x 43 G signals in the experiments using the outer limits of the wavelength range of the inline amplifiers.



(a) TX



(b) RX

Figure 2: Optical spectrum of transmission experiments

3. FIELD PMD MEASUREMENT OF REPEATERED SUBMARINE CABLE

We measured the PMD of the installed submarine facilities to confirm that the mean DGD did not exceed 2.6 ps. Measured facilities were 6 pairs of 900-km transmission fibers and 12 inline repeaters.

Wide wavelength range, automatic PMD measurements cause two problems with regard to inline amplifiers. One is the accumulation in ASE (Amplified Spontaneous Emission) noise. The other is transient optical surge. Optical surges are generated by the short optical signals used to transfer equipment status from transmitter to receiver.

We applied two techniques to solve the problems caused by the inline amplifiers. One was the insertion of programmable optical filters to reduce the cumulated ASE noise. The other was the use of continuous dummy lights to suppress the optical surges. Figure 3 shows the PMD measurement setup. At the transmitter, we injected continuous dummy lights together with the PMD measurement signal. At the receiver, we used a programmable optical filter to suppress the dummy lights and ASE noise. As shown in Figure 3, the dummy lights were suppressed to under the ASE noise level at the receiver.

To get highly accurate PMD data by measuring a wide wavelength range, we divided the optical amplifier bandwidth into three sections, shorter, center, and longer wavelengths. The bandwidth of each section was about 10 nm.

Figure 4 shows the measured results. Measured DGD values were around 1 ps, which satisfied our specifications. We calculated the mean value of DGD for each fiber and added 2 sigma as a margin, see Figure 5. Because the PMD measurements involved averaging over a finite sample set, accuracy was intrinsically limited. So we evaluated the measured value following [11]. We confirmed that the DGD of installed fibers satisfied our specifications even with the 2 sigma margin. In total, the results confirmed that the installed submarine systems can offer 30 x 43 G WDM transmission.

4. CONCLUSIONS

We developed and deployed a new 900-km submarine WDM system that offers 43-Gbps / ch transmission. Using RZ-

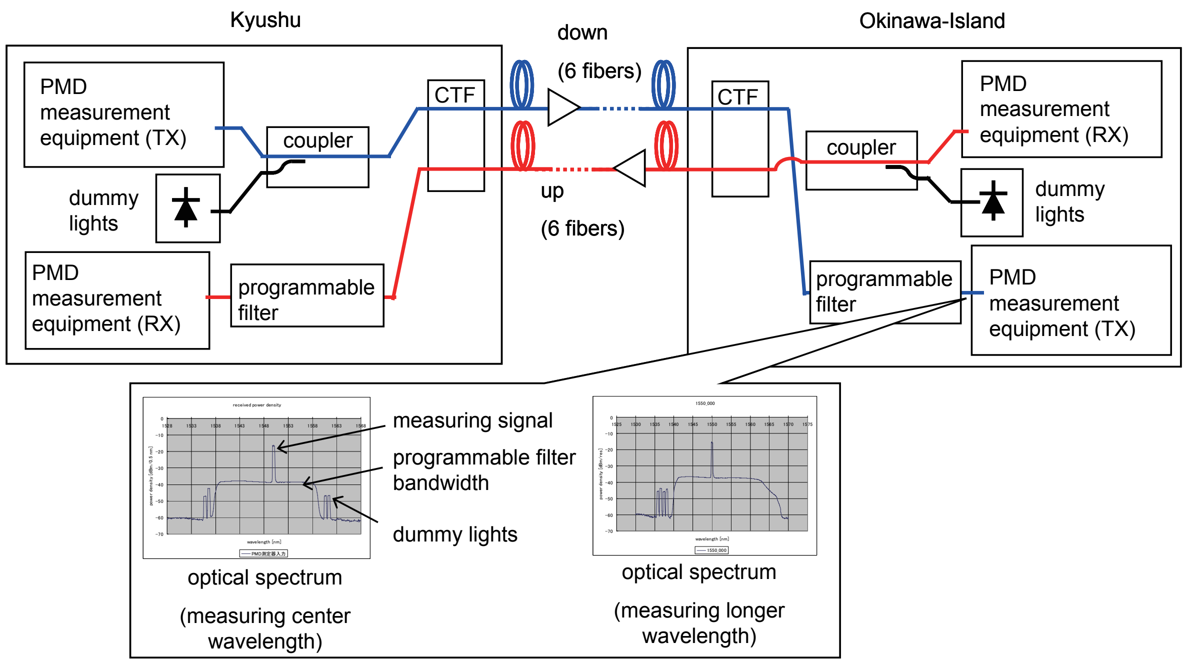


Figure 3: PMD measurement setup

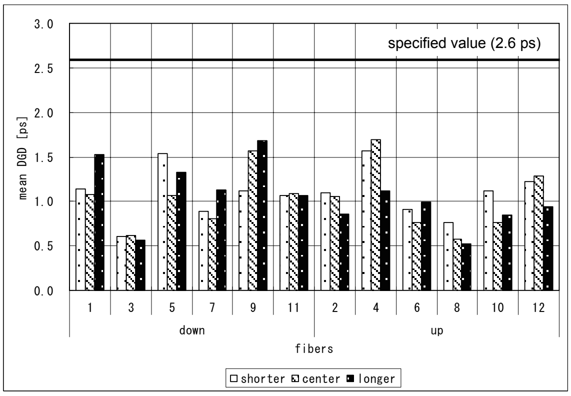


Figure 4: Measured mean DGD

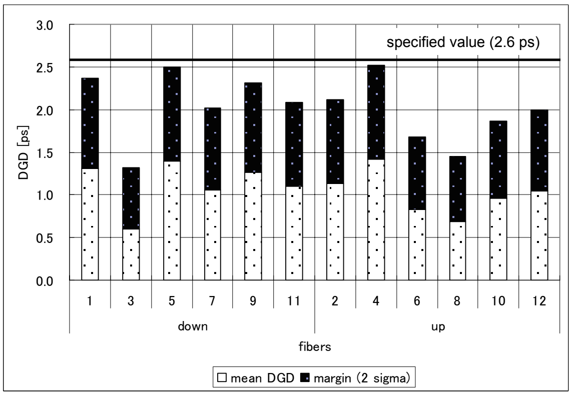


Figure 5: Evaluated DGD value

DPSK modulation format, we realized 30 ch x 43 G DWDM transmission. In our design, the transmission line consists of 11 spans of NZ-DSF and two spans of SMF, mean repeater span length is 74 km, and end to end DGD of submarine facilities is under 2.6 ps. We confirmed the transmission performance of our design by computer simulations and transmission experiments in our laboratory. We also measured the PMD of installed submarine facilities. All results confirmed that the installed submarine facilities could achieve 30 ch x 43 G WDM transmission.

5. REFERENCES

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