Transmission Experiment using Installed Submarine Cable for System Upgrade with RZ-DPSK

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Abstract

We have shown that a capacity of the transpacific system designed to support 8 x 2.5 Gbit/s can be increased to a factor of eight by using 16 x 10 Gbit/s RZ-DPSK in transmission experiments using a deployed submarine cable.

Introduction

Rapid increase of the internet traffic leads to several plans to deploy new transpacific submarine cable systems. From an economical view point, however, it is attractive to upgrade existing systems to increase its capacity by replacing the transponders. Recently various kinds of advanced modulation formats including DPSK are intensely studied in high-speed optical transmission and it is shown that they are one of effective solutions for the system upgrade [1]. To date, some reports on field trials show the effectiveness of RZ-DPSK for the system upgrade. In such reports [2,3], the system length can be doubled by using RZ-DPSK with keeping the total capacity and the channel bit rate of 10 Gbit/s. The upgrade of bit rate of legacy systems with 2.5 Gbit/s channels is also meaningful, since major channel interface in long-haul transmission systems shifted to 10 Gbit/s. In this paper, we conduct transmission experiments with a recirculating loop configured by a deployed submarine cable system and investigate the effectiveness of RZ-DPSK for upgrading legacy submarine cable systems with 2.5 Gbit/s channels.

Experimental Setup

The target transpacific submarine system is originally designed to carry 8 x 2.5 Gbit/s NRZ-OOK signals. A deployed submarine cable system with the same fibre and repeater type as the target system was used to investigate the system upgradability.

Fig. 1 shows the experimental configuration. In the transmitter, sixteen DFB LDs oscillating from 1553.3 nm to 1559.0 nm at 50 GHz interval were used. Even and odd channels were combined separately and fed into two cascaded $LiNbO_3$ (LN) modulators: the first one is for 10.7 Gbit/s data-coding in NRZ format with a 2^{31}-1 pseudo-random binary sequence (PRBS), and the second one is for bit-synchronous RZ forming. The duty ratio of RZ pulse was set to 50%. A pre-coder for DPSK was not used in this experiment due to the nature of PRBS. The WDM signals were dispersion pre-compensated and launched to the installed fibre with polarization scrambling at around 20 kHz to let the signals experience all the possible polarization dependence in the transmission line. In the receiver, the measured channel was selected with optical filters and dispersion post-compensated. Then the selected signal was demodulated by a Mach-Zehnder delay interferometer (MZDI) and detected by a balanced receiver. The transmission performance was evaluated by measuring a bit error rate (BER) with an error detector.

One fibre pair in the installed submarine cable was used as a transmission line. The deployed fibre are nonzero dispersion shifted fibre (NZDSF) with a dispersion and dispersion slope of around -2 ps/nm/km and 0.07 ps/nm^2/km at the centre of the signal band. The accumulated dispersion is compensated for by SMF inserted after the first span from Station A. The nominal span length is 50 km and the span loss is compensated for by EDFAs pumped at 1480 nm. The 1,200 km transmission line was configured with a loop-back at Station B. Since the accumulated dispersion of the target system is compensated for with about 500 km interval, spools of dispersion adjusting fibre with a dispersion of -1,240 ps/nm and 850 ps/nm were inserted at Station A and Station B, respectively.

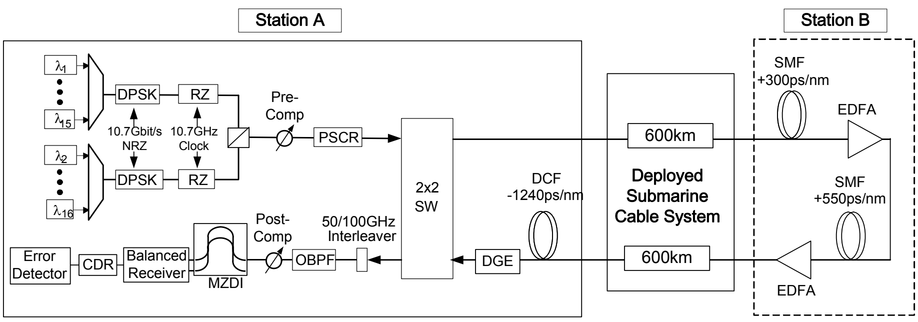

Fig. 1: Recirculating loop experimental setup using deployed submarine cable system

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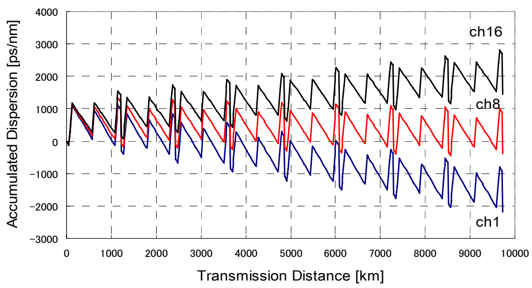
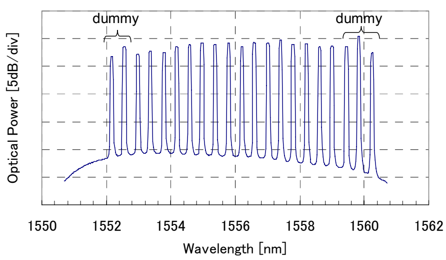


Fig. 2: Dispersion Map

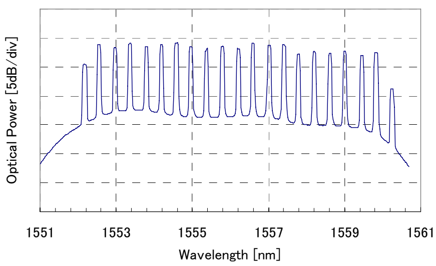
A dynamic gain equalizer (DGE) was used to emulate the gain profile of the target system with around 8 nm gain bandwidth. The recirculating loop was configured with the 1,200 km transmission line and transmission performance in transoceanic distances was evaluated.

Results and Discussion

The repeater output power of the deployed submarine system is 8.5 dBm, which is 0.5 dB higher than that of the target system. To adjust the channel power, some dummy lights were launched with the WDM signals. Fig. 3 shows the optical spectrum measured with sixteen WDM signals and five dummy lights. The best transmission performance was obtained in this configuration after 8,500 km. This indicates that some dummy lights is also required in the target system, since adding five dummy lights to sixteen WDM signals results in the channel power reduction of 1.2 dB.



(a) Before transmission



(b) After 8,500km transmission

Fig. 3: Optical Spectrum measured with CW lights

Fig. 4 shows the measured OSNR and Q-factor calculated from the measured BER. The average and worst Q-factor obtained after 8,500 km transmission was 11.4 dB and 10.9 dB, respectively, which exceeds the FEC limit of a concatenated code with 7 % redundancy. Similar transmission performance was obtained for all channels even without dispersion slope compensation in transmission line.

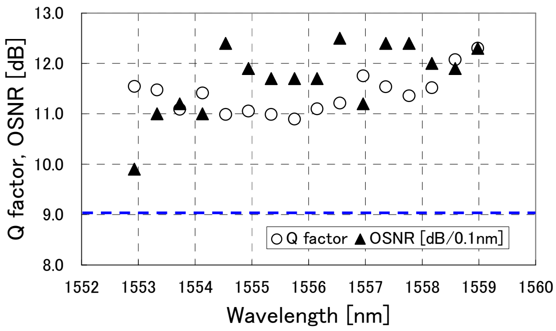


Fig. 4: Measured Q factor and OSNR after 8,500km transmission

Fig. 5 shows the transmission performance of Channel 9 as a function of transmission distance. In Fig. 5, the transmission performance with 10.7 Gbit/s RZ-OOK format is also shown. For RZ-OOK signal reception, the MZDI was removed and an input port of the balanced receiver was used. As shown in Fig. 5, the performance degradation with transmission distance was similar for RZ-DPSK and RZ-OOK, which indicates that the nonlinear penalty of RZ-DPSK was not larger than RZ-OOK even in transoceanic transmission. The obtained Q factor with RZ-OOK was around 1.5 dB lower than that with RZ-DPSK, and sufficient performance could not be obtained with RZ-OOK in transpacific transmission.

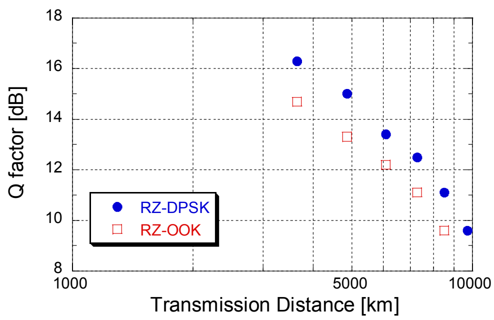


Fig.5: Transmission distance dependency (ch9)

Conclusions

We have conducted a recirculating loop experiment using a deployed submarine cable system and shown that a capacity of the trans-pacific system designed to support 8 x 2.5 Gbit/s NRZ-OOK can be increased to a factor of eight by using 16 x 10 Gbit/s RZ-DPSK.

References

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