IMPROVEMENT OF SUBMARINE SYSTEM TRANSMISSION USING 100GBIT/SEC DP-QPSK WITH LEGACY FIBER TYPES BY UTILIZING NONLINEAR COMPENSATION ALGORITHM

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Abstract: The effect of using the nonlinear compensation algorithm to the existing submarine cable systems using NZ-DSF and DMF were examined, and the improvement was confirmed. Moreover, in case of coexistence of 10 Gbit/sec OOK signal, the effect of the algorithm was confirmed as well, which is very effective for overlaying 100 Gbit/sec DP-QPSK signal to the existing legacy fiber installed submarine transmission system.

1. Introduction

To satisfy the demand of the increase of transoceanic capacity, new system configuration is being studied with digital coherent technology.
On the other hand, existing system using legacy types of fiber limits the transmission lengths due to the larger nonlinear degradation.
This indicates that in the legacy fiber type system, the introduction of the nonlinear compensation technology is highly expected to be introduced for the large improvement of the performance. Recently nonlinear compensation technologies are making progress [1, 2].
In this paper, we present our examination of nonlinear compensation effect on existing submarine transmission systems using legacy fiber types.

2. Applying nonlinear compensation

We adopted PBP (Perturbation Back Propagation) [1] and NPCC (Nonlinear Polarization Crosstalk Canceller) [2] for the nonlinear compensation (NLC) by data processing at the receiver side. The number of steps of PBP is assumed to be 3.
The effect of NLC on the existing transmission system using legacy fiber types such as NZ-DSF (Non-Zero Dispersion Shifted Fiber) and DMF (Dispersion Managed Fiber) is examined by simulation.

3. Examined result

3.1 NZ-DSF system

Table 1 and Figure 3.1 show simulation parameters and dispersion map.
In Figure 3.2, we explain the change in the Q vs. OSNR characteristic by the NLC for a signal at 1559 nm.
Received Q value is expected to be improved by the nonlinear compensation (NLC). The optimal OSNR which reflects to the increase of input power by 1dB and Q value is improved by 1.2 dB.
This may shift the optimal optical output power of each repeater, which requires 100G signals to be adjusted to be overlayed.

Table 3.1 parameter for NZ-DSF system

Bitrate	127.156 Gbit/sec
Number of channel	5
Wavelength	1530-1560 nm
Modulation format	NRZ/RZ-aligned/interleaved DP-QPSK
Nonlinear compensation algorithm	PBP (Perturbation Back Propagation) and NPCC (Nonlinear Polarization Crosstalk Canceller)
Channel spacing	50 GHz
Repeater NF	4.5 dB
Fiber dispersion	-2.9 ps/nm/km
Dispersion slope	0.055ps/nm^2/km
Aeff	50μm^2
Loss	0.208 dB/km
Span length	75 km
Transmission length	4,024 km

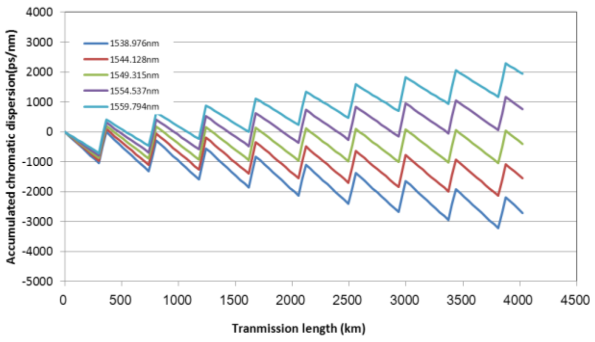

Figure 3.1 Dispersion map for NZ-DSF system

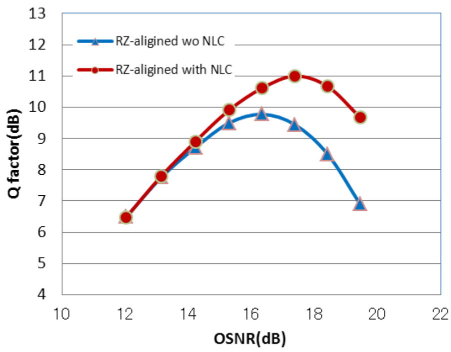

Figure 3.2 OSNR dependence of Q value after NZ-DSF 4000km-transmission (1559.794nm).

In Figures 3.3 and 3.4, relative Q characteristics with and without NLC were shown respectively. Relative Q (ΔQ) is defined as the difference from the reference Q value, which is the best Q value without NLC (RZ-interleaved at -3 dBm/ch) in both Figures. Interleaved means that the signals of dual polarization are half bit shifted. The sensitivity and the amount of the improvement of each modulation format were examined at this channel.

Hereafter, NRZ/RZ-interleaved DP-QPSK and NRZ/RZ-aligned DP-QPSK are abbreviated in the graphs as NRZ/RZ-i and NRZ/RZ- a, respectively.

We observed that the advantage of RZ-interleaved against the other cases, which is observed for the case without NLC, is no longer effective if we use NLC. This is because NLC compensates nonlinear degradation which took the role of RZ-interleave to mitigate as well.

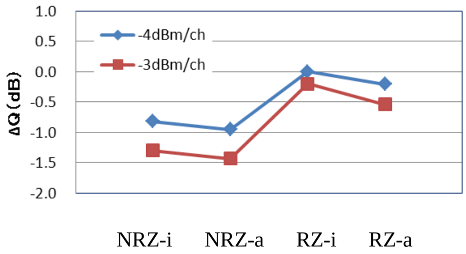

Figure 3.3 Q factor without NLC
(ΔQ is normalized at Q factor of RZ-i without NLC at -4 dBm/ch)

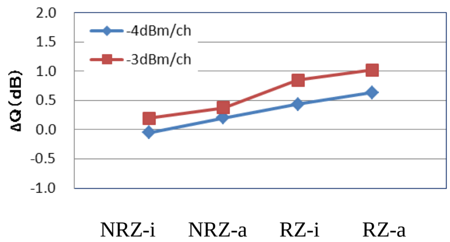

Figure 3.4 Q factor with NLC
(ΔQ is normalized at Q factor of RZ-i without NLC at -4 dBm/ch)

In Figure 3.5, the channel dependence of Q value was shown. The amounts of the improvement by NLC are from 0.5 to 1.6 dB on the entire signal bandwidth. The maximum improvement was observed in the condition of NRZ-a for 1560 nm.

Four adjacent signals were set to both sides of the evaluated channel.

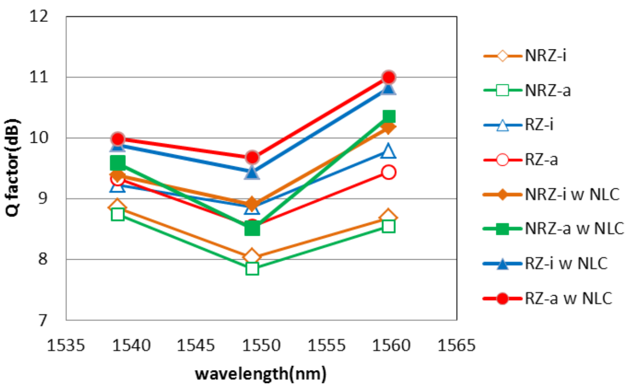

Figure 3.5 channel dependence of Q value

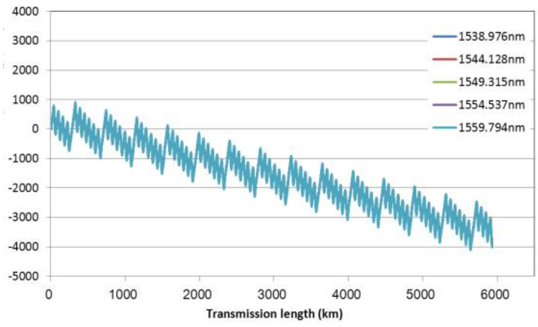

Figure 3.6 Dispersion map for DMF system

3.2 DMF system

Figure 3.7 shows the OSNR dependence of Q value of RZ-aligned DP-QPSK after DMF 6,000 km-transmission. RZ-aligned was chosen according to the result of NZ-DSF case using NLC.
The optimal ONSR (fiber input power) rises by 2.5 dB, and Q value is improved by 1.3dB.

Table 3.2 parameter for DMF system

Bitrate	127.156 Gbit/sec
Number of channel	5
Wavelength	1530-1560 nm
Modulation format	NRZ/RZ-aligned/interleaved DP-QPSK
Nonlinear compensation algorithm	PBP (Perturbation Back Propagation) and NPCC (Nonlinear Polarization Crosstalk Canceller)
Channel spacing	50 GHz
Repeater NF	4.5 dB
Fiber dispersion(+D/-D)	20.5/-39.5 ps/nm/km
Dispersion slope(+D/-D)	0.06/-0.109 ps/nm^2/km
Aeff(+D/-D)	113/31 um^2
Loss(+D/-D)	0.168/0.235 dB/km
Span length	62.4 km
Transmission length	5,939 km

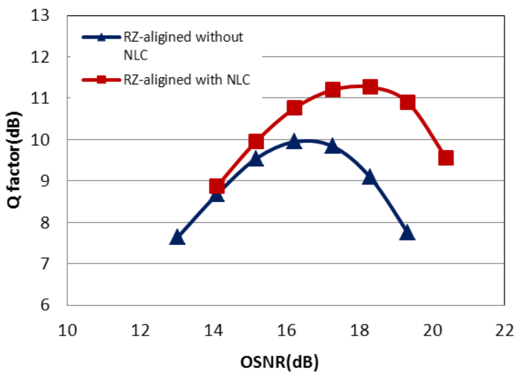

Figure 3.7 OSNR dependence of Q value after DMF 6,000km-transmission (1550.114nm).

4. Mixture with coexisting 10 Gbit/sec OOK signal.

Upgrading capacity on existed system with legacy fiber types by using 100G DP-QPSK, the signal degradation of 100G signal may occur by an existing signal. Especially, when an existing signal is 10G OOK, this deterioration should be large. This deterioration can be mitigated by enlarging the channel spacing and thus enlarging walk off. To maximize the system capacity, on the other hand, it is preferable to minimize this spacing.
In a DMF 6000-km transmission simulation, a 100 Gbit/sec RZ-aligned DP-QPSK signal and one 10 Gbit/sec OOK signal were propagated with various channel spacing to examine on this trade-off.

The Q value can be improved and Q margin can be obtained by applying NLC. The wavelength spacing between the 100G and 10G OOK signals can also be reduced as a consequence.

The channel spacing dependency is shown in Figure 4.1. The improvement by NLC is the reduction of the penalty.

If we assume the Q criteria to be 10 dB, the channel spacing can be narrowed down to 50 GHz by introducing NLC, while it has to be as large as 300GHz without NLC.

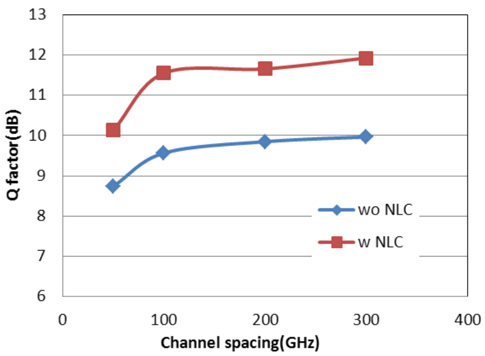

Figure 4.1 channel spacing dependence between 100G DP-QPSK and 10G OOK signal

5. Conclusion

The improvement with PBP and NPCC was confirmed with the NZ-DSF and DMF legacy systems over 4,000km. It was also confirmed that the wavelength spacing between 100G DP-QPSK and existing 10G OOK signal can be reduced thanks to the NLC algorithm.

Acknowledgement

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[2] L. Li *et al.*, “Nonlinear Polarization Crosstalk Canceller for Dual-Polarization Digital Coherent Receivers” OFC2010, paper OWE3.