A STUDY OF UPGRADEABILITY USING THE RZ-DPSK FORMAT ON EXISTING WDM TRANSMISSION SYSTEM

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Abstract: We examined a technique for upgrading a system by using RZ-DPSK and confirmed its feasibility. Optimizing the channel interval reduces the interference between signals in a system with a mixture of RZ-OOK and RZ-DPSK. Optimization of waveform improves the transmission performance.

1 INTRODUCTION

By using the modulation format, which has excellent receiver sensitivity, it is possible to increase the capacity or reduce the price of submarine optical communication systems. RZ-DPSK is expected to provide a 3-dB improvement in comparison with RZ-OOK modulation. For this sensitivity improvement, the number of repeaters can be decreased by 30 - 40% because of an easy OSNR calculation at long segment such as transpacific route. Considering the typical construction of new cable system, the ratio of prices of a submerged plant is large (about 60%). It is effective to the reduction in the entire cost to decrease the number of optical repeaters.

In addition, adopting RZ-DPSK can increase the number of channels, in a system whose channel number is limited by OSNR. Since the spectrum spread is 10% less than by RZ-OOK, RZ-DPSK can reduce the channel interval from 37.5GHz to 33.3GHz.

On the other hand, as international traffic increases, there is strong demand for increasing the transmission capacity of submarine cable systems.

In this study, we investigated the possibility of upgrading the existing WDM transmission system using the RZ-DPSK format.

2 SYSTEM UPGRADE

There is demand for increasing the transmission capacity of submarine optical cable systems to meet the increase in communication traffic. One way to do this is to lay a new submarine optical cable and construct a submarine terminal. The others are upgrades. Following three methods are practically provided.

2.1 Addition of new tributary to a vacant slot in the SLTE

The upgrade method includes increasing the optical channels by connecting an optical transmitter and an optical receiver to vacant ports of a multiplexer and a branching filter in an existing WDM optical transmission device (Fig.1-1). This is the cost effective method, which requires no modification of the existing connection of SLTE from the initial. This is applicable for the WDM system, which has the capability of full WDM connection ports. Since the WDM part of the existing SLTE is not changed, the possible number of wavelengths is limited by the number of wavelength of the existing SLTE. Also, the channel spacing of new tributaries is not flexible. Therefore, the adopting RZ-DPSK is not suitable for this upgrade method in order to realize maximum number of wavelength.

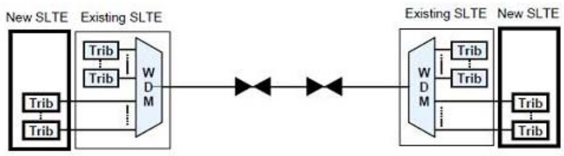

Fig 1-1 Upgrade by adding new Tributaries

2.2 Addition of new SLTE to existing SLTE via optical coupler (coupler insertion: CI)

A further method is to provide optical branches respectively on the transmission side and on the receiver side of the terminals corresponding to existing optical signals (optical channels) relative to the initial configuration of the WDM optical transmission system, to increase the number of terminals corresponding to the new optical channels (Fig.1-2). Accordingly, it may be possible to increase the number of more wavelength by using RZ-DPSK.

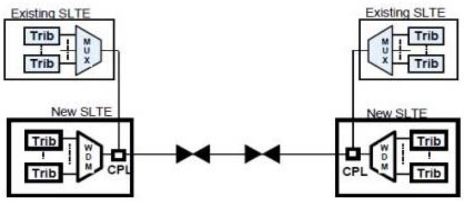

Fig 1-2 Channel Upgrade using coupler insertion

2.3 Replacement to new SLTE from the existing SLTE

Another method is to replace the existing SLTE with a new one. A high capacity new SLTE is deployed to the system instead of the existing one. This method is expected to provide the highest capacity by adopting the newest technologies to improve the performance deployed in new SLTE. Moreover, the upgrade method is suitable for a dark optical fiber that has been laid already but not used.

In case of this upgrade method, the largest number of wavelength may be obtained by using RZ-DPSK.

3 FEASIBILITY FOR UPGRADING WITH RZ-DPSK

RZ-DPSK can increase the number of channels of the system that is limited by OSNR. However, there are some points to be careful about for upgrading to existing system with RZ-DPSK.

3.1 Combination of RZ-OOK and RZ-DPSK

When a phase modulation method such as RZ-DPSK is applied to the optical signal to be increased, if the modulation method of the existing optical signal adjacent to the optical signal to be increased in the wavelength range is not phase modulation but intensity modulation such as RZ-OOK, then the transmission characteristic of the phase-modulated optical signal to be increased may deteriorate due to interaction with the intensity-modulated optical signal. In other words, the phase-modulated optical signal carries information on the optical phase, but there is a possibility that information of the intensity-modulated optical signal may be carried on the phase of the phase-modulated optical signal as noise due to cross phase modulation (XPM) from the adjacent intensity-modulated optical signal. If this occurs, then the transmission characteristic of the phase-modulated optical signal deteriorates, which causes a problem.

The magnitude of this deterioration is proportional to the magnitude of average at time of overlap integration of two signals. Therefore, it depends on the channel spacing, chromatic dispersion and light power.

Figure 2 shows the result of our experiment on the penalty by XPM from RZ-OOK to RZ-DPSK at 7,000 km. The penalty is small in the area where the accumulated chromatic dispersion is large, but rapidly increases in the area where the accumulated chromatic dispersion is small as the channel interval narrows.

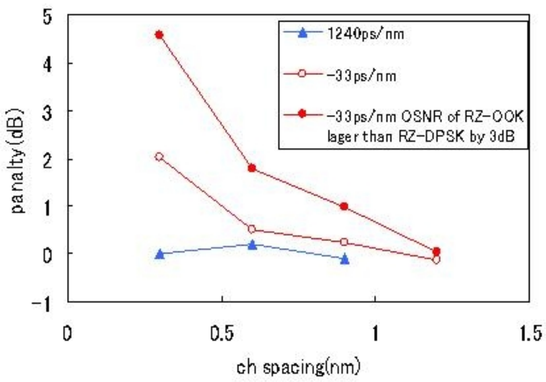

Fig 2 channel spacing dependence of signal degradation

In case of upgrade that is addition of new SLTE to existing SLTE via optical coupler as described in section 2.2, it is necessary to allow 1 nm or more as a guard band between existing signal and new RZ-DPSK signal in the zero chromatic dispersion region especially.

3.2 Influence of phase noise by accumulated ASE

Furthermore, RZ-DPSK is known to be influenced by phase noise by accumulated ASE noise [4], and the receiver sensitivity deteriorates, particularly in the zero dispersion region [5].

Although it has been reported that the transmission characteristic of RZ-DPSK is inferior to that of RZ-OOK over long distances, it greatly depends on the parameters of the transmission system used in these comparisons, as pointed out in [5]. Especially, for realistic channel intervals at 37.5 GHz or 33.3 GHz, the sensitivity of DPSK is better than that of RZ-OOK. This is thought to be because as the spectrum extension of RZ-OOK is large, crosstalk grows, and so sensitivity deteriorates.

Moreover, the parameters of RZ-DPSK are optimized, and the result of correspondence is shown in the Figure 3. The pulse duty was optimized as a parameter. The change of Q value when duty is changed in the state of constant optical power is shown. The duty was varied by adjusting the bias of the LiNbO3 modulator of the pulse caver. Moreover, driving amplitude has been adjusted if necessary.

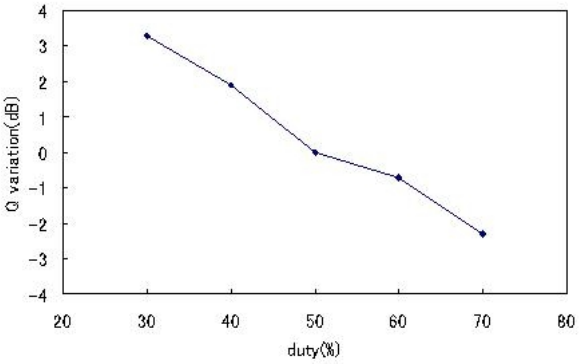

Fig 3 Duty dependency of Q factor

The improvement with a channel deteriorated in zero dispersion region of the WDM transmission （37.5GHz interval ） is shown in Figure 4. Q value has improved 1dB by optimizing DUTY from 50 to 30%.

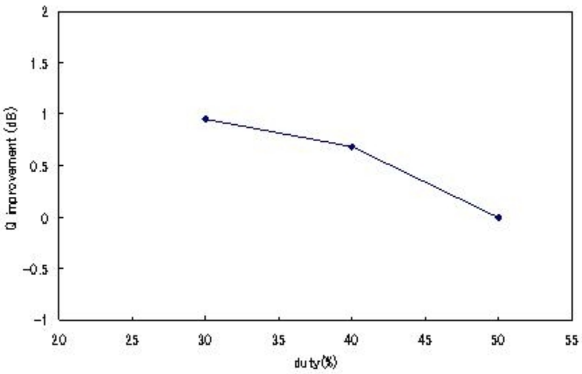

Fig 4 Sensitivity improvement
by Duty optimization

Q factors at around zero chromatic dispersion region that becomes a restriction of the system design can be improved by using this technique.

In case of upgrade that is replacement to new SLTE from the existing SLTE as described in section 2.3, there are two approaches to improve the characteristics in the region in the system design as the above;

(1) RZ-OOK is applied only to the zero dispersion region. (2) The parameters of RZ-DPSK are optimized.

4 SUMMARY

We investigated methods for avoiding interference with existing signals in the case of using RZ-DPSK for upgrading the optical submarine transmission system. We also investigated measures against sensitivity deterioration when only RZ-DPSK signals apply to the existing system.

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