Assessment of Capacity Upgrade Using 40Gbps DPSK Transmission in 10Gbps DWDM ROADM Networks

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Abstract: We present a detailed study for capacity upgrade using 40Gbps DPSK transmission in 10Gbps optimized 50GHz spaced DWDM ROADM systems. It was found that further optimizing the chromatic dispersion pre-compensation for 40G channel can significantly improve its transmission, and the neighboring 10G channels have negligible impact on the 40G transmission.

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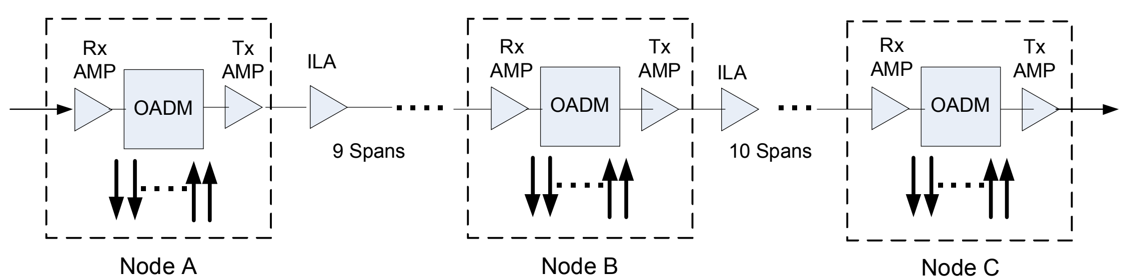
Introduction

In order to meet the rapid increasing capacity demand, increasing the transmission rate of individual channel of the deployed DWDM systems becomes another option in addition to deploying new DWDM optical line systems [1]. For example, carriers are adding 40 Gbps channels into the existing legacy 10G optimized DWDM systems [2, 3]. However, there are many challenges to add high rate optical transmission channels to a low rate optimized DWDM systems. First of all, it is desirable that the high rate channels can transmit the same distance as the low rate channels since the add/drop sites have been deployed based on the low rate signals, which puts a great constraint on the transmission margin for the high rate channels. Secondly there are additional penalties when adding the 40G channels in the 10G DWDM systems compared to the 40G only or 10G only optimized DWDM systems. For examples, the optimum chromatic dispersion compensation scheme and launch powers are different between the low rate and high rate channels, the penalty due to the crosstalk between the high rate and low rate channels could be higher than that of between the pure high rate or low rate channel only cases, and the narrow channel spacing could also introduce much higher penalty for high rate channel than the low rate channels.

In this work, we intend to investigate the penalties and limitations of adding 40G DPSK (differential phase-shift keying) channels into legacy 10G optimized 50GHz DWDM ultra long haul ROADM networks. The effect of launch power of 40G channels on their performances and the impact from neighboring 10G channels were studied in details. The chromatic dispersion pre-compensation penalty for 40G channel was characterized based on the optimized 10G DWDM systems.

Test Configuration



Figurer 1. Experiment configuration. The 40G channels are transmitted from Node A to Node C, and expressed through the Node B. The total transmission distance is 1520 km of SMF fiber.

We set up a ROADM DWDM mesh network using six ROADM nodes which have been widely deployed in the field. The transmission was optimized for 10Gbps NRZ (non-return-zero) OOK (on-off-key) 80 channels (50GHz spaced over the C-band) over SMF fiber, and ROADM nodes are made of 50GHz spaced wavelength blocker or wavelength selective switch with 100% add/drop capability. The transmission test for this work was carried out on the longest transmission link of the setup, and the test configuration is shown in Fig. 1. The optical transmission line between the Node A and B consists of 9 spans 80 km of SMF fibers, and 10 spans between Node B and C. The average loss of the fiber was 0.19 dB/km, average PMD less than 0.05ps/sqrt(km). The span loss of all the spans was adjusted to about 21 dB by line padding. There are dispersion compensation modes (DCM) placed in the mid-stage of in-line amplifiers, booster and pre-amplifier, and the dispersion map used was 10G optimized.

The 40Gbps transponders transmit NRZ-DPSK signals and have a tunable dispersion compensation module (TDCM) integrated with the receiver to dynamically optimize the residual chromatic dispersion based on the feedback of the preFEC BER. The 40G signals transmitted from Node A to Node C via express Node B. In order to characterize the chromatic dispersion compensation impact for 40G channels, we added fixed DCMs between the 40G transponder transmitter and the channel multiplex port. The launch power of all 80 channels can be controlled individually; we altered the power of 40G and 10G channels to study the impact of 10G channels to the neighboring 40G channels and to characterize 40G channel's performance against the launch power.

Results and Discussions

Figure 2 shows the preFEC BER versus the additional chromatic dispersion added at the transmitter side for three channels which covers almost the entire C-band. The configuration had a DCM in the booster with a pre-compensation ratio of 37%. From the figure, we can see that the optimum pre-compensation for 40G is significantly different from 10G, the optimum pre-compensation for 40G is 170 to 340 ps/nm more than that for 10G signals. Without the additional pre-compensation, the preFEC BER of 40G could be degraded for about 1 order of magnitude. It is important to note that this optimized additional pre-compensation value would change if the span length of the first span changes or the fiber type is other than SMF. It may be a good option to use a TDCM instead of fixed DCM for this additional pre-compensation optimization for dynamic optimal adjustment.

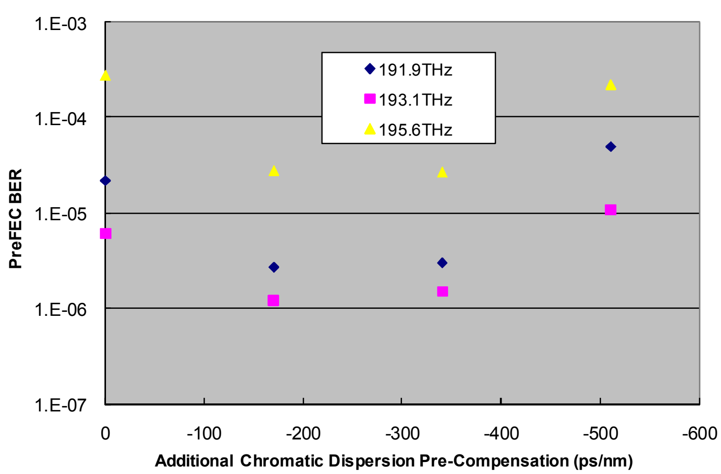


Figure 2. PreFEC BER of 40G channels versus the chromatic dispersion values for additional pre-compensation. The three 40G channels are located at 191.9, 193.1 and 195.6 THz with 10G neighboring channels.

Next we investigate the impact of launch power on 40G DPSK transmission's performances. As an example, Fig.3 shows preFEC BER of the 40G channel at 191.9 THz against its launch power. We allocated four 10G channels on each side of the 40G, and all the 10G channels' power was kept at its optimum value of 1.5 dBm/ch. The results indicate that the optimum launch power is about 2 dBm per channel for the DPSK 40G transmission. If the launch power is reduced below the optimum value, the transmission becomes OSNR limited. On the other hand, once the launch power is above 2 dBm per channel, the non-linearity impairments set in and overtakes the benefits of enhanced OSNR. The figure also shows the preFEC BER comparison for the 40G channel when the neighboring 10G channels were turn on and off. To our surprise, it can be seen that the impact of neighboring 10G to the 40G is very small even at the 50GHz spacing. This finding is highly beneficial for the carriers since there is no channel count reduction or restriction for the DWDM systems when adding 40G DPSK channels.

Figure 4 shows the 40G DPSK channel's preFEC BER as a function of the launch power of its neighboring 10G channels, where the launch power of the 40G channel was kept at 1.5 dBm. Both the maximum and average preFEC BER over the measured 15 minutes bin are presented. The results demonstrated that 40G channel's performances degrade when the launch power of its neighboring 10G channels is above 1.5dBm, but do not changes when the power is below 1.5 dBm/ch.

Intuitively we can expect that the above findings will not apply for the transmission using non-zero dispersion shifted fibers because the non-linearity properties in these fiber types are different from those in SMF used in this experiment.

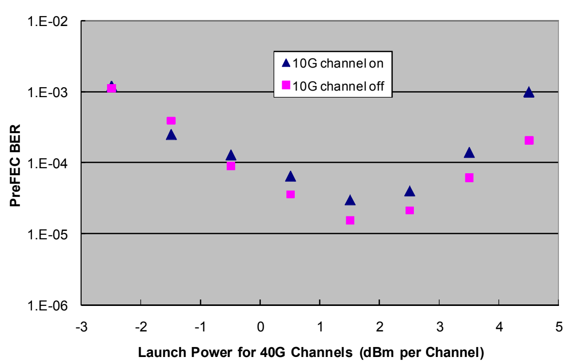


Figure 3. PreFEC BER versus the launch power of 40G channels with the neighboring 10G channels turning on and off.

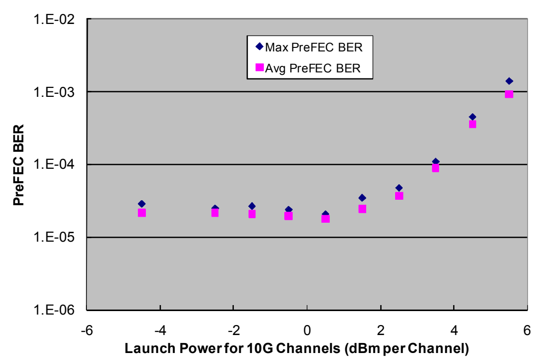


Figure 4. PreFEC BER of 40G channels versus launch power of neighboring 10G channels.

Conclusion

We carried out a detailed study of capacity upgrade of using 40Gbps DPSK transmission in deployed 10Gbps DWDM ROADM networks. It was found that further optimizing the chromatic dispersion pre-compensation for 40G channels can significantly improve their transmission performance, and it is recommended that using a TDCM in the transmitter side of 40G transponders can optimize the pre-compensation and simplify the operation. Moreover, the optimum launch power for 40G transmission is slightly different from that of 10G channels. However, the performances of 40G transmission experience negligible impact from its neighboring 10G channels even at 50GHz channel spacing in the normal operation.

References

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