Unique On-line Loop Testing System Methodology for Coherent Systems

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Abstract: We propose a methodology for 46Gbps polarization-division-multiplexed binary phase shift keying (PDM-BPSK) coherent commercial linecard achieving transmission on the recirculating system with on-line testing mode. Comparison experiments between adapted on-line and commercial version were executed on back to back, transmission over 1139km straight line, 5695km dispersion managed loop system, and over 6600km another dispersion managed fiber system, the results were matched very well and indicated its feasibility.

1. INTRODUCTION

Recirculating loop testing system is proved to be an effective and industrial best practice especially for ultra long-haul system [1]. It could simulate the field configuration for both SLTE (Submarine Line Terminal Equipment) and fiber configuration before we make real investment to remove the biggest technical risk for project delivery, and provide fundamental support for new technology research and validation.

Usually, limited to the loop working characteristics, on-line mode meets obstacles to emulate the linecards over the recirculating loop system especially for coherent detection with digital signal processing (DSP) age coming. As a result, off-line is also a common method used in the loop system to simulate the ultra long system transmission performance when the length of transmission link can not meet with the length requirement of the straight-line systems. However, it will inevitably decrease the confidence of the real effect of the coherent system when deployed in the real cable.

In this paper, we first propose a unique on-line loop testing method for coherent systems. Furthermore, to prove on-line loop testing methodology feasible, We executed comparison experiments on back to back (BTB), transmission of 31x 46Gbps PDM-BPSK signals over 1139km straight-line and 5695km loop system of dispersion managed fiber, and 64 x 46Gbps PDM-BPSK signals transmission over 6600km another dispersion managed fiber system.

2. ON-LINE METHODOLOGY

The DSP chipset is the critical component for the on-line cards receiver based on coherent technology, since it must perform algorithms to track and retrieve the incoming phase and polarization state of the signal in real-time, consequently allowing a real-time error counting and bit-error-ratio (BER) computing accordingly. It is used to estimate and compensate the chromatic dispersion (CD), track the polarization, compensate the differential group delay and recover the carrier phase.
It will cost quite long time due to the huge quantitative algorithm calculation, so electronic calculation time can hardly keep up with the optical signal changing in the loop.

We carefully analysed the processing time, and found that the CD estimation (CDE) and CDC, Clock Recovery (CR) cost long time. For shortening the algorithm processing time, we would optimize CDE&CDC and CR.

Provided that acquiring system transmission performance after N roundtrips, the system configuration was settled, so the residual CD was known. We configured the CDE range of the DSP at this given value to shorten estimation period before the N loop signal arriving. At the same time, we needed an external burst signal to trigger the DSP. When the N-roundtrip signals arriving and trigger pulse valid, the CDE and CDC started working and repeated several times to eliminate the abnormal points. The CDE&CDC time would be considerably decreased.

CR function block is also time-consuming. Unlike the end to end field, lab system transmission sites are located in the same room. We usually use the same linecards as transceiver. Combining this characteristic, we can use the local clock instead of CR.

After careful adaption combined with loop characteristics, we reconfigured the loop controlling scheme and selected the most important functions to make the processing time matching the linear loop length. We called it adapted on-line version.

After validation, the shortest length of loop link is less than 600km that makes the DSP processing time less than 3ms. On-line mode being successfully deployed in the recirculating loop obviously decreases the amplifiers and fibers expenditure for ultra long system research.

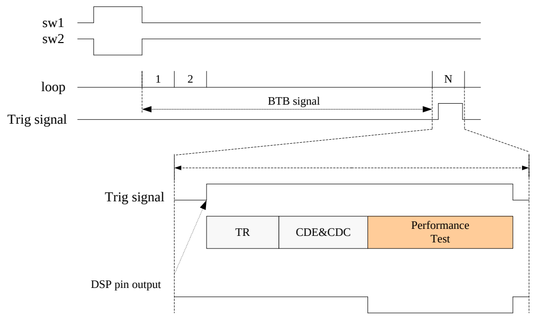

Fig 1: on-line test timing diagram

3. BTB SETUP

The first verification scenario was BTB that was basically to investigate the difference between the released board version and the adapted on-line version. The experiment setup was as figure 2. One 46Gb/s PDM-BPSK modulator was used to generate the bulk modulated loading channels. We then de-correlated the loading channels with a couple of WSS (wavelength selective switching) to decrease the penalty induced by the signals correlation for modulating by the same modulator. At the same configuration for SLTE with the project deployment, the loading channels were divided with DEMUX and then coupled with commercial linecard with MUX. The operating band covered from 1536.22nm to 1560.20nm. We obtained the OSNR difference between adapted on-line and released version at the same BER by adding and adjusting the ASE (Amplified Spontaneous Emission) source level.

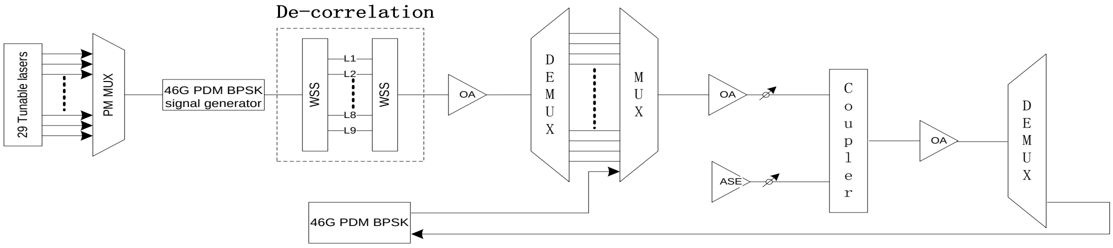

Fig 2: BTB configuration

4. BTB RESULTS

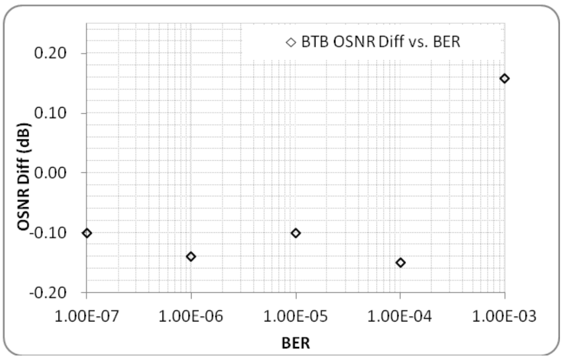

Fig 3: OSNR difference between on-line and commercial version versus BER

The result indicated that there was almost no difference between them. Based on it, we could make further validation, such as straight line and loop system.

5. TRANSMISSION EXPERIMENT SETUP

The SLTE configuration for system transmission was the same as BTB. The transmission link consisted of optical amplifier, dispersion managed fibers, adjustable equalizer. The fibers of 1139km loop link were composed of 18 hybrid transmission spans NZDSF, each combining two types of fibers with effective areas of 70 μ m^2 and 50 μ m^2 , respectively. The average dispersion coefficient of each hybrid span was adjusted at -3.3ps/nm.km. Two dispersion compensation spans were NDSF fibers of large effective area of 101 μ m^2 and chromatic dispersion of 18.7ps/nm.km at 1550nm. The average span loss was 14dB, which was equivalent to a span length of ~65km. The average optical amplifier output power was 14dBm. One gain equalizer was used in the link to compensate the uneven spectral gain profiles of optical amplifiers.

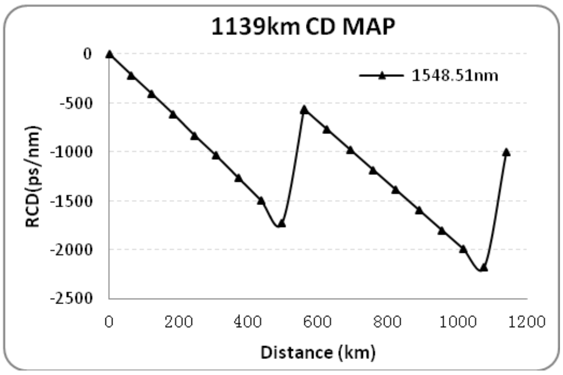

Fig 4: CD map for the 1139km loop link

Fig 5 shows the system configuration. T1 and T2 were AO (Acoustic Optical) switches. Firstly, we tested transmission performance over straight line by switching off T1 and opening T2; then acquired the one loop performance by interchanging the T1 and T2 status.

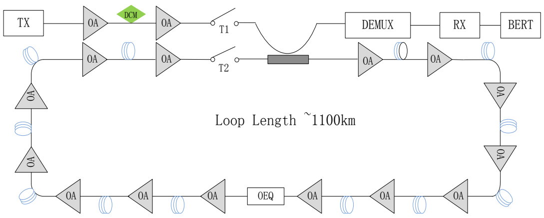

Fig 5: Loop system setup

6. TRANSMISSION EXPERIMENT RESULTS

31x46G PDM-BPSK at 100GHz channel spacing over 1139km straight-line and one loop transmission experiments with different card's version were executed.

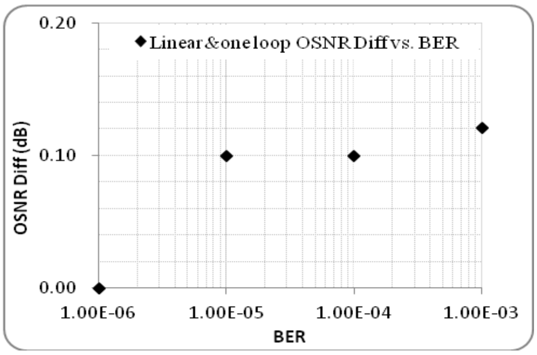

Fig 6: OSNR difference between on-line adapted and commercial version versus BER for 31x46Gb/s at 100GHz transmission over 1139km straight line and one loop system

The measurement results further proved the loop adapted version could truly reflect the commercial linecard performance.

We also report the performance discrepancy using adapted on-line linecard and off-line mode transmission over 5695km which was equivalent to five roundtrips. We adjusted the optical equalizer and applied pre-emphasis to keep the transmission performance balance for the operating band, which gave 17.2dB average OSNR for 31 channels. We selected 1548.11nm to test the transmission performance and the OSNR was 17.4dB. Fig 7 indicates the testing result.

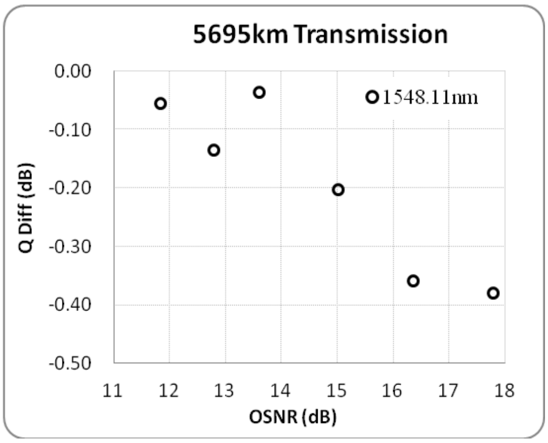

Fig 7: OSNR vs. Q difference after 5695km system transmission after five loops for off-line and on-line testing mode

The above two versions for linecard were in good agreement.

Furthermore, we also carried out the comparison experiment for 64x46Gb/s PDM-BPSK at 50GHz channel spacing over another 6600km dispersion-managed (DM) laboratory loop system transmission, which combined dispersion slope matched larger effective area positive dispersion fiber(+D type) and negative dispersion fiber(-D type) in each single span. The dispersion coefficient of +D and –D type fibers at 1550nm are +20.5 ps/nm.km and -44 ps/nm.km. Average span dispersion was -2.3 ps/nm.km. The effective area of +D and –D fibers were 110μm^2 and 28μm^2. The loop length was about 1214km with an average span length of 76km (16dB span loss). There were three compensated spans of +D type at transmitting and receiving side respectively.

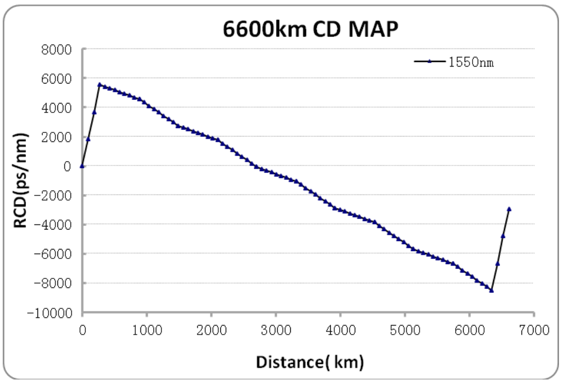

Fig. 8: 6600km system CD Map

Our extensive experiments' results are showed Fig 9, which showed that the penalties at 1E-3 difference between them were less than 0.5dB.

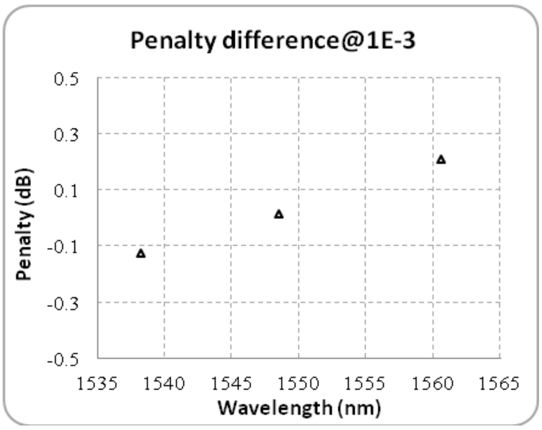

Fig 9: The penalty difference between on-line and off-line testing mode after 6600km system transmission

Compared with off-line mode, on-line testing has prominent advantage, which is allowed to monitor the long term system performance with tester.

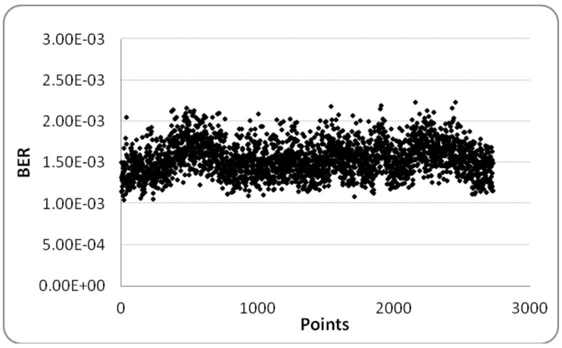

Fig 9: Long term BER monitoring data, the two points' interval is 30s

7. CONCULSIONS

This paper presents the methodology for the linecard with adapted on-line version used in the loop system. A large number of experimental results show that the adapted version can be matched very well with commercial version, which is obviously proved the on-line testing mode successfully achieved over loop system transmission. In addition, long-term transmission performance can be monitored. The recirculating loop system with On-line linecard is not only reducing the CAPEX but also clearing up the qualms for system performance.

8. REFERENCES

[1]Neal S Bergano, Senior Member, IEEE, "Circulating Loop Transmission Experiments for the Study of Long-Haul Transmission Systems Using Erbium-Doped Fiber Amplifiers" Journal of Lightwave Technology, Vol. 13, No. 5, IEEE 1995.