A NEW CABLE FAILURE QUICK ISOLATION TECHNIQUE OF OADM BRANCHING UNIT IN SUBMARINE NETWORKS

Hongbo Sun, Likun Zhang, Xin Wang, Wendou Zhang, Liping Ma (Huawei Marine Networks Co., LTD)

Email: sunhongbo@huaweimarine.com

Huawei Marine Networks Co., LTD / HuaWei Bld., No.3 Xinxi Rd., Shang-Di Information Industry Base, Hai-Dian District, Beijing P.R. China

Abstract: When cable faults occur in an undersea fibre communication system with an OADM function, performance of survival traffic maybe degraded or even interrupted. A new fault isolation scheme that induces zero penalty on survival traffic is discussed in this paper. Experiments detailed below shows that this scheme is safe to a submarine cable line with no risk of optical power transient during fault isolation operation and has no impact on transmission.

1. INTRODUCTION

A branching unit with OADM function is attractive to submarine networks carriers due to the benefits of flexible distribution of transmission connectivity between multiple landing stations, namely: cost sharing amplifier bandwidth, decrease transmission latency, simplified network management and improve traffic availability [1, 2].

For a submarine cable system employing an OADM BU, when cable faults occur in the trunk or spur cable line, some channels will be lost in the surviving line. As repeaters in a submarine system always work with constant optical output power, the surviving channels will share the overall launch power of the repeaters. This cause the power level of the surviving channels to increase dramatically and the nonlinear effect will be too strong to maintain their performance, causing this traffic to deteriorate or even shut down [1, 3].

Various fault isolation or recovery solutions for submarine cable systems with an OADM BU have been introduced to maintain survival traffic during the time waiting for repair [1-6]. A new fault isolation scheme is discussed here. The scheme has the advantage of high reliability, compact and low power consumption. Experimental results have demonstrated no impact on survival traffic in trunk or branch faults scenarios. An automatic mode which can provide quick fault isolation is also discussed. Further experimental work detailed here will also verify whether the schemes based on optical switching will introduce power transients to the surviving line.

2. SCHEME DESCRIPTION

Fig. 1 shows the typical optical route of submarine cable system with OADM BU. DWDM signals enter the input port of the BU, and are split into two paths by the OADM. In the express path, the drop bandwidth is blocked, and the express signals couple with the add signals to the output port of the BU. In the drop path, the dummy channels are looped from the add path to the drop path of the OADM via the internal loop path and combined with the dropped signals. The light path in the opposite direction is identical.

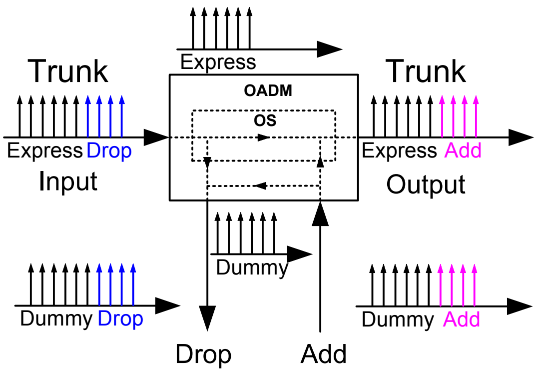


Fig. 1: A typical optical routing of an OADM BU

A new fault isolation scheme for cable faults in a submarine cable system with an OADM function is proposed. Fig. 2 shows the working principle of the scheme for trunk cable faults. When the trunk cable faults, the traffic channels from the trunk line will be lost, then nothing but the added channels will be transmitted in trunk line. To compensate for the lost channel power, the OADM BU will reroute the dummy channels from the branch station to the trunk line, and the power of the surviving traffic channels will be suppressed to its normal level.

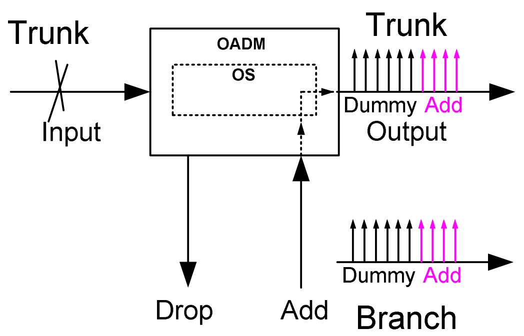


Fig. 2: The optical routing of an OADM BU with trunk cable fault isolation

When the spur cable faults, the OADM BU will reroute the drop channels back to trunk cable line to compensate the lost channel power as shown in Fig. 3.

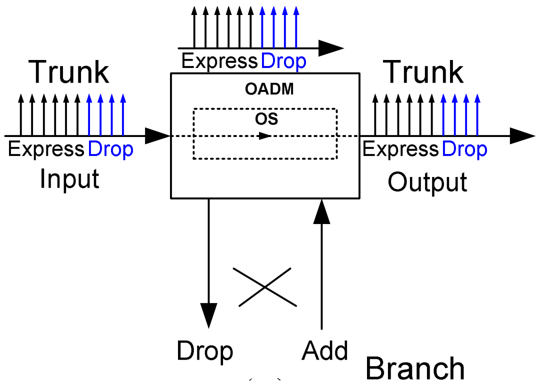


Fig. 3: The optical route of an OADM BU with spur cable fault isolation

The new scheme can be implemented by combining a high reliability, miniature optical switch with an OADM module as shown in Fig. 4, with the added advantage of low additional power consumption. The scheme has a symmetrical structure and so implementation in the opposite transmission direction is the same.

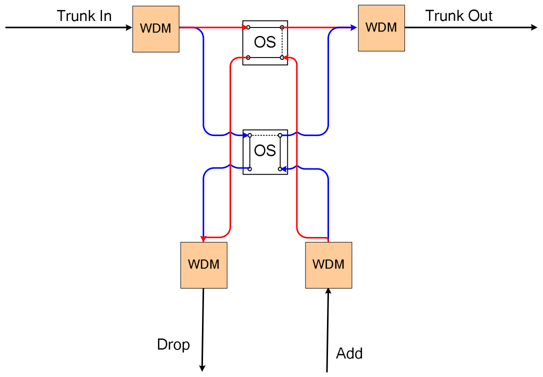


Fig. 4: Implementation of new fault isolation scheme

By monitoring input power at input port of the OADM BU, the fault isolation scheme can work in an automatic mode. In automatic mode, the OADM BU reroutes the light path to the presupposed status according to the detected cable fault pattern, and restores the traffic carried on the surviving channels quickly. Should the fault cable be repaired, the light path will restore to the normal operation status automatically.

For cable faults in trunk line, by monitoring the input power, any power loss, can be detected triggering the fault isolation operation which will reroute the internal optical path as shown in Fig. 2. The operation for spur line faults works in like manner as shown in Fig. 3 when power loss at spur input port detected.

3. EXPERIMENTAL DEMONSTRATION AND TEST RESULTS

In order to test and verify the new scheme and automatic fault isolation function, a bi-directional test bed with one fibre pair OADM BU was constructed as shown in Fig. 5. The test bed includes stations A, B and C deployed with SLTE. The OADM BU divides the system into 3 segments of S1 (1000km), S2 (1100km) and S3 (1000km). Each segment consists of several 66.7km spans of Corning Vascade® EX2000 fibre. The launch power of the repeater is +16dBm, with an average noise figure of 4.9dB, operating in the amplified band width range from 1530nm to 1564nm. The SLTE has a total of 40 channels spaced at 100GHz. There are 8 add/drop channels with bandwidth ranges from 1543.73nm to 1549.32nm, and the NMS is installed in each terminal station. Several cable faults scenarios are shown in Fig. 5, the label ‘cut 1’, ‘cut 2’ and ‘cut 3’ denote the different locations.

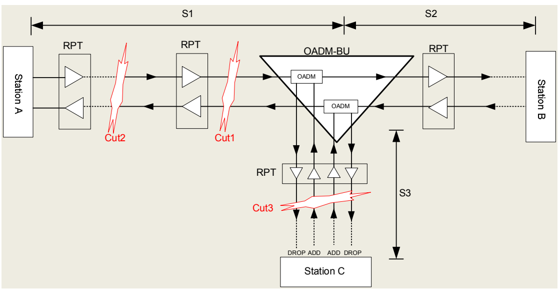


Fig. 5: The experimental demonstration set-up

The spectrum and transmission performance of the express channels and add/drop channels are tested at station B and form the baseline data for normal operation as shown in Fig. 6.

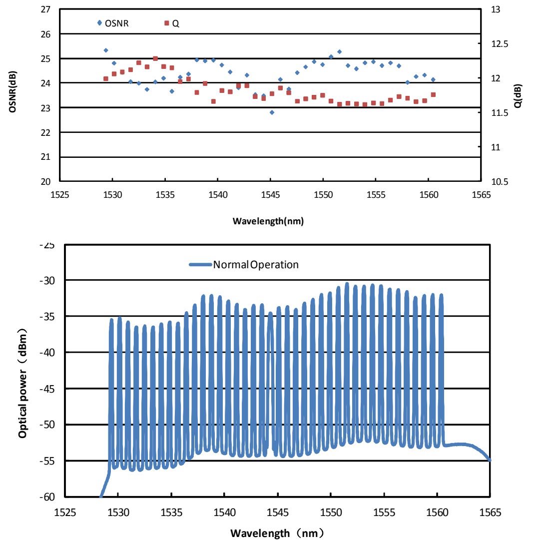
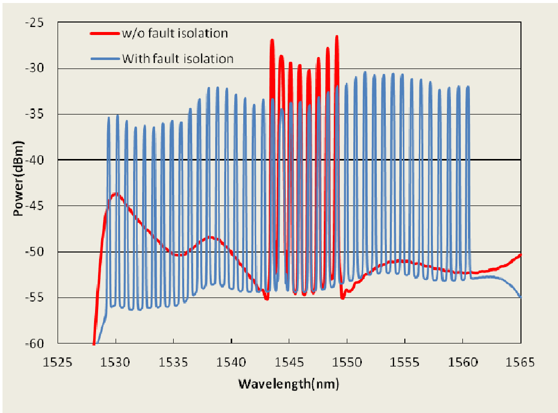
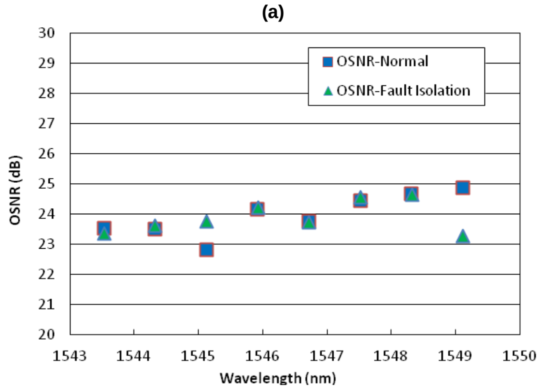


Fig. 6: Spectrum and transmission performance of express and add/drop channels at station B w/o cable cut

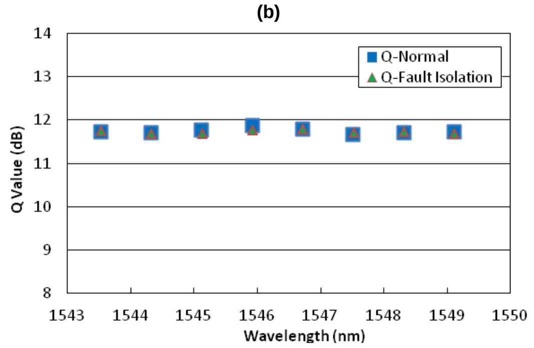
When the cable fault occurs in ‘cut 1’ in Fig. 5, the spectrum of the surviving channels is tested at station B as shown in red within Fig. 7. The optical power of each survival channels is about 5~8 dB higher than the original power in Fig. 6, and the traffics are disrupted by nonlinear impairments without fault isolation. When the OADM BU has finished the fault isolation operation after receiving a command from the NMS, the received spectrum at station B, including the survival and rerouted dummy channels is as shown in blue in Fig. 7. This indicates the survival channels return to normal power after fault isolation. The automatic fault isolation function has therefore been verified in this scenario. The results further indicate that the traffic could recover within one second. When a cable cut repair is simulated the optical circuit also restores to normal operation status quickly in automatic fault isolation mode.



(a)



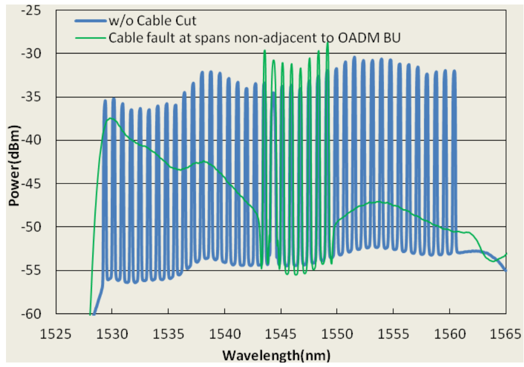
(b)



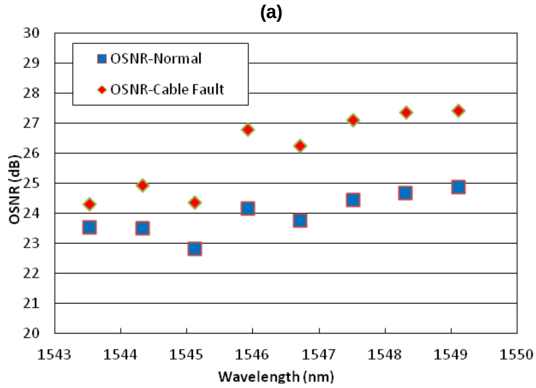
(c)

Fig. 7: (a)Spectrum (b)ONSR (c)Q value at station B w/wo fault isolation under cable 'cut 1' scenario

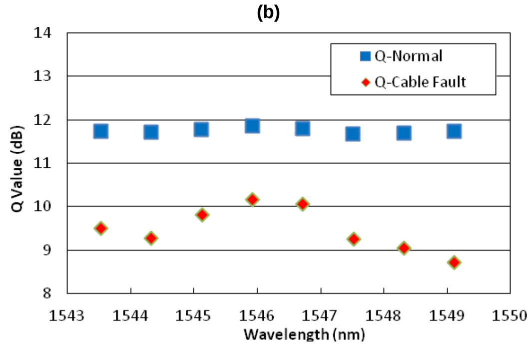
When a cable fault occurs in 'cut 2' in Fig. 5, the ASE output from the repeater adjacent to the BU will partial compensate the lost channel power provided the power supply of the repeater maintains. The received spectrum is tested at station B as shown in green within Fig. 8 (a). The transmission performance tested at station B shows that the degradation of the Q factor is about 2~3 dB, and shows that ASE from the adjacent repeater cannot entirely compensate for the lost channel power in the line to guarantee the performance of the survival traffic. If the transmission distance is extended then fault isolation will be necessary. When fault isolation finished, the performance recover same with the results showed in Fig. 7 (b) and (c).



(a)



(b)



(c)

Fig. 8: (a)Spectrum (b)ONSR (c)Q value at station B w/wo cable fault at spans non-adjacent to OADM BU

For the scenario that a cable fault occurs in 'cut 3' in Fig. 5, the fault isolation operation is similar with that of a trunk fault. Experiments have clearly shown that if the add/drop channels are a small portion of the full DWDM bandwidth, there is little impact on the optical transmission performance of the express channels, and no fault isolation action will be necessary in this occurrence [4].

4. ANALYSIS AND TEST OF OPTICAL POWER TRANSIENT

When a cable fault occurs, some channel power will be lost in the line. When the OADM BU finishes the fault isolation, the lost channel power will be compensated instantly. There is a risk that such a fault isolation operation may cause an optical power transient resulting in potential damage in the fibre line [7, 8].

To establish the level of risk, the test setup shown in Fig. 9 was used. The arrangement shown can simulate the adding of lost channels during the fault isolation operation in a cascaded EDFA chain. Using a dummy light source and optical switch to simulate the channel lost/add process, and combining this with a PIN diode, an amplification circuit and an oscilloscope it is was possible to detect any optical power transient in line.

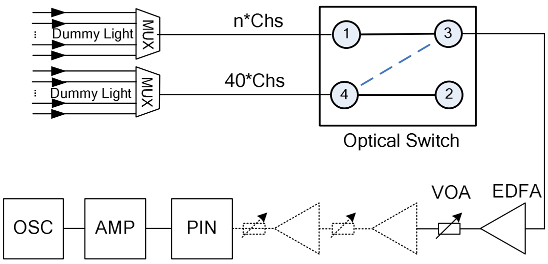


Fig. 9: The experimental setup for detection of optical power transient during fault isolation operation

To estimate the most severe situation, the n which denote the initial channel number is set to 1 to simulate only 1 channel left in surviving line when the cable faults occurs. The outputs at the first, second and fifth EDFA were measured during the optical path switching procedure. The strongest transient was detected at the output of the first EDFA, proving that the transient will not be amplified in the cascaded EDFAs. Fig. 10 shows the oscilloscope response measured at the first EDFA. By calculating the voltage level, the maximum increase in the optical power peak was found to be 1.39dB higher than nominal output during the optical switch operation; therefore the optical transient is low enough not to induce damage in the line. The reason for this is considered to be the 0.5 microseconds switch speed of the optical switch.

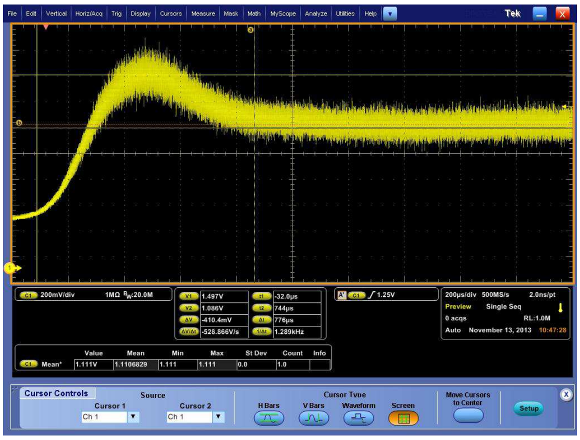


Fig. 10: The optical power transient measured in fault isolation simulation

5. CONCLUSIONS

The new cable fault isolation scheme of the OADM BU provides the advantages of high reliability, compact and low power consumption. The results of transmission experiments clearly show that such an OADM fault isolation system can be achieved without penalty on survival traffic. By monitoring traffic power at the input port, the OADM BU can quickly identify and isolate faults without the need for manual operation at terminal stations in some scenarios. Testing also demonstrates that an optical switch will not introduce an optical power transient sufficient enough to cause damage to the submarine cable line.

6. REFERENCES

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