PROTECTING SURVIVAL TRAFFICS UNDER CABLE-FAILURE CASE OF OADM TOPOLOGY

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Abstract: When cable faults occur in an OADM system, Q performance of survival traffics maybe impacted or even interrupted due to signal power redistribution. In this paper, light path re-routing based recovery solutions are discussed with recovery features demonstrated in a straight line system.

1 INTRODUCTION

OADM undersea systems bring attractive benefits of flexible distribution of transmission connectivity between multiple landing stations. It could save costs by sharing amplifier bandwidth, decrease transmission latency, simplify network management and improve traffic availability [1-5].

However, OADM topology undersea cable systems also bring new challenge on power management. Submarine repeaters work in constant output power mode, so, when some of the channels are absent, the remaining channels will redistribute the output power and cause to the increase of channel output power. This may introduce negative influences, such as increase of non-linear penalty and receiver overload, sometimes could even cause traffic interruptions.

Essentially, OADM topology breaks the independence of different submarine line digital segments (SDLS). It is important to take necessary steps to isolate fault segments, and keep the performance of survival channels stable.

Two types of fault recovery methods have been studied. The first is an internal ASE loading method [3, 5], in which optical amplifiers are inserted both in the OADM express and add paths. Once cable faults happen, the specific amplifier generates ASE noise to compensate the lost input power. Another is a terminal loading tone method [3]. Under situation of cable failure, loading tones need to be turn on or increase power to maintain the survival traffic channels' power stable.

In this paper, we will introduce and demonstrate innovative OADM fault recovery solutions which are effective, cohesive and simply.

2 PRINCPLE OF CABLE FAULT IMPACT ON OADM SURVIVAL TRAFFICS

In a cable cut situation of OADM networks, part of the channels is absent, the remaining channels are amplified by repeater with channel power automatically redistributed and increased.

The power increase level of survival channels follows the law of:

$$\Delta P = 10 \times \log\left(\frac{1}{1-r}\right) \qquad (1)$$

"r" is channel absent ratio (CAR) due to cable faults. Figure 1 plots out that the survival channels' power increase with CAR.

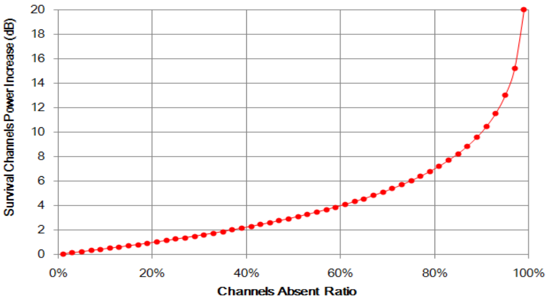


Figure 1. Power redistribution of survival channels

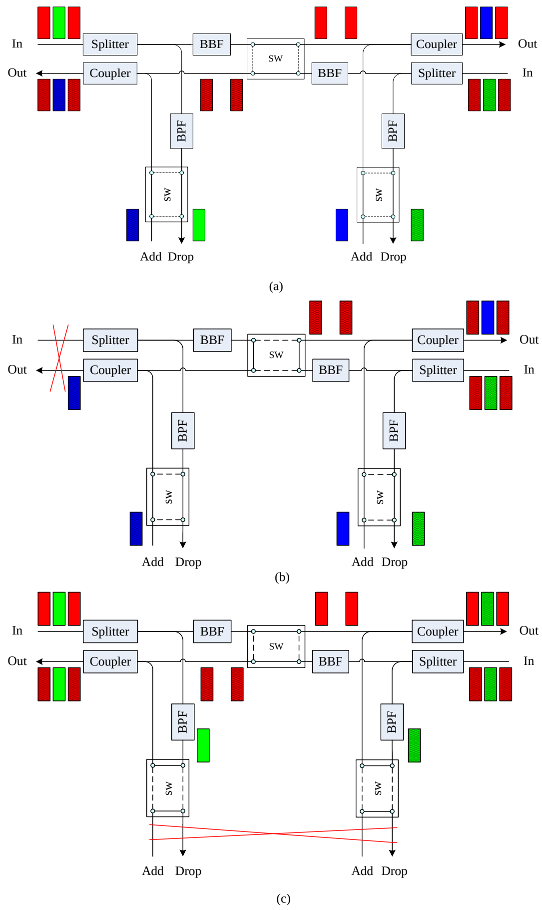
The power increase of survival channels leads to both OSNR and non-linear penalty increase. OSNR change could be estimated by the summation of all repeaters' channel output power over the link. As non-linear penalty is related with channel power, fibre effective area, accumulated transmission length, dispersion map, channel spacing, and modulation format etc., the non-linear penalty is difficult to estimate accurately and have to take simulations or testing approaches. And receiver overload issues may happen due to significant power increases. The final performance variations of survival traffics are contributed by the combination results of OSNR, non-linear penalty and receive power change.

Although the phenomena of impact on survival channels have been observed in Laboratory and field fault and recovery demonstrations [1-4], it is still uneasy to manage survival traffic power well along the link with part of bandwidth unavailable. In some situations, even methods of ASE loading and loading tones have been adopted, performance degradation on survival traffics could still be observed.

3 METHODOLOGIES OF OADM FAULT RECOVERY

As the fault impact comes from power redistribution, it is necessary to shape the optical spectra as initial as possible. We take an innovative but simple approach to achieve this as the following:

As communication systems always work with fibre pairs, looping back the signal light could fully compensate the lost channels from fault side. So, we propose OADM architecture as figure 2. It is based on a broadcast and band blocked OADM. A 2x2 optical switch is inserted between the express signal paths of opposite transmission direction, and is located between band block filter (BBF) and coupler. Other two optical switches are inserted between add and drop paths adjacent to the band pass filters (BPF).



Note: red bar - express channels, green bar - drop channels, blue bar - add *channels, purple bar - loading channels, gridding - opposite direction.*

Figure 2. (a)OADM with loop-back function, (b) Light flow of trunk fault recovery, (c) Light flow of branch fault recovery

In normal working cases, the switches pass through the express channels and add/drop channels respectively. Whilst in situation of trunk fault, the switches loop back the express channels to the opposite direction. Similarly, in branch faults, the switches loop back the drop channels to the add direction.

We also propose another architecture with the similar technique, in which bypass function is adopted to compensate the lost channels. The light flow of normal working case and fault recovery cases are showed in figure 3.

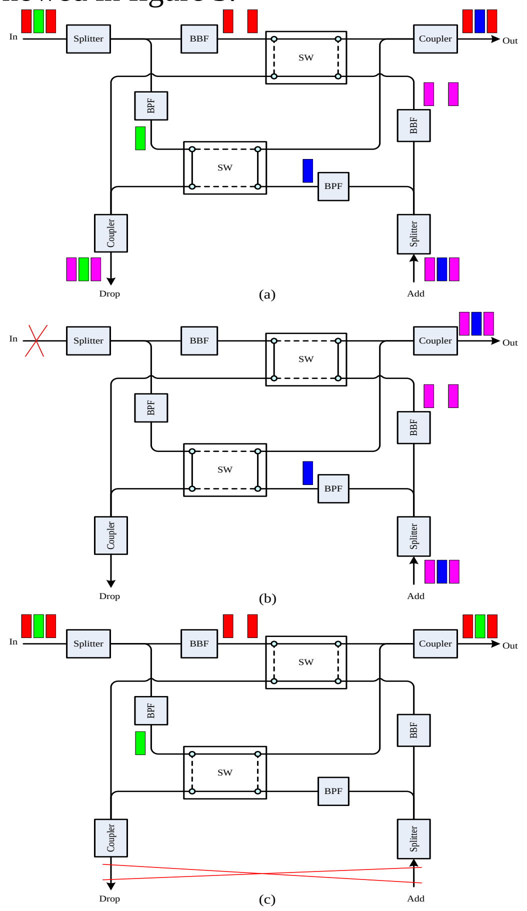


Figure 3. (a)OADM with bypass function, (b) Light flow of trunk fault recovery, (c) Light flow of branch fault recovery

This architecture's limitation is that the branch loading tones are required for the entire life time, but still offers attractive and flexible functions, such as express and add/drop bandwidth exchangeability, fibre pair add/drop and none add/drop.

In summary, optical spectra could be shaped as initial by adopting these architectures to maintain the power level of survival traffics, so performance of survival traffics could be guaranteed. And these recovery solutions are independent of terminal loading tones operation, e.g. turn on/off or change power level. In this way, the recovery management is simplified. Moreover, implementations of these solutions offer beneficial features to the OADM BU design, such as compact size, low power consumption and universal applicability.

4 FAULTS AND RECOVERY DEMONSTRATION

We have experimented fault and recovery features in a straight line system with a bypass functional OADM. Figure 4 shows system configuration. The OADM BU is positioned around 1/3 of the trunk length, 435 km away from station A. The distance between station C and the OADM BU is also around 435km. ASE noise and non-linear penalty accumulation of ultra long transmission are simulated by fixed ASE loading at receiver side and NZDSF fibre with 50um^2 effective area accordingly. The repeater span length is 100km with an attenuation of 20dB. Station A and station C share the same light configuration, which consists 77 loading channels with 50GHz spacing and a full C band tuneable channel delivered by a 112Gb/s PDM-QPSK line card, also used for acquire of Q performance at 100GHz grid. Among them, 63 channels pass through the OADM, 15 channels are located in the middle of whole bandwidth dropped from the trunk, and another 15 channels are added from the OADM branch, with an add/drop bandwidth ratio of around 19%. And two extra 50GHz grid channels, as shown in figure 5, one at each side between the add/drop and express bands, are abandoned for filter guard-band.

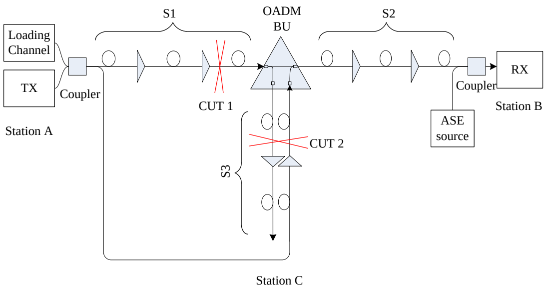


Figure 4. Experiment configuration

Cable cuts close to the OADM BU, on segment s1 and s2, have been studied, which covers the worst case of cable fault and repair scenario. In the normal working status, both the express traffic and the add traffic to station B have the Q performance of around 11.2dB.

In cut 1, the survival channels' power increases about 7dB and becomes closed to the receivers' overload threshold, all other add channels are thoroughly interrupted as indicated 0dB of Q factor in figure 6. After re-routing, the branch loading channels compensate the lost express channels, with the Q factors of add traffic recovered to previous levels.

In cut 2, the survival channels' power increases about around 0.9dB, and the Q factors slightly drop about 0.2dB, which is contributed by the combination of increase of OSNR and non-linear penalty. After re-routing, the power level and Q factor recover to the initial level.

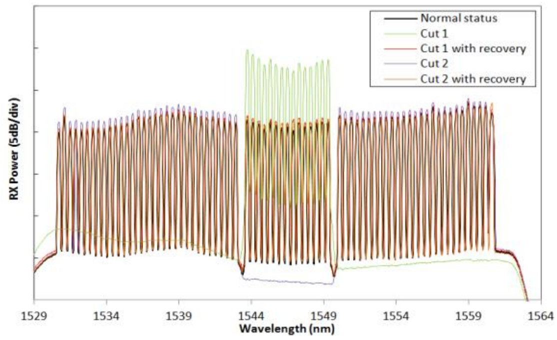


Figure 5. RX spectra of station B

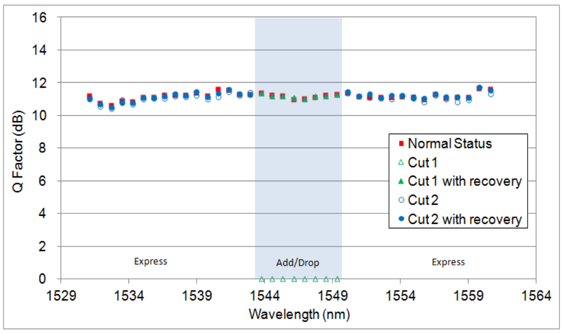


Figure 6. Q factor of survival channels

5 CONCLUSIONS

In this paper, two types of light path re-routing based OADMs supporting fault recovery are discussed and demonstrated with no impact on survival traffics in scenarios of trunk and branch faults.

In OADM topology networks, these light path re-routable technology could offer great advantages on fault recovery, make survival traffics available, and avoid performance degradation during cable faults and repair, even at the end of system life circle and with limited Q margin remained.

6 REFERENCES

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