A NOVEL PUMP-REDUNDANCY SCHEME FOR MULTIPLE FIBER-PAIR SUBMERGED REPEATER

Yuhe Li, Changwu Xu (Huawei Marine Networks)
Email: liyuhe@huaweimarine.com

Huawei Marine Networks Co., Ltd. B2-5F, TEDA MSD, NO.62, Second Avenue, TEDA, Tianjin, China 300457

Abstract: This paper describes a novel repeater pump-redundancy scheme for multiple fiber-pair submarine cable systems. The repeater amplifiers can share pump lasers based on the flexible redundancy architecture, to ensure the system reliability and robustness. The components interconnection scheme and redundancy design have perfect symmetry and scalability, which can be applied for all multiple fiber-pair repeaters with both even fiber-pairs and odd fiber-pairs. Compared to the traditional pump-redundancy design, this novel pump-redundancy scheme achieves a better balance between system reliability and cost. The effects on repeater performance due to pump failure are analyzed and compared with those of traditional designs. The features and benefits of the novel pump-redundancy scheme are detailed in respect of design flexibility, system reliability and cost effectiveness.

1. INTRODUCTION

Reliability is especially important to a submarine fiber-optic cable communication system. The system reliability mainly comes from product reliability. Pump laser, as the active component, has much higher failure rate than other passive components within a submerged repeater. Redundant design of the pump lasers can help to improve the product reliability and the system reliability.

The 2×2 pump-redundancy scheme is a general design. Two EDFAs share the power from two pump lasers via a 50/50 fusion coupler. This design tolerates one pump laser failure at most in each fiber pair. The two EDFAs will not work if both pump lasers fail.

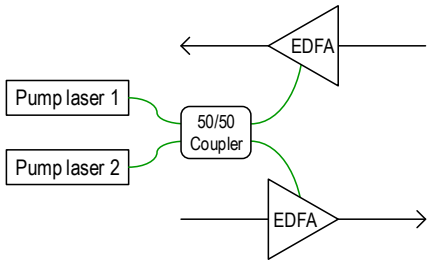

Figure 1: 2×2 Pump-redundancy Scheme

The improved 4×2 redundant scheme can effectively improve the repeater reliability by doubling the pump lasers. Two EDFAs share the power from four pump lasers, which tolerates three pump lasers failure at most in each fiber pair. However, this design also doubles the total cost of pump lasers.

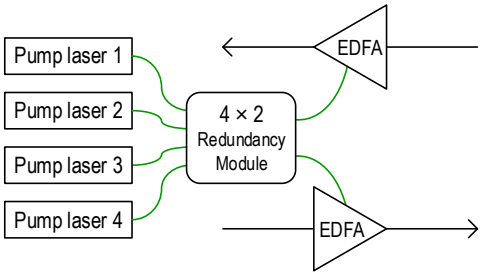

Figure 2: 4×2 Pump-redundancy Scheme

In recent years, the 4×4 redundant scheme [1] is proposed. Four EDFAs from two fiber pairs share the power equally from four pump lasers, which improves the cost performance. However, this architecture is not suitable for odd fiber-pair systems such as three fiber-pair repeater or five fiber-pair repeater.

Copyright © SubOptic2019

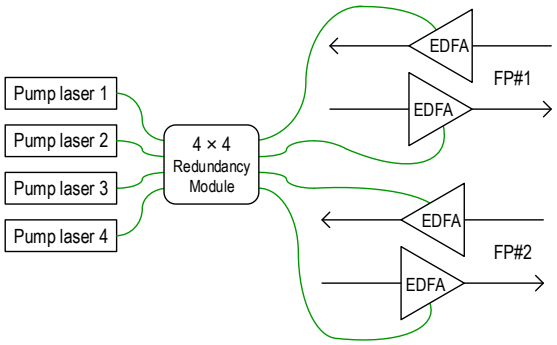

Figure 3: 4×4 Pump-redundancy Scheme

In this paper we present a novel pump-redundancy scheme for multiple fiber-pair systems, which achieves a better balance between system reliability and cost. In addition, this design has perfect symmetry and scalability, which can be applied for all multiple fiber-pair repeaters no matter even fiber pairs or odd fiber pairs.

2. PUMP-REDUNDANY SCHEME OF MULTIPLE FIBER-PAIR SYSTEMS

Figure 4 illustrates a novel pump-redundancy scheme and design architecture. Take a five fiber-pair repeater for example, a series of pump lasers and EDFAs are cross-connected via two-stage optical fiber couplers.

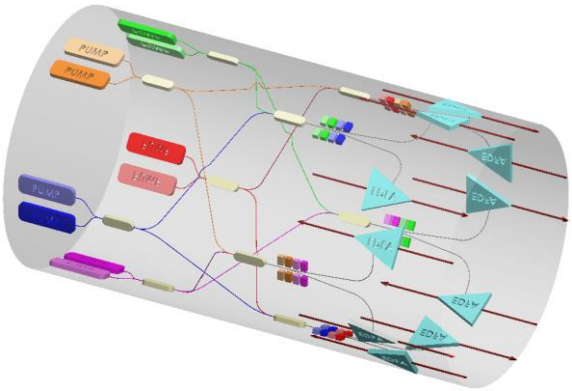

Figure 4: Novel Pump-redundancy Scheme of Five Fiber-Pair (5FP) Repeater

Figure 5 is the planar graph of Figure 4, which is much easier to read. Two pump light from each group, such as P01 and P02, converts to two first-stage redistributed pump light via the first-stage 2×2 coupler. Either first-stage pump light contains 50% the power of each initial parent pump light. Similarly, two first-stage pump light from different first-stage 2×2 couplers converts to two second-stage redistributed pump light via the second-stage 2×2 coupler. Each second-stage pump light contains 50% the power of each first-stage parent pump light. Thus, each EDFA is powered by four pump lasers with 25% the power of each pump, and each pump laser provides equal power to four EDFAs.

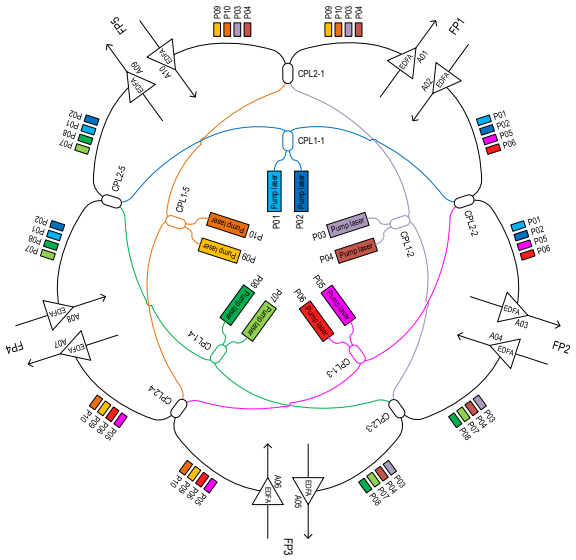

Figure 5: Planar Graph of 5FP Repeater Pump-redundancy Scheme

This pump interconnection scheme can apply the traditional 4×4 redundant architecture, as well as other M×N architectures, in both even fiber-pair and odd fiber-pair repeaters. In addition, the architecture has perfect symmetry and can be expanded infinitely for multiple fiber-pair repeaters in theory.

Compared to those traditional pump-redundancy architectures, the novel scheme achieves a much better balance between system reliability and cost as well as the application flexibility. The flexible design can meet the special requirement of different systems with different fiber pairs.

The multiple fiber-pair architecture based on a 4×4 pump-redundancy design is compared

with other traditional architectures, which is shown in table 1.

Item	Traditional Design			Novel Design based on 4×4
	2×2	4×2	4×4	
Average Qty. of pumps (multiples of EDFA)	1× EDFA Qty.	2× EDFA Qty.	1× EDFA Qty.	1× EDFA Qty.
Max allowed Qty. of pumps failure related to one EDFA	Allow 1 pump failure	Allow 3 pumps failure	Allow 3 pumps failure	Allow 3 pumps failure
Application of even fiber pairs (≥2FP)	√	√	√	√
Application of odd fiber pairs (≥2FP)	√	√	×	√

Table 1: Comparison of Different Pump-redundancy Design

The novel pump-redundancy design has a higher cost performance than the 2×2 and 4×2 redundant designs, i.e., the same average pump quantity per EDFA as 2×2 design but allowing more pumps failure, the same allowed pumps failure quantity as 4×2 design but cutting the pumps quantity /cost by half. The novel design can be applied in odd fiber-pair systems while the traditional 4×4 redundant design cannot.

3. DESIGN FLEXIBILITY

This novel pump-redundancy scheme can offer a great deal of design flexibility to fulfil the different requirements of the system performance.

➢ Fiber-pair Group

The novel pump-redundancy design allows two EDFAs in one fiber pair respectively powered by two second-stage pump light from the different second-stage 2×2 couplers, as shown in Figure 5. This design can achieve the mathematical orthogonality, which will contribute to the fault localization of pump(s) failure.

Alternatively, the novel design also allows two EDFAs in one fiber pair respectively powered by two second-stage pump light from the same second-stage 2×2 coupler, as shown in Figure 6. This design can ensure the corresponding pump lasers to each EDFA are the same in one fiber pair. Thus, the effect on both EDFAs in one fiber pair due to pump(s) failure will be the same.

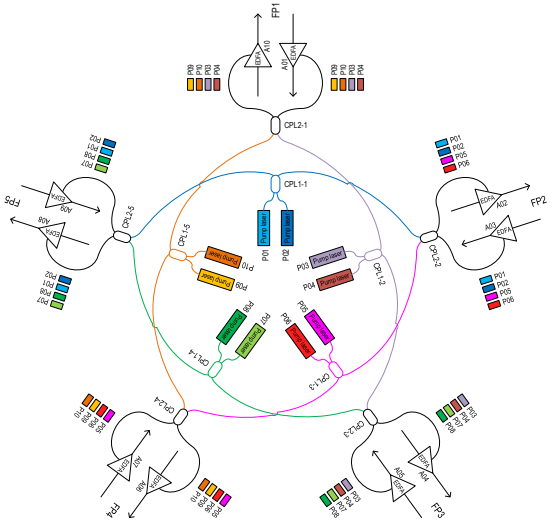

Figure 6: Two EDFAs in Each Fiber Pair Powered by the Same Pump Lasers

➢ Fiber-pair Quantity

This novel design can be applied for all multiple fiber-pair repeaters with both even fiber-pairs and odd fiber-pairs, such as three fiber-pair repeater shown in Figure 7 and eight fiber-pair repeater shown in Figure 8.

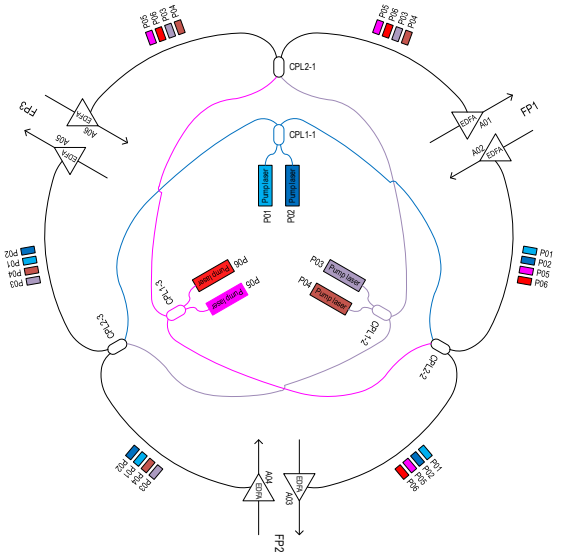

Figure 7: 3FP Repeater Pump-redundancy Scheme

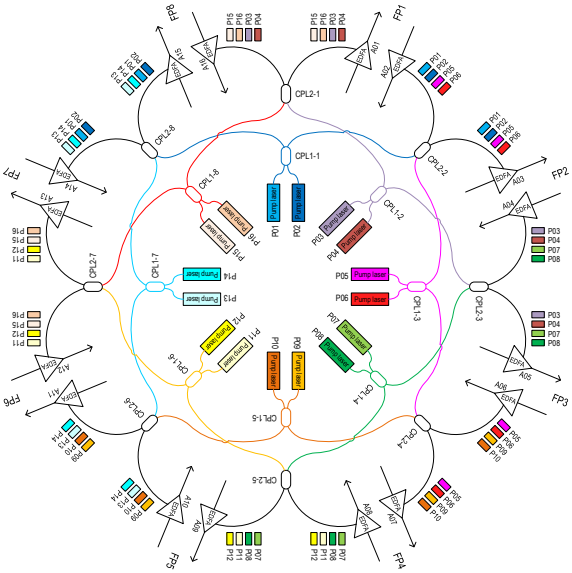

Figure 8: 8FP Repeater Pump-redundancy Scheme

➢ M×N Pump-redundancy Scheme

The novel pump-redundancy scheme allows more flexible architecture based on the same design principle, such as 8×8 redundancy architecture with three-stage optical fiber couplers, or other M×N architectures with multistage couplers.

With the same design principle, the pump-redundancy architecture can be designed as different forms according to the actual requirement, low cost or high reliability. The maximum allowed quantity of pump failure in the system shall also consider the performance budget and the system margin.

The M×N architectures is also highly significant in terms of the future multi-core fiber (MCF) systems, which do not require so high power for each fiber core. The M×N pump-redundancy scheme will effectively improve the cost performance of MCF repeatered systems.

4. CONCLUSION

In this paper, a novel repeater pump-redundancy scheme is presented. Based on the improved 4×4 redundant design for multiple fiber-pair interconnection, each pump laser provides equal power to four EDFAs and each EDFA is powered by four pump lasers with one quarter power of each. The redundant architecture has perfect symmetry and scalability, which can be applied for all multiple fiber-pair repeaters with both even fiber-pairs and odd fiber-pairs.

Compared to the traditional pump-redundancy design, this novel scheme has a higher cost performance. The system reliability and robustness can be ensured without increasing the number of pump lasers. The design principle is also applicable to other M×N pump-redundancy designs for multiple fiber-pair systems.

5. REFERENCES

[1] Changwu Xu, “A more reliable pumps redundancy design”, SubOptic 2016