A MORE RELIABLE PUMPS REDUNDANCY DESIGN

Changwu Xu, Liping Ma, Zilong Wang, Xuanzhen Jia, Ming Song
xuchangwu@huaweimarine.com

Huawei Marine Networks, Huawei Bld., Xinxi Rd., Shang-Di, Hai-Dian District, Beijing, P.R. China, 100085

Abstract: This paper describes the benefits and practicalities of a more reliable repeater pump redundancy design by utilizing four pump lasers backup within a two fiber-pairs system. The test result shows that this sort of redundancy provides submarine systems more reliability and thus sturdier to tolerance of up to three pump lasers failure, which ultimately can be detected by COTDR equipment.

1. Introduction

As the active components within a repeaters, pump lasers are critically important in undersea fiber communication system, and the lasers backup is indispensable; the other factor in any such design is the selection of highly reliable pump lasers. In our usual design, two EDFA's in one fiber pair share two pump lasers which in turn can accommodate only one laser failure, while four pump lasers in some cases are offered as an optional redundancy on one fiber pair system.

This paper will demonstrate the workability of pumps redundancy for a four pump lasers backup for two fiber pairs system. Comparing with two pump lasers backup, this four pumps redundancy makes submarine system more reliable and stronger to tolerate pump laser failure.

2. Four pumps redundancy

Figure 1 illustrates the architecture of four pump lasers backup for two fiber pairs. The output power of each pump laser is equally divided into four parts by power divider, and evenly distributed over the four EDFAs. By adjusting the operating current, the output power of any pump laser could be same to each other. In other words, if one pump laser fails, each EDFA will therefore only lose a quarter of the pump power.

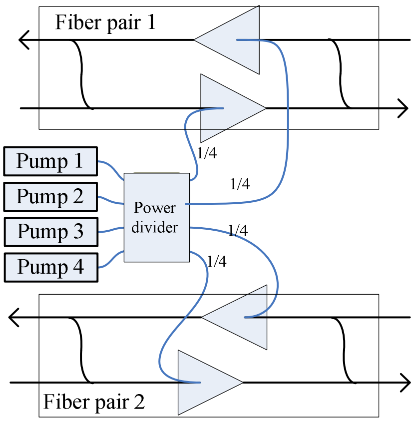

Figure 1: Four pumps in a two fiber pairs system

This pump architecture design can easily be extended to more fiber pairs system, the power divider should be designed to keep the energy of every EDFA equally comes from the four pump lasers, and each laser pump providing the same pump power.

3. The transmission system and pump failure test results

To demonstrate the benefits of the four pumps redundancy design, a transmission test bed is set up to measure the changes in the repeater parameters and the system performance when pump failure occurs.

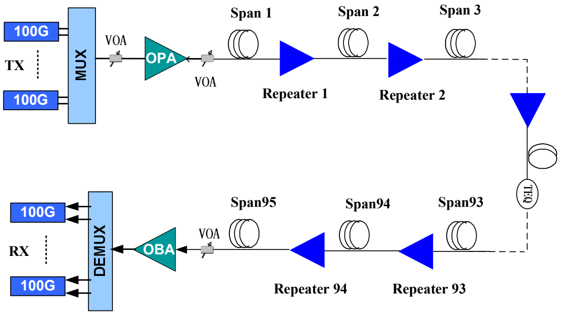

Figure 2: The transmission path during pump failure tests[Note 1]

Note 1:
OBA : Optical Booster Amplifier
OPA : Optical Pre- Amplifier

The experimental setup is illustrated in figure 2. The system capacity is 80 channels 100Gbit/s with PDM-QPSK modulation. The transmission line consists of more than 6100 km Corning EX2000 fiber, 94 repeaters, several TEQs and SEQs.

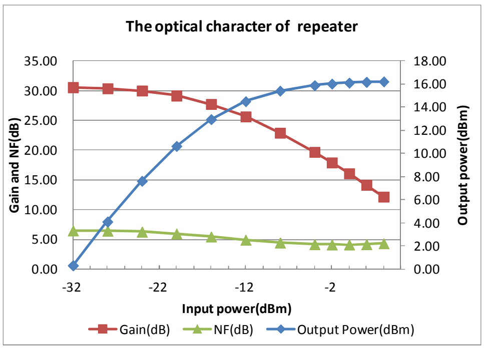

Figure 3: The optical characteristics of a typical subsea repeater

The repeaters in figure 2 have 4 pump lasers backup which is illustrated in figure 1, and EDFAs are working at a deep gain compression state, which is illustrated in figure 3. The gain compression characteristic mean that the repeater can self-compensate the output power and gain when its input power drops off; in which case, the optical power level along a chain of repeaters could automatically self-correct.

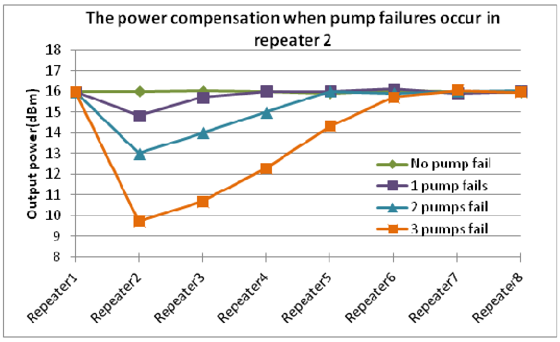

Figure 4: The power compensation when pump failures occur in repeater 2

Figure 4 illustrates the optical power self-adjusting from repeaters 1 to 8 when a pump failure occurs in repeater 2. If the pump lasers fails in repeater 2, the output power of repeater 2 will decease, but the optical power can self-compensate from repeaters 3 to 6, and return to the normal level after repeater 6 even though three pumps failure.

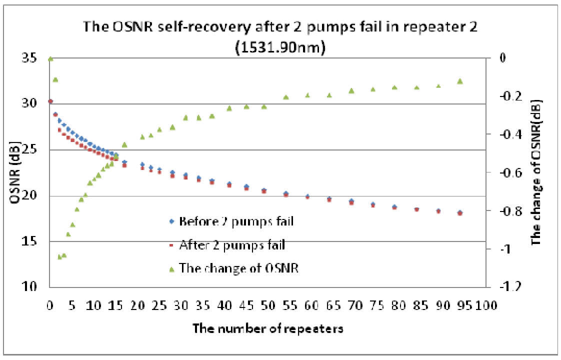

Figure 5: The OSNR self-recovery when 2 pump lasers fail in repeater 2

Similar to the optical power self-adjustment option, the OSNR can also self-recover along a chain of repeaters when pump failures occur. Figure 5 illustrates the OSNR of 1531.90nm along the transmission line before and after 2 pump lasers failed in repeater 2. The maximum decrease of OSNR appears at repeater 2, the OSNR then begins to self-recover along the transmission line, and the degradation is less than 0.2dB at the last repeater.

The OSNR of all channels at the RX side is measured when one, two, and three pump lasers failed in repeater 2, which is illustrated in figures 6 and 7. The test results show that the degradation of RX OSNR is less than 0.2dB when 1 or 2 pumps failure, and less than 0.7dB when 3 laser pumps failed.

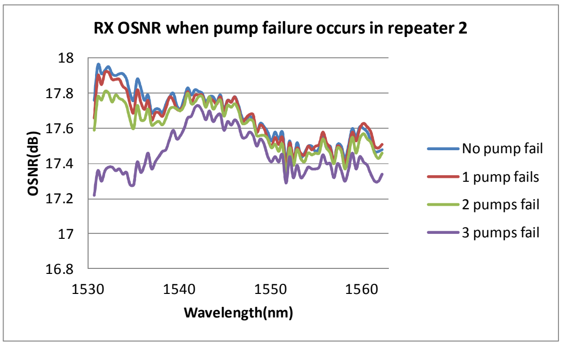

Figure 6: RX OSNR when pump lasers fail in repeater 2

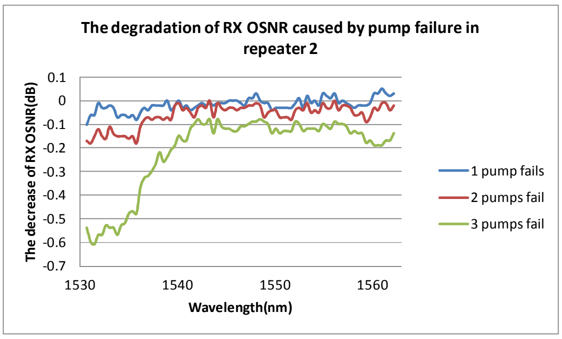

Figure 7: The degradation of RX OSNR caused by pump failures in repeater 2

Therefore, according to figure 5, the worst case would be if the pump failure happens in the last repeater, because there is only one OBA to compensate optical power. So we measure the OSNR of all channels at RX side when one, two, and three pump lasers failed in repeater 94, this is illustrated in figures 8 and 9. It should be noted that the degradation of RX OSNR is still less than 0.7dB when 3 laser pumps failed due to the strong compensation by OBA.

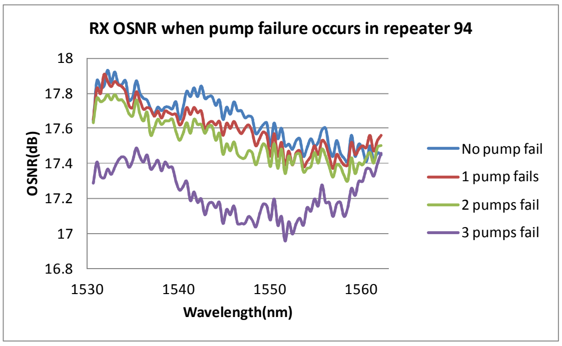

Figure 8: RX OSNR when pump lasers fail in repeater 94

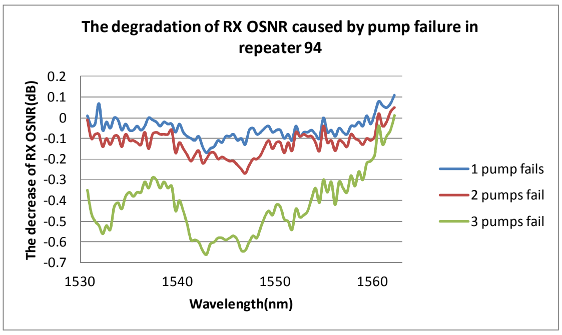

Figure 9: The degradation of RX OSNR caused by pump failures in repeater 94

4. The pump failure monitoring

The COTDR test system is required to monitor the working state of repeater, as shown in figure 10. It includes 4 repeaters over five spans, the total system length is only 500km and the noise is very small. The accuracy of COTDR equipment will decrease if the system noise increases. To simulate the noise for a 7000km transmission system, dummy lights and ASE are added at the end of span 5.

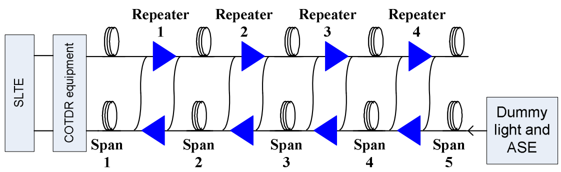

Figure 10: The COTDR test bed

Figure 11 illustrates the COTDR curves when pump failures happen in repeater 2; with the baseline (no pump failure) being the green curve. In this instance, the

COTDR equipment could work out the gain of repeaters, by differentiating with baseline, it also can determine the changes of the gain.

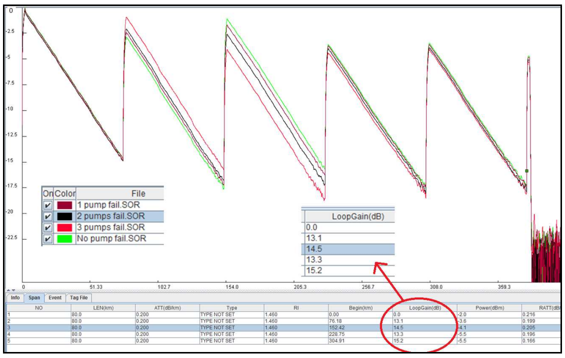

Figure 11: The COTDR curves (Test conditions: Pulse Width :20us, Pulse peak power: -4dBm, Average times: 100,000)

Theoretically, the gain of repeater with 4 pump redundancy will decrease 1.25dB when one laser pump fails, 3dB when two laser pumps fail and 6dB when three laser pumps fail. The accuracy of the COTDR equipment is +/-0.5dB, therefore, when one, two or three pumps fail, the change in the gain tested by the COTDR will be -1.25+/-0.5dB, -3.0+/-0.5dB and -6.0+/-0.5dB respectively.

Table 1 and table 2 are the test results of repeater gain and the changes of the gain(△ Gain) caused by pump failures in repeaters 1 and 2. The △Gains are marked as red. By contrasting with the theoretical values, we can determine that the △Gains when pump failures are in line with the theoretical results..

The accuracy of the COTDR equipment is checked by the optical power meter as shown in tables 1 and 2, the differences between the COTDR and the optical power meter shown as being less than 0.53dB; including any testing error.

Number of failed pumps	Test Equipment	Items	Repeater 1 (Pumps fail)	Repeater 2	Repeater 3	Repeater 4	Theory value
0 (Base line)	SLM	Gain(dB)	15.60	13.60	13.40	15.40	
1	SLM	Gain(dB)	14.20	14.20	13.70	15.50	
		△ Gain(dB)	**-1.40**	0.60	0.30	0.10	-1.25+/-0.5
	Optical Power Meter	△ Gain(dB)	-1.27	0.59	0.05	0.02	
	Optical Power Meter - SLM		0.13	-0.01	-0.25	-0.08	
2	SLM	Gain(dB)	12.40	15.40	13.50	15.50	
		△ Gain(dB)	**-3.20**	1.80	0.10	0.10	-3.0+/-0.5
	Optical Power Meter	△ Gain(dB)	-2.93	1.38	0.10	0.02	
	Optical Power Meter - SLM		0.27	-0.42	0.00	-0.08	
3	SLM	Gain(dB)	8.80	16.60	13.90	15.60	
		△ Gain(dB)	**-6.80**	3.00	0.50	0.20	-6.0+/-0.5
	Optical Power Meter	△ Gain(dB)	-6.27	2.90	0.26	0.04	
	Optical Power Meter - SLM		0.53	-0.11	-0.24	-0.16	

Table 1: The change of the repeater gain caused by pump failures in repeater 1

Number of failed pumps	Test Equipment	Items	Repeater 1	Repeater 2 (Pumps fail)	Repeater 3	Repeater 4	Theory value
0 (Base line)	SLM	Gain(dB)	12.10	17.50	11.80	15.40	
1	SLM	Gain(dB)	12.70	16.00	12.50	15.30	
		△ Gain(dB)	0.60	**-1.50**	0.70	-0.10	-1.25+/-0.5
	Optical Power Meter	△ Gain(dB)	0.59	-1.29	0.61	0.05	
	Optical Power Meter - SLM		-0.01	0.21	-0.09	0.15	
2	SLM	Gain(dB)	13.10	14.50	13.30	15.20	
		△ Gain(dB)	1.00	**-3.00**	1.50	-0.20	-3.0+/-0.5
	Optical Power Meter	△ Gain(dB)	1.33	-2.96	1.37	0.11	
	Optical Power Meter - SLM		0.33	0.05	-0.13	0.31	
3	SLM	Gain(dB)	14.60	10.70	14.90	15.30	
		△ Gain(dB)	2.50	**-6.80**	3.10	-0.10	-6.0+/-0.5
	Optical Power Meter	△ Gain(dB)	2.82	-6.30	2.90	0.28	
	Optical Power Meter - SLM		0.32	0.50	-0.20	0.38	

Table 2: The change of the repeater gain caused by pump failures in repeater 2

5. Conclusion

The four lasers pump redundancy design described in this paper ensures the reliability and strengthens the tolerance of submarine system during the life time of the system without increasing the number of laser pump. The test results were carried out on a 6,100km optical transmission system with the degradation of RX OSNR being less than 0.2dB whenever one or two laser pumps failed, and less than 0.7dB when three laser pumps failed. It has been demonstrated that the gain changes of the repeaters caused by the laser pump failures can be detected by the COTDR equipment, and the number of pump failures be identified by the changes in the gain.