Experimental demonstration of using wet-mate connector in offshore long-distance Raman amplified optical links

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Abstract: Deploying fibre cables to offshore installations may desire a pluggable construction for sub-sea use. Sub-sea connection of fibre cables, carrying high power Raman pump power, using a wet-mate connector is demonstrated for the first time.
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1. Introduction

When deploying offshore installations such as oil and gas platforms, fibre cables running from the top of the platform down into the sea are typically simultaneously installed. These cables are utilized for various applications such as connecting monitoring solutions, remotely operated submarines and sub-sea fibre communications. When deploying a fiber to an oil installation for communication purposes, typically a so-called J-tube for transport of the sub-sea fibre cable from the sea floor up to the offshore installation, e.g.an oil-platform, is normally preferred. However, sometimes space in such a tube is not available, pushing the need of using the existing fibre-cables already installed between the seafloor and the offshore installation. For such a scenario, Wet-Mate connectors [1] are available at the sea-floor for connecting to the platform. By using a Remotely Operated Vehicle (ROV), the fibre cable can be connected under water in the sea through these connectors. Other use-cases applying Wet-Mate connectors include mobile platforms, such as drilling platforms and floating installations where Wet-Mate connectors are already available from the time of the installation. These platforms may be moved a few km around in an area needing fibre-optical communication links. Also, for this use-case, Wet-Mate connectors may be applied for connecting to sub-sea fibre-optical cables for communication purposes.

A typical fibre-cable deployment offshore can be found in the network of Tampnet in the North-sea, connecting more than 250 offshore oil and gas installations to Norway and the U.K. and providing Terabit capacity links between Norway and the U.K. This network is using passive fibre cables with span lengths up to ~300 km. To transmit Terabits of capacity over spans of this length, distributed Raman amplification plays a key role for achieving sufficient Signal to Noise ratio [2]. However, for Raman-amplified systems, it is of special importance that splices and connectors close to the Raman amplifier pump source have low loss [3]. Hence, for the proposed use-cases requiring a Wet-Mate connector located close to the pump of a Raman amplifier, attenuation and reflection in the Wet-Mate connector become highly critical performance parameters.

In this paper we demonstrate experimentally and characterize for the first time the performance of a system using a Wet-Mate connector located close to the pump of a high-power distributed Raman amplifier.

2. Challenges combining wet-mate connectors with Raman amplified systems

The use of Distributed Raman Amplification (DRA) to increase span length or Cascaded Raman Amplification, which involves third-order pumping [4] to further improve span lengths, requires that high power in the range of 1 to 5 Watts be launched into the fiber link. Typical connection of the high-power Raman pump to the transmission fiber is via a fusion splice that provides a maximum loss of 0.1 dB. This is within the limits of the maximum loss allowable within the first 10 km of the link where the pump power is highest.

Replacing the fusion splice with a connector requires the connector to have a low insertion loss. A high insertion loss will reduce the pump power producing the DRA and consequently the Raman gain. As a general rule insertion loss between the Raman pump and the outside plant should not exceed 0.5 dB. Other important considerations are low back reflection to avoid damage to the Raman pump and the ability of the connector to withstand high power for an extended period of time without degradation in performance.

Furthermore, the performance must be repeatable as the connector may be subject to multiple connect/disconnect cycles. Any contaminant on the mating surface during these cycles will result in burning the connector.

The Seacon HydraLight Wet-Mate connector model applied in this experiment has a maximum insertion loss of 0.5 dB. It has an angled end face, limiting back reflections to less than -50 dB, and is specified with an accumulated operating time in excess of 290 million hours, resulting in a Mean Time Between Failure (MTBF) of better than 61 million hours with a 99% confidence level.

3. Experimental setup

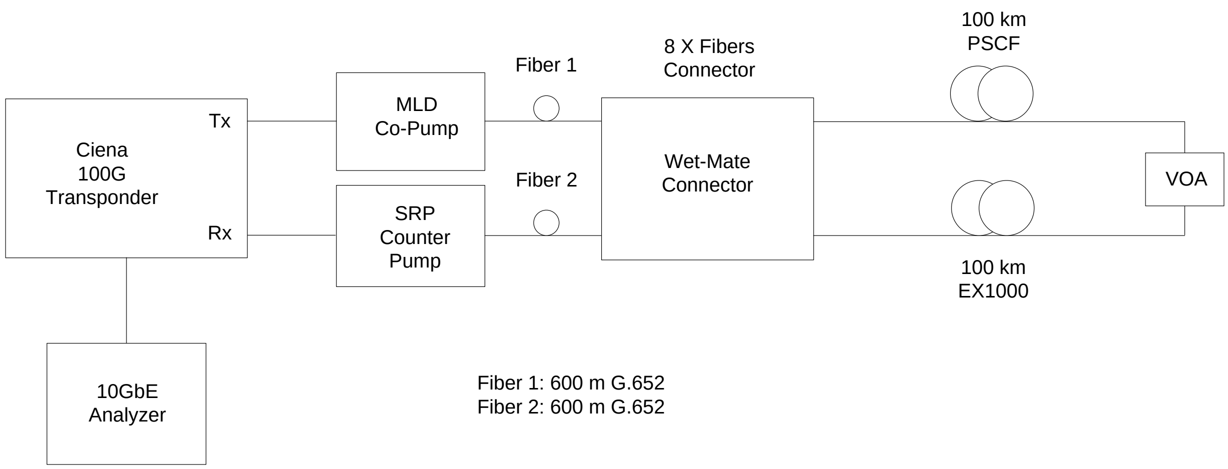

Fig 1. Test setup with 1W Multiplexed Laser Diode Raman Co-Pump (MLD), 3W Third-Order Super Raman Counter Pump (SRP), Wet-Mate Connector, 100 km of Pure Silica Core Fiber (PSCF), 100 km of Corning Vascade EX1000 Fiber and Variable Optical Attenuator (VOA).

A 1 x 100 Gb/s test link (see Fig. 1), emulating a 400-km span (68 dB), was set up with a 1 W Co-Pump and a 3 W Super Raman Counter Pump from MPB Communications, a 100G Transponder from Ciena and a SEACON Hydralight Wet-Mate connector in a loopback configuration. A variable optical attenuator (VOA) was inserted between the fiber spans to allow the total link loss to be varied. Both the Co- and Counter Pumps were connected to the Wet-Mate connector through 600 m of G.652 fiber. This configuration emulates real system configurations, with the connector on the sea bed and the pumps on the platform.

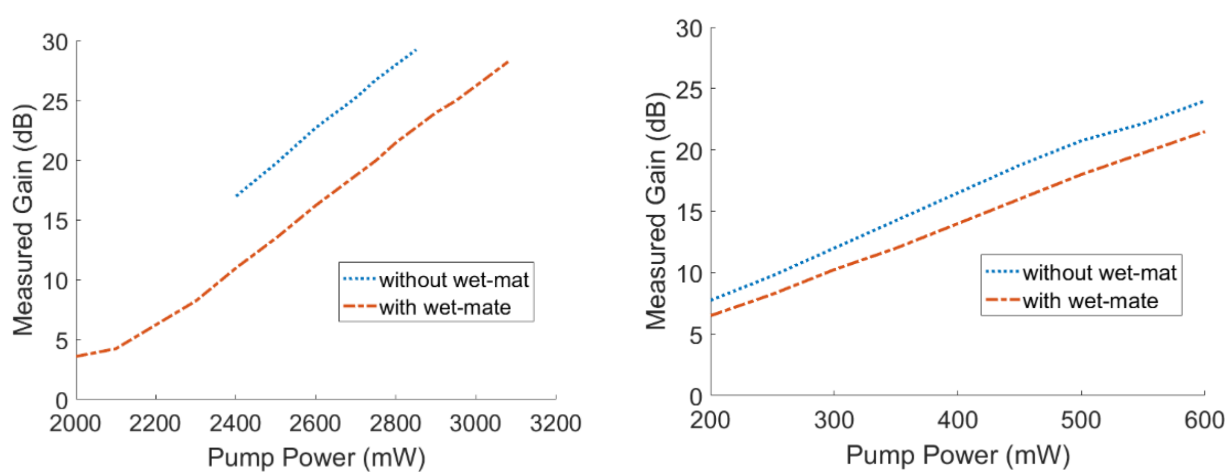

Fig 2. Counter Pump (left) and Co-Pump (right) ON/OFF Raman Gain as a function of Pump Power without and without Wet-Mate connector

Initial reference tests were done without the Wet-Mate connector for reference. Co- and counter pump Raman gains were measured as a function of pump power with an Optical Spectrum Analyzer. The connector was then introduced into the link and the same tests were repeated. During the subsequent transmission test, the received signal power and Bit Error Ratio (BER) were continuously monitored and recorded over a total soak period of 68 hours with a 10 Gigabit Ethernet (GbE) Analyzer from EXFO model FTB-1-S2-16G.

The gain-measurements in Fig. 2 show that the Raman counter-pump gain is lowered by 6-6.5 dB when inserting the Wet-Mate connector and that the gain difference shows a slight power dependence. For the co-pumping, a stronger power dependence is found, the gain difference varying from 1.25 dB for 200 mW of pump power up to 3.5 dB for a pump power of 600 mW. To check the system margin, i.e. the amount of attenuation tolerated by the system, the VOA between the fibre spans allowed the emulation of both longer fibre spans and the effect of potentially using a fibre with higher attenuation than the 0.17 dB/km typical of the fibre types used in the setup. The dBQ values were measured as attenuation levels were gradually increased. At 73.8 dB of total span loss, traffic was lost. At 73.55 dB, traffic recovered. The system was soaked for 14 hours at 73.55 dB with no bit errors.

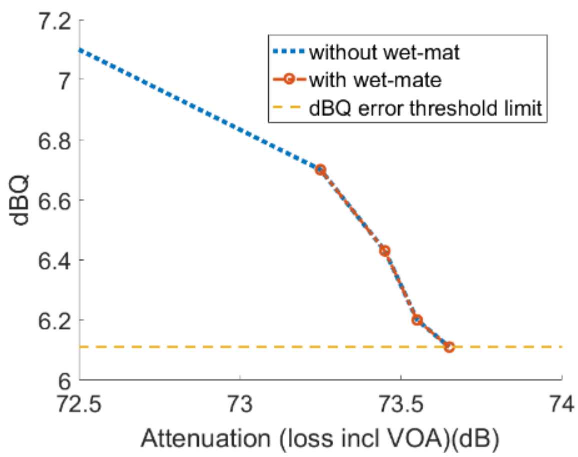

Fig 3. System Margin and Performance with and without Wet-Mate connector

4. Conclusion

This paper has, for the first time, explored using Wet-Mate connectors in combination with distributed Raman amplification. For sub-sea offshore fiber communications, Wet-Mate connectors are important components enabling a flexible connection sub-sea between the fibre cable and the offshore installation. Distances from shore to oil platforms may typically be in the range of 200-300 km, and high-capacity transmission over such long passive fiber links will benefit from using Raman amplification. The Wet-Mate connectors impact on gain in the Raman amplifier when the Wet-Mate connector is located close to the Raman pump has been explored. The Wet-Mate connector introduced ~0.5 dB loss which is within its specifications. An increase in counter-pump and co-pump power of approximately 20 % and 15 %, respectively is required to compensate for connector loss and maintain the Raman gain. The results of a 68-hour soak test showed Quality Factor Standard Deviation <0.01. There was no degradation in the performance of the connector after being subjected to high power from the Raman pumps. This paper has presented results demonstrating that Wet-Mate connectors can successfully be used for sub-sea connection of offshore installations where using distributed Raman amplification is desirable due to long fibre spans on e.g. passive sub-sea cables.

5. References

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