Increasing flexibility by using Remote Optically Pumped Amplifier (ROPA) in subsea passive fibre-optic cable installations

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Abstract: Passive optical subsea fibre cables ease installation and operation by avoiding subsea power, but limit maximum span length and link attenuation. By using Raman amplification in combination with subsea ROPA techniques, span lengths can be extended. A ROPA may typically be pumped using fibres in the data-communication cable. However, in this paper we also demonstrate that it alternatively may be pumped using a separate fibre cable, originating at an offshore installation located along the cable path, less than 36 km from the cable trunk. As a result, a span length of 500 km is achieved. Furthermore, in subsea installations using wetmate and swivel connectors, maximum optical power limitations may limit maximum transmitter launch power and hinder the use of Raman amplification. The ROPA pumping power is typically lower than what is needed for achieving sufficient Raman amplification. In this paper we also demonstrate that using a ROPA as an in-line amplifier enables a workaround ensuring sufficient SNR when connectors are limiting the optical power.

1. INTRODUCTION

Passive subsea fibre cable systems have lower cost, are more flexible and more reliable than active cables with amplifiers since a power feed along the cable and subsea electronics are avoided. The passive cables are therefore lighter, more environmentally friendly by avoiding any electromagnetic fields around the cable, and less expensive because a power feed is not needed. They can also be seen as more robust because they are simpler and any power failures will be avoided. For active cables, so-called shuntfaults, leaking currents from the power conductor in the subsea cable to ground through the seawater may occur. This happens if there is a fault in the isolation of the cable due to, for example, the cable moving slightly, due to underwater currents, over sharp stones, or alternatively due to a fishing tool (trawl) that has been dragged across the cable. A drawback with the passive cable technology is the distance limit due to attenuation. To transmit Terabits of capacity over spans of hundreds of kilometers, distributed Raman amplification may play a key role for achieving sufficient Signal-to-Noise ratio [1]. Installing Raman pump sources at both termination points of a passive cable segment allows using the transmission fibre as an amplification medium, achieving significant reach extension. The use of Raman amplification does however require high-power tolerance and moderate loss in any wetmate [2] or swivel connectors in the transmission path [3]. This becomes of particular importance for Cascaded Raman Amplification, which involves third-order pumping [4] to further improve span lengths. This type of distributed Raman amplification requires high power in the range of 1 to 5 Watts to be launched into the fibre at the receiving end of the link.

In this paper, we demonstrate two different applications where an extended reach is demonstrated by inserting a subsea Remote Optically Pumped Amplifier (ROPA) inline along the passive cable [5]. A ROPA is a passive EDFA device pumped by optical power fed through an optical fibre from a remote source. ROPAs are typically pumped from one of the endpoints of the cable, limiting the distance from the endpoint to the ROPA unit due to attenuation in the fibre delivering the optical pumping power. In addition to using this method, we also demonstrate a novel approach, allowing the location of ROPAs at a flexible distance from cable endpoints, by pumping the ROPA from a cable separate from the data cable, originating at an offshore installation located along the cable path, up to 36 km from the cable trunk. In the Tampnet subsea network, both solutions, feeding ROPAs through separate cables and a solution feeding the ROPA in-line along the data-cable are used. In this paper we compare ROPA solutions and explain where the different solutions are applicable in our passive cable subsea network.

2. ROPA PUMP LOCATED ALONG THE CABLE PATH

In Tampnet's cable reaching from Lista in Norway through the offshore installation Valhall and ending at Lowestoft in the U.K., an EDFA amplifier in the Valhall-Lowestoft span was initially located in a dry-room at an offshore installation along the cable path. However, when the offshore installation was decommissioned, a subsea ROPA was installed at the same location as the offshore installation, replacing the EDFA. A ROPA is now installed subsea in the span and fed with a pump signal through a separate cable originating at the closest offshore installation, Cygnus, located approximately 36 km from the cable trunk.

An alternative longer cable path is also possible by routing the cable through Cygnus and amplifying the signal by EDFA amplifiers in a dry-room at the offshore installation. However, this adds approximately 72 km, resulting in adding 360 microseconds of latency to the cable path. For low-latency services like gaming and financial services (e.g. high-speed trading), latency is critical and must be minimized. Hence, since this subsea cable is part of a route offering one of the lowest-latency routes from Stockholm and Oslo to London, enabling a route with minimized latency is critical.

The cable paths in Tampnet's North-sea network are illustrated in Figure 1. The red circle illustrates the location of the ROPA in the cable path and the location of the offshore platform where the ROPA pump laser is located.

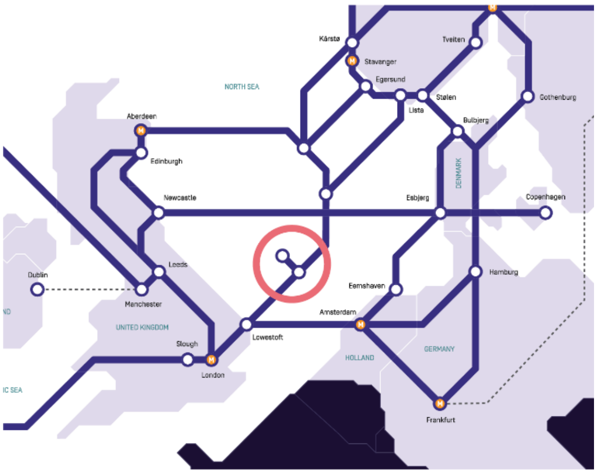

Figure 1: Cable path from Norway to the U.K. using ROPA.

The transmission system configuration is illustrated in Figure 2. Both co-propagating and counter-propagating Raman pumping is applied in addition to the ROPA for increasing the span length along the cable. By combining these techniques, we have demonstrated that sufficient SNR can be reached in an optical path with a total length of approximately 500 km.

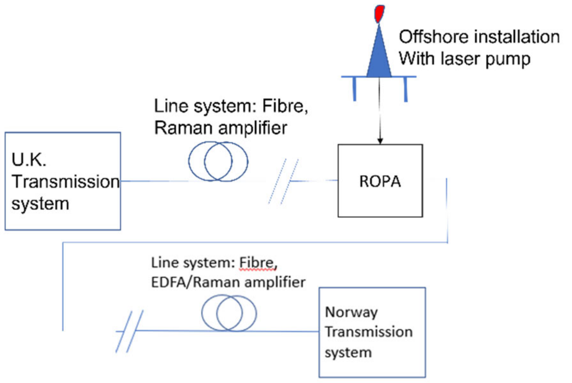

Figure 2: The transmission and line system with the ROPA pumped remotely from an offshore installation. The complete system consists of both Raman and EDFA amplifiers in dry-rooms at offshore installations along the path, and the ROPA which is located approximately 160 km from Lowestoft (UK).

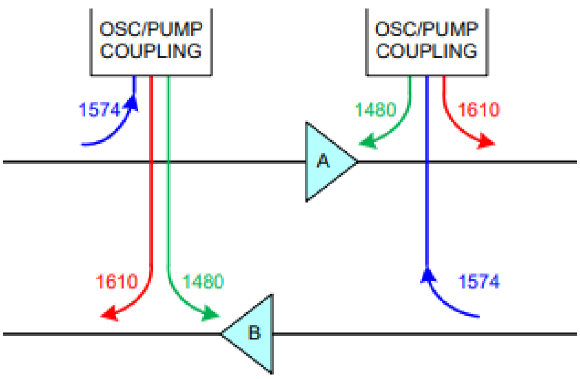

Figure 3: Pumping of the ROPA through a separate fibre cable from a remote source using 1480 nm. The 1610 nm and 1574 nm wavelengths are used as Optical Supervisory Channels (OSC) for fiber integrity monitoring for eye-safety purposes.

Figure 3 illustrates how the ROPA is pumped and also how the fibre integrity is monitored using Optical Supervisory Channels (OSC) in the system. An important feature is that if a fibre break occurs, the system must be shut down immediately due to eye-safety. For example, if a fibre break causes a loss of signal of the 1574-nm OSC arriving at the ROPA pump unit on the right in Fig. 3, the ROPA pump will immediately shut down and the pilot tone on the 1610-nm OSC which it is transmitting to the terminal to the right of Fig. 3, will switch from Tone 2 (which signifies all is OK) to Tone 1, which tells the Raman co- and counter-pumps at the right-side terminal to shut down. They will also shut down if they receive no 1610-nm signal, which would be the case if the fibre break was in the main trunk cable leading to the terminal on the right. Using this mechanism, unexpected eye exposure to strong infrared light is avoided.

3. HANDLING POWER LIMITS IN OPTICAL CONNECTORS USING ROPA

In the Gulf of Mexico (GuM), in a link between the offshore platforms Lucious, Stones and Holstein, Tampnet is using a different configuration of the ROPA for achieving sufficient system margins in the transmission system. The link enables both a direct connection from Lucius to Holstein, bypassing Stones, and a connection Lucius-Stones and Stones-Holstein. The links are illustrated in Figure 4.

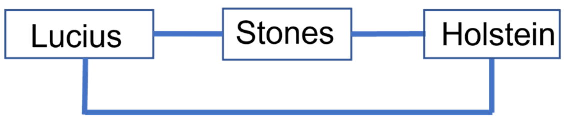

Figure 4: Fibre linking the platforms Lucius, Stones and Holstein.

The main challenge in these links are the optical power limitations for optical components used in the transmission path. A maximum of 300 mW of pump power is allowed through wetmate connectors and, in addition, at the Stones platform, a special swivel type of connector limits power to 0.5 mW. This type of power limitation may typically be present in environments where equipment may be exposed to explosive gas (Where ATEX requirements must be fulfilled.) Because of the strong limitation in maximum transmission power allowed from the Stones platform, Holstein and Lucius are not reachable without in-line amplification.

For this purpose, ROPA amplification is used for boosting the signal from Stones towards both the Lucius and Holstein platforms. Since the power limitation through the connector at Stones also disables any powerful pumping to the ROPA from Stones, all pumping of the ROPAs is performed from the receive side at Holstein and Lucius, respectively. On the transmit side from Holstein and Lucius towards Stones, transmit launch power is sufficient for reaching Stones without in-line amplification.

For the direct link between Lucius and Holstein, link attenuation is too high for achieving a sufficient SNR without in-line amplification. Using distributed Raman amplification would increase the SNR, but this option is not possible because of the limitation in maximum power through the wetmate connectors in the transmission path. Hence, also for this configuration, using in-line ROPA amplification in the transmission path is a good option for increasing the SNR to a sufficient level. For these configurations the ROPA is pumped from the same fibre as for the data transmission, with a pumping wavelength separate from the data-transmission wavelengths. The ROPA locations and pumping directions are illustrated in Figure 5.

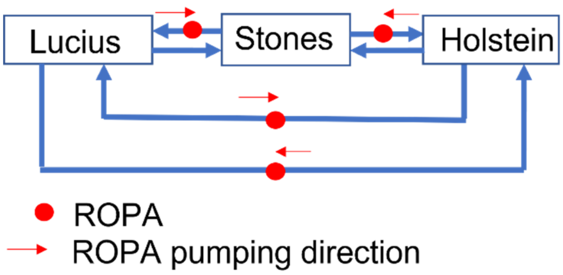

Figure 5: ROPA amplifiers and pumping directions in the fibres linking the platforms Lucius, Stones and Holstein. The red circles indicate the ROPA in the transmission path while the red arrows indicate the direction of the pumping light. All pumps are counter-directional to the data transmission path.

4. SUMMARY AND CONCLUSION

In communication to offshore installations using passive subsea cables, there are several use cases where using Remote Optically Pumped Amplifiers (ROPA) is an attractive solution. In this paper we have shown a use case on how combining ROPA with passive subsea cables and Raman amplification enables long-distance transmission spans up to 500 km in length. The ROPA is then located approximately midway in the link and pumped from a separate fibre cable located on an offshore installation along the path.
In a second use case, a ROPA solution is applied to overcome the challenges related to power limitations in wetmate and swivel connectors, that typically are used in offshore installations. Depending on the type of connectors, they may limit the maximum transmission launch power and preclude the use of Raman amplification because of the high pumping power. We have demonstrated that by inserting the ROPA as an in-line amplifier, and pumping from the receive side, we avoid the restrictive power limitation resulting from the use of a swivel connector while still enabling sufficient SNR on the links.
Also, for another use case, a fibre link consisting of several wetmate connectors in the path, the Raman pumps can’t be used due to power limitations in the connector. Without in-line amplification, the total attenuation of the link becomes too high for reaching a sufficient SNR. For this use-case, an in-line ROPA amplifier pumped from the receive side enables boosting the optical power sufficiently for reaching a sufficient SNR.
To conclude, we find that when using passive optical fibre cables, both reach and power budget limitations can be overcome by using ROPA amplifiers. Also, especially for offshore installations, power limitations may be challenging due to the need of special connectors like swivel and wetmate connectors. For meeting these challenges, the

ROPA is shown useful for achieving a sufficient SNR.

5. REFERENCES

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