XTERA™

Line Monitoring and Control in Subsea Networks

This paper discusses how submerged equipment is monitored and contrasts different methods of doing this. It also considers what features are required by the increasing sophistication of submarine systems like "open" systems, reconfigurable branching units, etc.

Introduction

Until recently the main purpose of line monitoring, or supervisory, was to monitor the repeater status, detect system degradation and locate faults. As systems become more complex the submerged equipment may need, however, to be controlled as well as monitored. The Branching Unit (BU) is a good example: while electrical switching can be controlled by power-feed currents, several suppliers have used supervisory signaling as a way of addressing some of the issues that this can create. It is also clear that optical switching / reconfigurable wavelength-routing will need a mechanism for telling the BU which wavelengths go where.

Supervisory Schemes

Before discussing other benefits that supervisory can offer it is worth examining the various schemes that are currently in use. These schemes go from passive monitoring through an optical high loss loop-back path to a command-response approach that requires a communication channel between the terminal equipment and the submerged equipment.

Loop-Back Scheme

In the loop-back scheme (originally developed by AT&T and KDD) a small fraction of the output signal of each amplifier is sent back using some form of passive optical coupler, as shown in the following schematic (Figure 1). More recent schemes use reflective filters to reflect two wavelengths and thus get more information, but the principle is essentially the same.

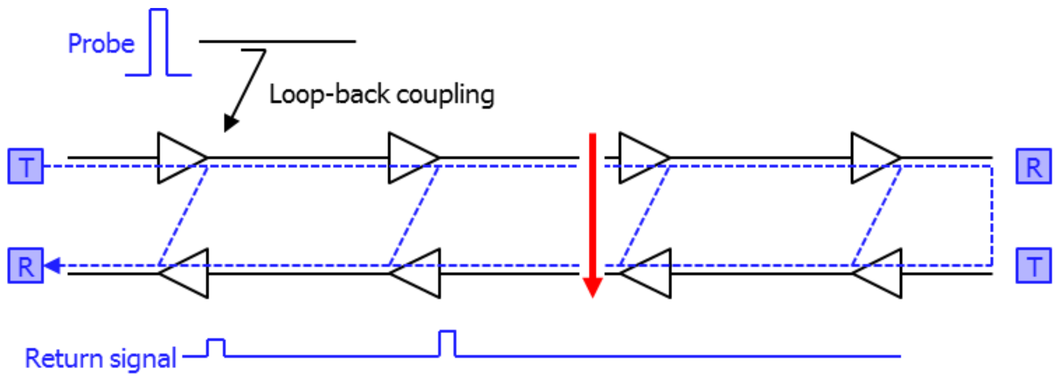

Figure 1: Schematic of loop-back supervisory approach.

If a probe optical pulse is sent, then for each amplifier a pulse will be returned at a different time and with an amplitude depending on the overall loop loss. A submarine cable break (represented by the vertical red arrow in Figure 1) will be obvious and loss changes can also be monitored. The coupling ratio, however, needs to be quite small to ensure that the sum of the cross-coupled signals is much smaller than the traffic signals and long-term signal averaging is required to recover the signal.

In some cases coding and correlation is used rather than a simple pulse, but the principle is the same and measurements take between minutes and hours depending on the precision required.

Because the loop loss includes both Go and Return fibers, it's often necessary to make measurements from both ends of the system.

Coherent OTDR (COTDR) Scheme

Coherent Optical Time Domain Reflectometry (COTDR) relies on a slightly different coupling scheme, to return backscattered light, as shown in the following schematic. The diagram in Figure 2 shows just the COTDR path, but a loop-back path can also be included, in which case the COTDR trace also shows the short pulses characteristic of that scheme.

The return signal now consists of a number of OTDR traces, one from each repeater section, which has the benefit that a fiber break can be located with greater precision than using the simpler loop-back scheme (where only the broken span can be identified with zero information on the fiber break location inside the span).

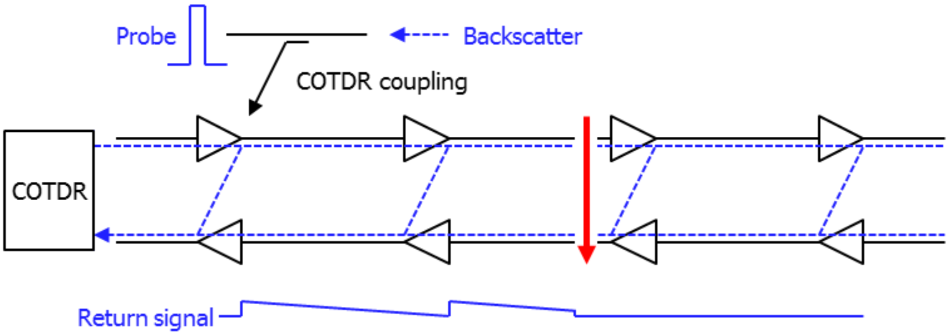

Figure 2: Schematic of coherent OTDR supervisory approach.

The backscatter signals, however, are very small and a combination of coherent detection (for improved detection sensitivity) and long-term time-averaging are usually used to recover a signal, with precision increasing with the averaging time. The return backscatter signal as a function of time or fiber length is shown at the bottom of Figure 2: this signal shows a saw-tooth trace. The tooth height is equal to the span loss while the tooth length represents the span length.

Active Scheme

A completely different approach (originally developed by Alcatel and STC) is to request information from the amplifiers. A digital request, containing the amplifier address, is sent and the amplifier with a matching address then sends a digital response in both Go and Return directions.

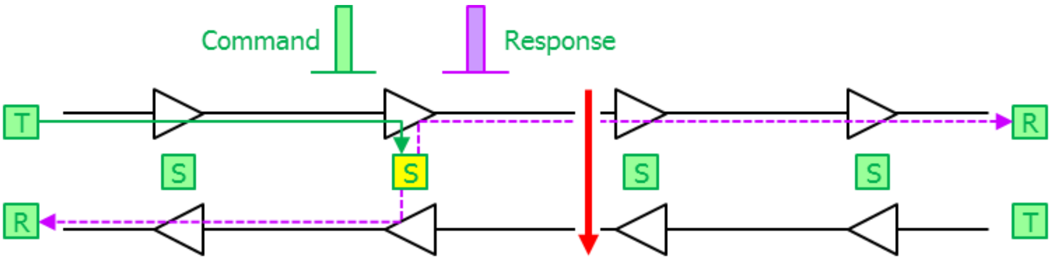

Figure 3: Schematic of active command/response supervisory approach.

The response contains, as a minimum, measurements of send and receive light levels, along with pump current/health.

It is possible to provide additional information e.g. internal voltage levels, temperature, acceleration etc., as Xtera's submerged amplifiers do. The response is sent almost immediately, and even scanning a large number of amplifier-pairs takes only a few minutes.

Comparing the Different Schemes

The passive schemes, loop-back and COTDR, have some similarities, both essentially measuring only optical loss. COTDR, however, offers the possibility of measuring the position of a loss change, while the loop-back scheme can only locate it to being between two amplifiers. Both require lengthy averaging for a measurement which isn't generally a problem, but does make it difficult to determine precisely when a change occurred. The focus on loss means that pump health can only be assessed when the pump output has dropped to the point where the amplifier output has degraded significantly.

An argument for the simple passive schemes is that because they require nothing more than the addition of passive optical components they must be more reliable than the active command-response scheme.

In fact the only components that Xtera had to add to the submerged equipment to provide this functionality were those needed to provide electrical filtering to extract the supervisory signals, which are detected by a monitor that was already present to control the amplifier output. Address and command recognition were simple functions which could be added to the Integrated Circuits (ICs) used to control the amplifier, so the impact on reliability would have been small anyhow and became minimal, as the ICs are duplicated.

The command-response scheme provides a much more rapid measurement and can report on pump currents before the amplifier output is affected (enabling preventive maintenance); it can also provide a range of other useful data. It can locate a fault or loss change to the nearest amplifier, but cannot provide higher precision, hence Xtera’s amplifiers also include the coupling needed for COTDR.

The supervisory scheme also offers the possibility of changing the operating parameters or configuration of submerged equipment, a facility which will be discussed further in the following section.

The command-response scheme provides rapid measurement and offers the possibility of changing the operating parameters or configuration of submerged equipment.

What Is Needed and What Is Helpful

In response to insatiable capacity needs, the traffic capacity of submarine systems has increased greatly over time, in part due to the development of higher bandwidth amplifiers, in part thanks to better terminal technology – coherent detection and multi-level/dimensional transmission formats. Branching units have also become more sophisticated, with reconfigurable wavelength routing an objective in many systems. Commercially there have also been changes, notably the upgrading of existing systems with third-party equipment and more recently the purchase of line plant separately from the terminal equipment. How do these affect the supervisory requirements?

Pump Performance Monitoring

The optical bandwidth increase has required significant increases in the output power of pump lasers and moves to composite amplifiers (such as C + L, or EDFA + Distributed Raman Amplifier – DRA) are likely to continue this trend, with each new system needing more power than the previous one. With higher powers and shorter development cycles it seems prudent to be concerned about the reliability of pumps, even if the track record of reputable suppliers has so far been good. Having a scheme that makes it possible to monitor pump performance, e.g. drive current, output power and temperature, means that unexpected ageing will be detected at an early stage.

Open Systems

A second factor making more comprehensive monitoring desirable is the recent interest in "open" systems. With submerged equipment and terminal equipment coming from different suppliers there is the obvious potential for difficulties if system performance degrades. Does the problem arise because of the terminal degradation, or is it due to submerged equipment? With good details of light levels, pump currents and other submerged parameters it becomes much easier to decide: without these there is the potential for wasting time and effort debating whether the terminal or the submerged line is the source of the problem.

Extra Information for Free

A further factor is the belief that while certain information may not be necessary, it may be helpful. An example is the accelerometers Xtera put in its prototype repeater, which were intended for use only during sea-trials. Customer feedback was that the information they provide would be helpful; it was suggested that having them in the repeater would both allow monitoring of the arrival of the repeater on the seabed and encourage the marine installer to ensure a gentle landing! While Xtera cannot say whether this encouragement works, the accelerometers have revealed a significant difference between the time at which the repeater actually arrives on the seabed and the predicted time, and we are now working to see how this information can be used to improve the deployment process. Data from trials of the branching unit (shown in the following figure) illustrates the information available.

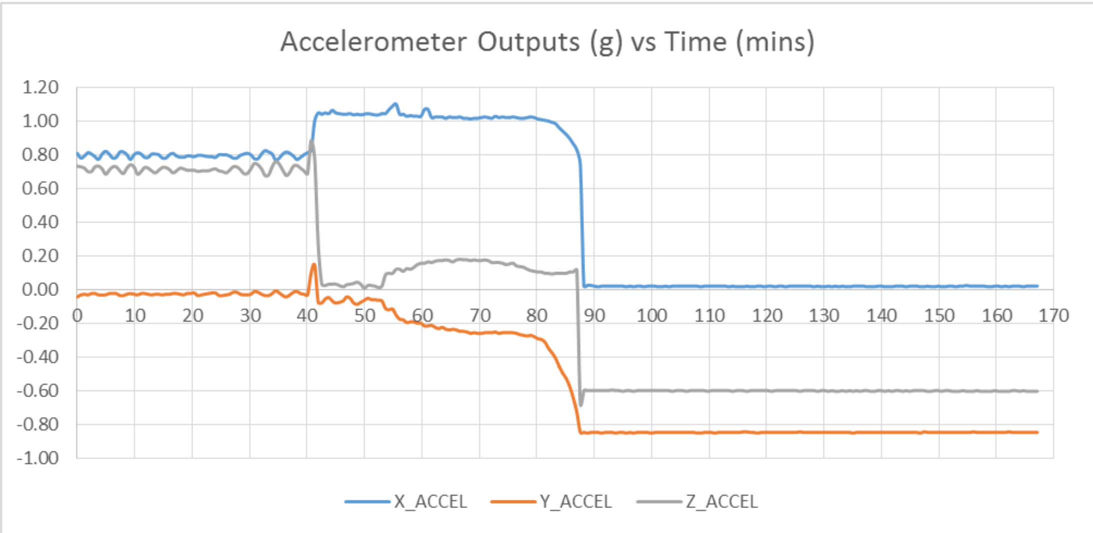

Figure 4: Acceleration data during branching unit deployment.

From this it's quite clear when the branching unit arrives on the seabed and it is also possible to deduce a degree of twisting during deployment.

From the Y and Z values after arrival, one can see that the final inclination is twisted axially by around 55 degrees, something that otherwise would be apparent only by sending a Remote Operated Vehicle (ROV) to inspect the deployed submerged equipment and take photographs.

Remote Control of Submerged Plant

The ability to provide remote control of submerged units, however, is probably even more valuable.

Branching units often provide power-switching and in the first designs the power-switching relays were controlled by the current flowing through the branching unit. This was a solution aiming for design simplicity, but it created complexities in powering up and re-configuring. It was not easy for people who rarely did this to ensure that the current flow was as required and it typically took a long time due to the required coordination between all the landing stations. Under fault conditions a branching unit might change its power configuration and for a non-expert it takes some time to work out what has happened by analyzing all the power-feed data.

Using the supervisory to switch the relays and to report the branching unit powering configuration removes many of these issues. Powering up and reconfiguring are further simplified due to additional features provided by Xtera, to ensure that the branching unit configuration is not affected by power glitches, and that "hot-switching" doesn't damage the relay contacts.

Further useful branching unit features that require commands are the control of switchable Reconfigurable Optical Add Drop Multiplexers (ROADM) units and the ability to lock the grounding of a branching unit leg for safety while a repair is carried out – in this case no configuration commands are permitted until the code used to lock the branching unit is resent.

The active command-response scheme simplifies the powering up and reconfiguring of branching units.

Gain tilt resulting from cumulative repairs is a concern for long-term system operation. Some suppliers address this by providing adjustable tilt equalizer units, while Xtera's amplifiers have controllable tilt. In either case the ability to control submerged units is the key.

There are other ways that tomorrow's wider bandwidth amplifiers can benefit from remote control. Such amplifiers typically have multiple pumps with more complex control algorithms driving them – Xtera uses a combination of distributed Raman and EDF, with separately-controlled pumps. While the control scheme can be left to make adjustments autonomously, some users are concerned that this approach can mask ageing effects and they prefer to make the adjustments manually. There is also concern that any fixed control scheme will not necessarily be optimal for all modes of operation. For example there are cable systems which currently operate at reduced line current as a way of reducing the output power to accommodate changes from direct detection to coherent detection at a higher line-rate. The ability to control the power output of different fiber pairs independently, however, is something that can only be done with remote control.

Independent repeater power control on a per fiber basis is key in new subsea cable system models.

Given that different pairs may well be owned by different operators and thus be upgraded in varying ways and at different times, it seems clear that independent power control is very worthwhile.

Summary

Command-response supervisory offers faster responses and greater precision than a scheme based purely on loop-back and (with the correct implementation) it can measure useful parameters such as temperature, acceleration etc. adding almost nothing to the complexity of the repeater.

In the case of an "open" system the clarity that such information brings could help resolve a question of whether a problem is caused by the submerged plant or the terminal equipment.

Perhaps more significant is the use of commands to control submerged equipment, for example to reconfigure power or traffic routing in a branching unit – this last feature is really possible only if there is some form of remote control. The ability to control the behavior of individual fibers is also worthwhile where they may be carrying different line-rates and signal formats, as upgrades may occur at different times, or use different transmission formats.

Submarine systems are becoming more sophisticated, as are the commercial models for operating them. For this process to continue they need a supervisory scheme, which produces clear information and allows flexible control. Such a supervisory scheme, meeting today's and tomorrow's needs, is offered in Xtera's repeaters and branching units.

XTERA™

Maximizing Network Capacity, Reach and Value

Over land, under sea, worldwide

Americas
Corporate Headquarters
Xtera Communications – USA
500 W. Bethany Drive
Suite 100
Allen, TX 75013, USA
T +1 972 649 5000
F +1 972 747 0344

Europe
EMEA (UK)
Xtera Communications – UK
Bates House, Church Road
Harold Wood, Romford
Essex RM3 0SD, UK
T +44 (0) 1708 335 400
F +44 (0) 1708 335 425

Middle East
EMEA (UAE)
Xtera Communications – UAE
Unit #2H-05-72, Floor #5
Bldg #2, Plot #550-554
J&G, DMCC, Dubai, UAE
T +971 55 55 4 33 01

About Xtera Communications, Inc.

Xtera Communications, Inc. (NASDAQ: XCOM) is a leading provider of high-capacity, cost-effective optical transport solutions, supporting the high growth in global demand for bandwidth. Xtera sells solutions to telecommunications service providers, content service providers, enterprises and government entities worldwide. Xtera's proprietary Wise Raman™ optical amplification technology leads to capacity and reach performance advantages over competitive products. Xtera's solutions enable cost-effective capacity to meet customers' bandwidth requirements of today and to support their increasing bandwidth demand fueled by the development of data centers and related cloud-based services.

For more information, visit www.xtera.com, contact info@xtera.com or connect via LinkedIn, Twitter, Facebook and YouTube.

The information contained herein shall not be legally binding unless it is specifically confirmed in writing by Xtera or incorporated into the terms and conditions of a sales agreement.
Features and specifications are subject to change without notice.
Copyright © 2016 Xtera Communications, Inc.

Edition Date: August 2016
Version: 1.1