Application Note

Submarine Cable Testing

MW90010A
Coherent OTDR

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Background

With the submarine optical cable industry continuing to grow at a steady rate and the ever increase reliance on transcontinental data traffic, the importance of minimizing optical network downtime has become more critical than ever.

Required data rates will continue to increase but more importantly, the reliance on connectivity is becoming more and more the expected norm. This has caused several of the latest submarine cable cuts to become not only news within the industry, but also within the wider public arena.

C-OTDR Overview

What is it?
The Coherent Optical Time Domain Reflectometer (C-OTDR) is the only way to accurately measure and characterize the optical submarine network allowing accurate fault location to within 10 meters.

How does it work?
The C-OTDR works utilizing the Rayleigh backscatter caused by the impurities inherent in optical fiber to reflect light back to the source much the same as a standard OTDR. As the submarine network or “submarine portion” of the network consists of not only the optical fiber, but also EDFA’s (erbium-doped fiber amplifier), standard OTDR technology isn’t a viable option. EDFA’s only amplify in the forward direction and employ components which are unidirectional therefore the backscattered light is not able to return via its original path. The majority of installed and planned systems include an optical feedback path within the EDFA enclosure, this feedback path allows the backscatter light to be returned to the C-OTDR on the second fiber of the pair.

The Network

Network overview
The submarine optical network is made up of several key components:

- LTE (Line Terminal Equipment) - this can be provided from many different vendors, normally 10Gig interfaces
- EDFA Section - lying on the seabed at depths of up to 3+km and containing several different components
- EDFA (Erbium-Doped Fiber Amplifier) - optical amplifier used to increase the optical transmission signal
- Optical Feedback Path - part of the EDFA used during testing of the network
- Fiber - submarine cable normally consisting of only several fiber pairs, power feed and strengthening material.

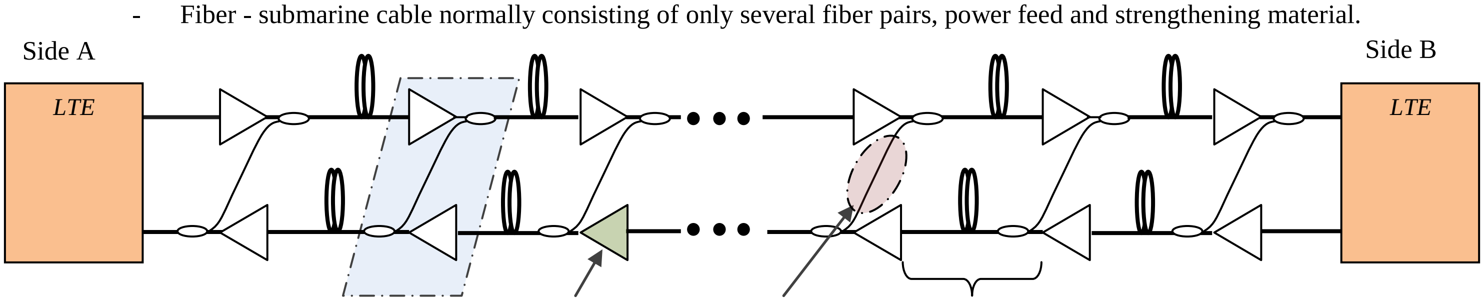

Fig 1; Major components of a Submarine System

C-OTDR

Working within the Network

Each submarine repeater has a path allowing the backscatter signal to pass backwards along the link, this path allows for monitoring the submarine portion of the optical fiber using the OTDR method. The distance between two repeater sections is joined by approximately 40 to 90 kilometers of optical fiber.

A submarine system uses multiple DWDM channels to increase the amount of total traffic between two locations (these DWDM signals are today normally at 10Gbps line rate while some companies are trialing 40Gbps). The C-OTDR probe pulse is assigned a DWDM channel.

The C-OTDR probe pulse and dummy pulse are normally placed as far away from the active traffic as possible to minimize any chance of interference. The dummy pulse occupies a second channel commonly adjacent to the probe pulse.

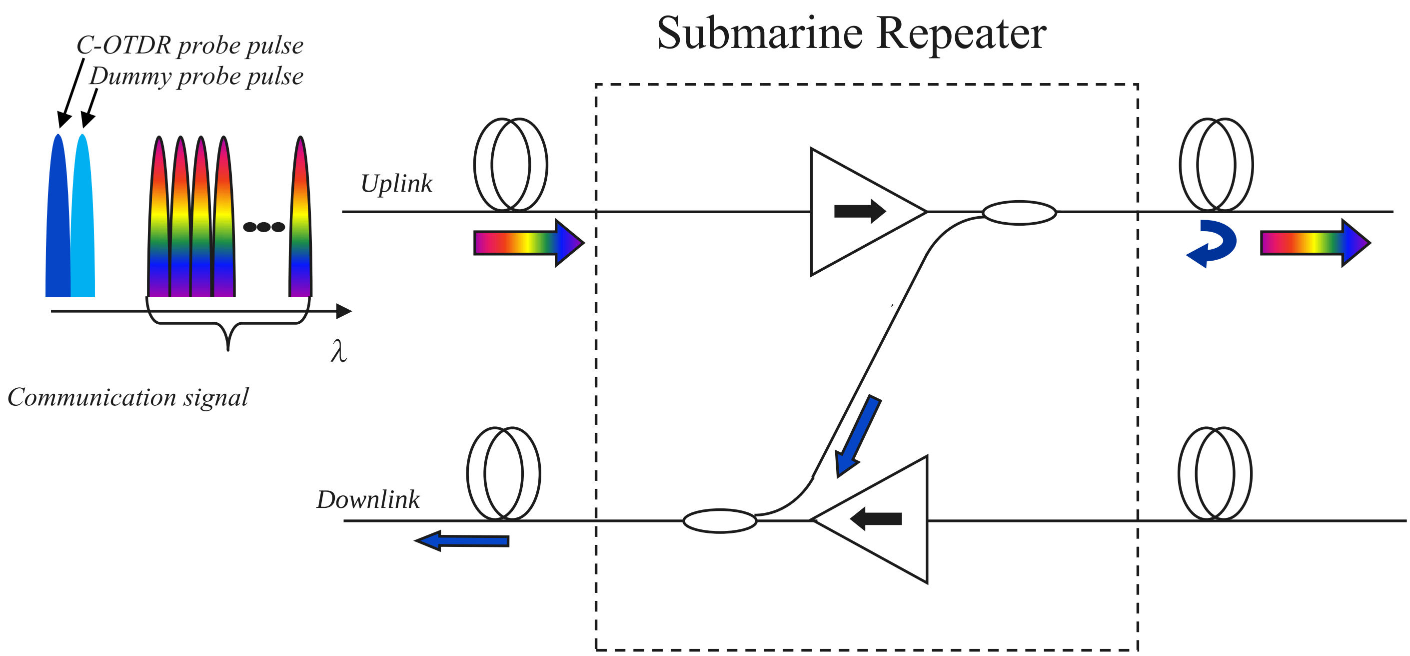

Fig 2; Submarine Repeater system showing C-OTDR return path.

The dummy pulse is required due to the automatic gain control system of the EDFA's. In a live system, the input to an EDFA is at a constant power level across multiple channels while C-OTDR testing is often completed on an unlit system (no traffic). When completing testing on an unlit system, the EDFA gain control is not able to maintain a stable output due to the pulsing power nature the C-OTDR presents to it. In order to avoid this problem, the C-OTDR is able to output on two channels which ensures a constant input level to the EDFA. The test pulse is being generated for a short period while the load pulse is on for the remainder of time while the ratio between the two is determined by the testing PW selected on the C-OTDR.

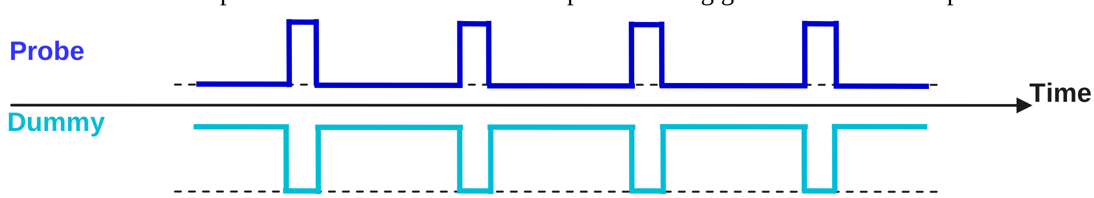

Fig 3; C-OTDR Probe and Dummy light

The C-OTDR works on the same basic principles of an OTDR which is by transmitting a light into the fiber then looking at the reflections (or backscatter) from the fiber under test. It also has the added ability to transmit on an adjustable narrow wavelength which allows the unit to be used in a live network alongside customer traffic within the DWDM network. On the receiver side of the OTDR there are several enhancements over a standard OTDR. The first major difference is the input of the C-OTDR is filtered to remove the active DWDM channels as well as extra noise. While the second and most important is the coherent detection. Coherent detection is a way of re-injecting the original transmitted wavelength allowing the resultant to show only information at exactly that wavelength. This method removes all other noise allowing for a large signal to noise improvement including reconstruction of data from well below the normal noise floor.

A submarine network is made up of many optical amplifiers to increase the power level to the DWDM wavelengths but this also increases the Amplified Spontaneous Noise (ASE) level. As each amplifier increases the ASE level, the coherent detection method enables the C-OTDR to see signals which would normally be considered hidden within or below this noise.

The block diagram Figure 4 offers an overview of the key areas of a C-OTDR.

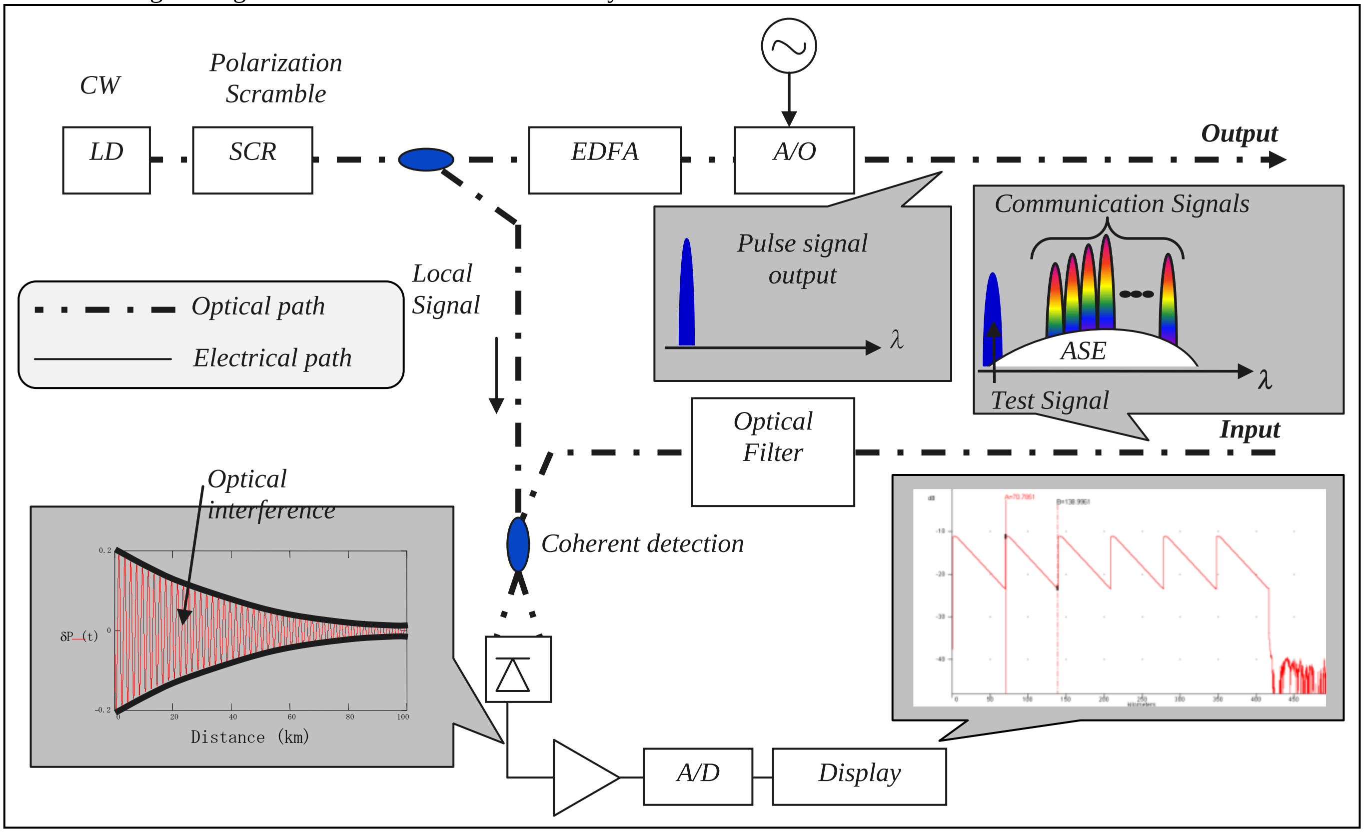

Fig 4; Basic internal working of a C-OTDR

Testing a severed network

A submarine network consists of pairs of fibers, direction A to B and B to A linked by the Optical Feedback Path at each repeater. The feedback path makes it possible for the C-OTDR to receive backscatter from the cable transmitting in the opposite direction. When testing a cable which has been totally severed (thus a single cut in a single location), the task is relatively straight forward however this can become more complicated in either of the following situations:

Single direction if the cable is severed (i.e. A to B but not B to A):

- The distance length will appear different depending on which end of the network you are testing from. The true fault location will only be shown when testing in the same direction as the transmission link fiber. Testing from the receiver end side, the fault will show the end location of the repeater directly following the cut location which could be inaccurate by as much as the distance of the repeater sections (up to 90km).

The cable is totally severed in two locations:

- A major cause of fiber cuts is due to seabed movement. This movement can cover a large geographical area and affect a large section of cable. A simultaneous cable cut in two locations can adjust the response and repair actions to be taken thus fully understanding this situation is very important.

Figure 5 shows testing from different ends of the network (not completed simultaneously):

- From direction A, the correct fault location is able to be identified while testing from direction B is incorrect.

By understanding how the OTDR technology and the optical feedback path work together, the true fault location can be quickly identified.

In a situation of two cuts within close proximity of each other careful evaluation reduces the risk of badly deploying expensive resources.

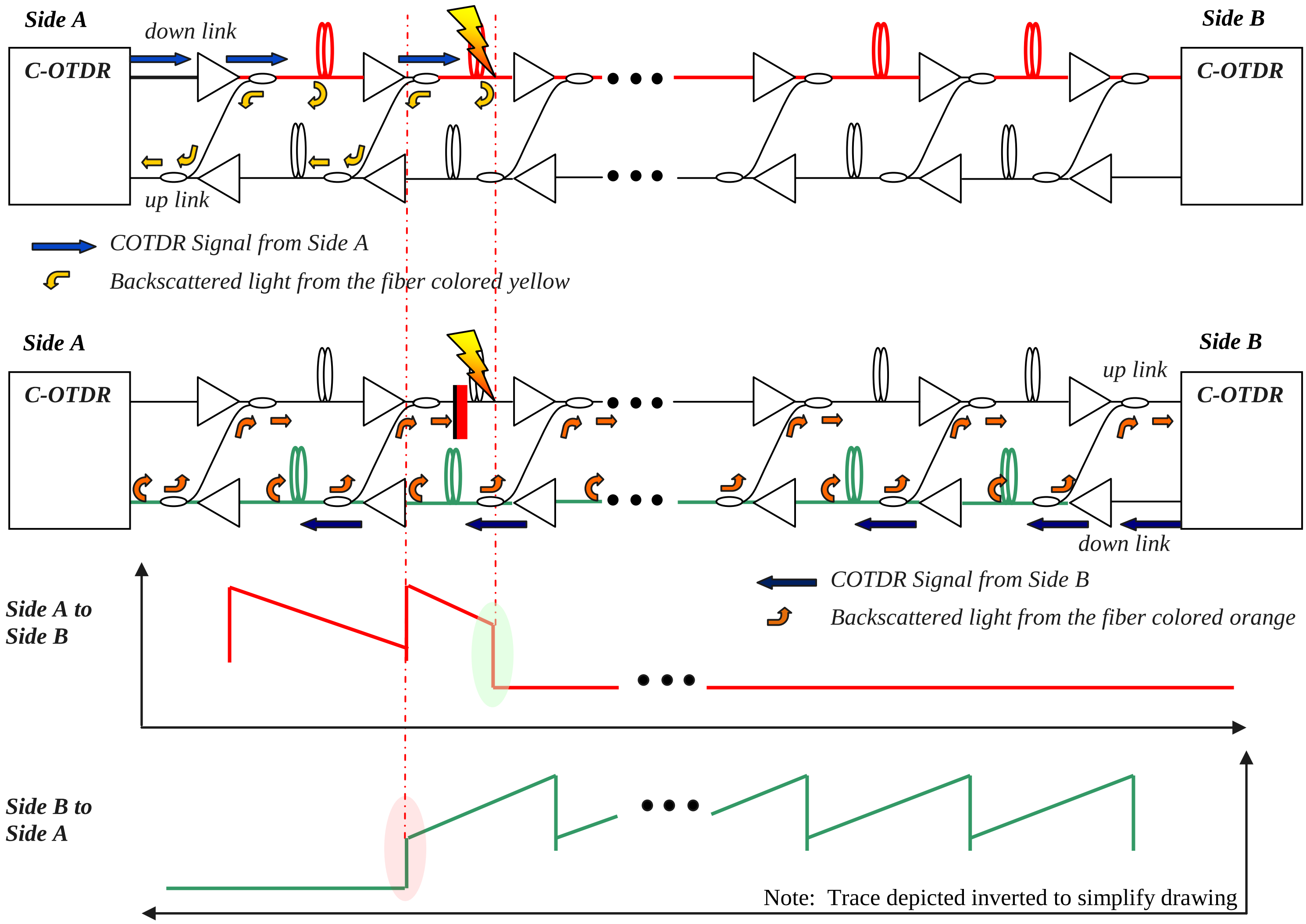

Fig 5; C-OTDR showing the repeater and break location

C-OTDR resolution

The importance of a C-OTDR comes from enabling accurate fault location on any length of submarine network. The data point resolution of many traditional OTDR's is normally determined by the km range setting of the OTDR. For example;

- An OTDR with only 50,000 data points will be affected by the range setting.

OTDR with 50,000 data points		Range / data points = Resolution
10km Range	0.2m resolution	10,000 / 50,000 = 0.2
100km Range	2m resolution	100,000 / 50,000 = 2

Table 1; OTDR Data Point resolution

This becomes an even more critical issue with submarine networks as the distance of the submarine portion is several orders of magnitude larger than terrestrial networks. Due to this the latest C-OTDR's are designed with 1.2 Million data points and automatically reduces the number of points depending on the distance range setting which has several advantages:

- Maintain the same 10m resolution irrelative of the km range setting
  - ➢ 10m resolution was selected as it ensures the C-OTDR is not the weakest point when locating a fault
  - ➢ 10m accuracy is well within the requirements for fault location in a Submarine Network.
- Reduce the processing time of the C-OTDR while calculating the trace
  - ➢ The C-OTDR can take approximately 8 samples per second [Note 1] each sample consisting of up to 1.2 Million data points. These samples are then averaged over time before the trace is displayed.
  - ➢ This processing time reduction is due to being able to reduce the number of data points being averaged when a range setting of less than 12,000km is selected.

Note 1

The number of samples per minute is dependent on several factors such as, speed of light, Range and Resolution of the OTDR. To complete 1.2 million data points (each 10m apart), the C-OTDR would be set to a range of 12,000km. The time taken for light to travel 12,000km (there and back) would be approximately 120mS, Thus 1second / 120mS = 8.3 scans per second.

Using a C-OTDR with less data points can become a large issue if the user was required to measure longer links.

- An example would be if the C-OTDR had a maximum of 10,000 data points and the range was set to 8,000km,
  - 8,000km / 10,000 = 800m (data point inaccuracy). See Fig 6,
    - This inaccuracy could cause extended delays in locating the end fiber fault, in turn delaying network restoration.

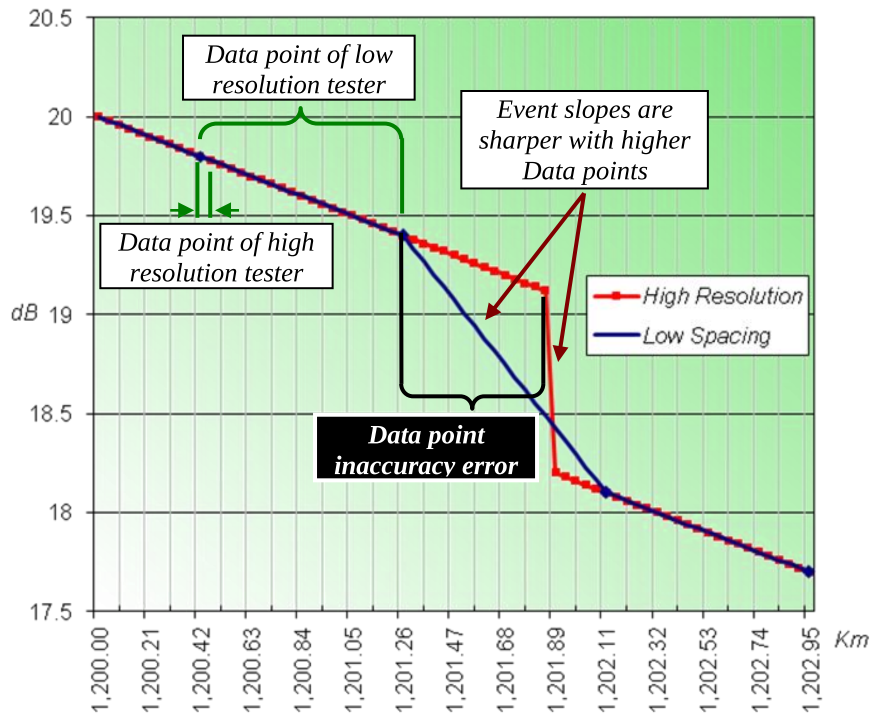

Fig 6; Data Point resolution of different C-OTDR's

Conclusion

Why the C-OTDR technology

The C-OTDR offers the best technology for testing submarine fiber optic cables. The newer generation of C-OTDR's allows for not only extremely accurate distance measurements, but also full characterization of optical events. The combination of the C-OTDR's coherent technology and submarine cable optical feedback path ensures thousands of kilometers of fiber can be characterized quickly and efficiently. With some basic knowledge and a simple interface, even an inexperienced engineer is able to ensure the expensive task of fault restoration is completed as quickly and efficiently as possible.

Anritsu Optical Solutions

MS9740A Optical Spectrum Analyzer The MS9740A is a benchtop optical spectrum analyzer covering 600 nm to 1750 nm. The MS9740A offers high-performance optical resolution and high-speed measurements to support the needs of customers.	
CMA5000a Multi-Layer Network Test Platform CMA5000 transmission test modules can support field installers and maintenance engineers who require a single tool for data network testing form n x 64 BER and physical interfaces of 1.5 Mbit/s to 10 Gbps for SDH/SONET. OTN networks on both 2.66 Gbps and 10.7 Gbps are also supported. Ethernet interfaces from 10 Mbit/s to 10 Gbps (LAN-PHY and WAN-PHY) allowing full data network testing abilities.	

Specifications are subject to change without notice.

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