TURNING-UP 40G SUBMARINE NETWORKS

Francis Audet, Senior Product Manager (EXFO), Email: <francis.audet@exfo.com>
Mai Abou-Shaban, Product Manager (EXFO), Email: <mai.abou-shaban@exfo.com>
Raymond Lai, Application Engineering Manager (EXFO)
Woe Chzee Cherng, Regional Sales Manager (EXFO)

ABSTRACT:
From the planning stage to the deployment stage of an under-sea fiber optics cable, a lot of time, money and efforts are invested. Yet a point that is often neglected and that can lead to unfortunate delays is the final acceptance test of the fiber: making sure it can deliver on the promised and expected bandwidth. This was often overlooked because legacy data rate were not extremely challenging to carry. Now with the deployment of 40Gbps, newer and tighter challenges are at hand, and one must understand and plan them properly. Some critical physical layer tests include Dispersion Testing such as Chromatic Dispersion and Polarization Mode Dispersion. Tests of some importance at 10Gbps are now un-avoidable at 40Gbps transmissions. Once these parameters have been fully qualified and optimized comes the system turn-up test. These include Signal Power level and Optical Signal to Noise ratio measurements, important in both repeated trans-oceanic or festoon links. And finally the network end-to-end level qualification; where all the relevant SONET/SDH tests are performed, including tests such as Bit Error Rate. This paper reviews the challenges brought forth by the advent of 40Gbps transmission as well as describing the in-depth importance of every test, where and how they should be performed. This paper also exposes and demonstrates a case-study of a trans-Atlantic dispersion acceptance test performed earlier this year.

1. INTRODUCTION

As the demand for bandwidth continues to grow at a tremendous pace in submarine networks, service providers have no choice but to ride the wave and adapt their networks so that they can offer more services to their customers. Yet with new technologies getting closer down the road, providers are faced with difficult choices. In this context, upgrading from a 10Gbit/s to a 40Gbit/s advanced modulation format becomes a necessity—but not at any price. The three main drivers behind each upgrade is that service providers want to use existing fibers and network elements, to maximize revenues from infrastructure already in place; they want to improve operation flexibility, which translates into more efficient provisioning and increased revenues from new services to their customers and they want to increase the density of the network elements to optimize central office space and power consumption. However, upgrading from 10Gbit/s to 40Gbit/s, or even to 100Gbit/s, has a significant effect on the tolerance to optical impairments such as the level of noise with the signal, chromatic dispersion (CD) and polarization mode dispersion (PMD).

Both chromatic dispersion and polarization mode dispersion have been known facts for almost a decade now, yet testing these parameters on OC-192/STM-64 is not always done de facto. But now, with the current penetration of 40Gbit/s, both are becoming an even bigger issue. The new speed of 40Gbit/s comes in many flavors, yet even the most resistant OC-768/STM-256 (40Gbit/s) can only tolerate a fraction of what OC-192/STM-64 (10Gbit/s) can accept, both in CD and PMD. The typical acceptable CD is around 10% of the 10Gbit/s tolerance levels. The PMD tolerance is typically 25% of it. PMD values that were acceptable may not be anymore. CD compensation schemes were effective at 10Gbit/s but the residual compensation is much too high for 40Gbit/s transmission. PMD specifically was never compensated. Either it was hoped to be good, or more often tested. When found to be too high, the fiber was limited to lower speeds. But chromatic dispersion was compensated via simple dispersion-compensating modules (DCMs), which are deployed automatically and installed by system vendors. On the other hand, accurately testing for this parameter allows one to fine-tune each stage of compensation, as well as perform (if required) end-to-end compensation adjustments to remove excess residual dispersion. The following case study highlights the importance of CD and PMD measurements in 40Gbit/s submarine deployments;

2. CASE STUDY:

Submarine network going from UK to New York was tested for Dispersion parameters. The one-way trip (UK-USA) was 6008km in length, and was comprised of 144 amplifiers (EDFA). Two fibers were tested: A4 and A5. The following tests were performed:

- CD and PMD on fiber A4, CD made twice, to validate repeatability
- CD and PMD on fiber A5, PMD made twice, to validate repeatability

The results were quite revealing:

	Lambda Zero (nm)	Residual Dispersion at 1550nm (ps/nm)	PMD (ps)
Fiber 4A	1552.02	-1060	3.928
Fiber 4A Repeat	1552.04	-1065	Not Tested
Fiber 5A	1551.86	-978	1.65
Fiber 5A Repeat	Not Tested	Not Tested	185

These results were in the range expected: Chromatic Dispersion compensated properly and therefore barely low enough for 10Gbit/s, but clearly out of specifications for any 40Gbit/s. PMD below the 10Gbit/s tolerance, but one of them, fiber 4A, not passing the 40Gbit/s typical PMD tolerance (2.5ps being the typical value).

To prove the accuracy of the test measurements, loopback tests were performed. Chromatic Dispersion being linear, looping it on itself should result in doubling the value. PMD being stochastic, the total expected value would be the quadratic sum.

	Lambda Zero (nm)	Residual Dispersion at 1550nm (ps/nm)	PMD (ps)
Fiber 4A Looped	1552.08	-2247	5.284
Fiber 5A Looped	1551.95	-2025	Not Tested

Both loopback results are within the expected range of value (considering the test equipment uncertainty), confirming the validity of the single direction tests and therefore the conclusions. This clearly proves the importance of CD and PMD tests for 40Gbit/s submarine deployments, regardless of if it operates 10Gbit/s flawlessly.

The second parameter to be monitored in 40G networks is Optical Signal to Noise Ration (OSNR); which is an excellent way to provide a representation of all the optical noise effects. Typically, there is a direct relationship between OSNR and bit error rate (BER); higher OSNR leads to a lower BER. OSNR is generally measured by using the interpolation method, as recommended in IEC 61280-2-9. This method is based on the assumption that noise level is generally flat between and under adjacent peaks. Unfortunately, the interpolation approach is not possible when the peaks are very closely spaced as shown in figure-1 below—as with large 40Gbit/s signals or ultra-dense wavelength-division multiplexing (UDWDM)—and crosstalk becomes dominant over ASE noise.

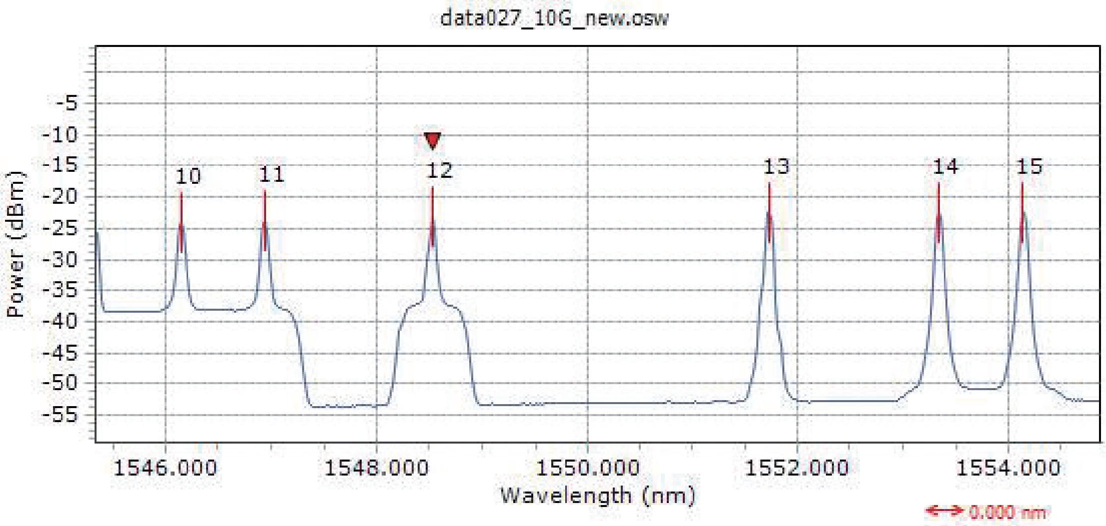

Figure 1 - A case where interpolation is not possible: when the noise under the peaks is not flat

In this case, an innovative method based on advanced analysis using fundamental differences between signal and noise, namely polarization and spectral characteristics, allows an adequately measurement of the noise within the channel, without having to turn off the transmitter. This approach is referred to as In-band OSNR measurement and takes advantage of built-in polarization diversity detection combined with a polarization controller to measure the power versus the wavelength on two polarization axes for multiple polarization states; thereby discriminating between the polarized and non-polarized power and isolating the noise from the signal inside the channel. Relying on sophisticated algorithms that work concurrently on the signal shape enables the user to automatically achieve accurate and repeatable OSNR measurements in 40G networks.

Finally, qualifying the OC-768/STM-256 40G payload is an essential part of turning-up 40G submarine links and is typically conducted through the end-to-end, bit error rate (BER) test across the network. With this test, service providers can be sure that all new 40G circuits in service are proven capable of handling any of the demanding services that may be placed on them in the future. Therefore, these test routines and more, when performed without the proper test equipment, can prove complex and cumbersome to perform.

