CD AND PMD TESTING: MEETING TODAY'S CHALLENGE AT LIMITED COSTS

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The massive deployment of ROADMs in metro mesh networks. The explosion of 10 Gbit/s—and even 40 Gbit/s—transmission. Widespread triple-play services. All of these technological developments, along with several other market factors, are putting tremendous pressure on installed networks. However, in today's highly competitive industry landscape, capital expenditures (CAPEX) and operational expenditures (OPEX) are what make it or break it for network service providers.

This added pressure on networks translates into new technology challenges, namely when it comes to chromatic dispersion (CD) and polarization mode dispersion (PMD). More specifically, since they are an even bigger hindrance at higher transmission speeds, CD and PMD must be measured more regularly than ever. Yet, more than ever, budgets to do so are limited. The need to test grows—much faster than testing budgets. What is required is an efficient, affordable means to accurately testing both dispersion types.

One way to make testing more efficient and affordable is to carry it out from a single end of the link, since this reduces CAPEX (one test instrument instead of two) and OPEX (one technician instead of two, fewer truck rolls). For instance, during fiber characterization, OTDRs are used to check end-to-end continuity, span loss, splice and connector quality, all from one end of the link. Although some single-ended CD analyzers are offered, they generally lack accuracy. And up to recently, single-ended PMD analyzers were unheard-of.

Clearly, there was a market need for a test technology that would accurately measure CD and PMD in one instrument and from a single end, such as EXFO's FTB-5700 Single-Ended Dispersion Analyzer.

Chromatic Dispersion

The OTDR-Like Approach

A few years ago, a single-ended CD measurement method was introduced which required no expertise nor test boxes at the far end. While sparing the need for a second test instrument, this method presents several well-known flaws.

1- The difficulty to achieve a perfect fit

Chromatic dispersion is the rate at which the delay changes as a function of wavelength. The best and most common way to calculate it is therefore to measure delay between a certain amount of wavelengths, and then "fit" those points together according to a certain mathematical model defined by industry standards.

Several fiber types, including G.652 and G.655 fibers, are modeled using the 5-term Sellmeier equation, which requires five data points to be known in order to solve it and obtain an accurate fit. Consequently, a test method that only provides four data points (such as a four-wavelength OTDR) can only lead to an inaccurate fit and to CD calculation errors. In turn, this causes a systematic error that distorts chromatic dispersion results and that can't be calibrated. This means that the OTDR-like approach to measuring CD produces consistently flawed chromatic dispersion results, and that it cannot be deemed accurate nor standards-compliant.

2- The complexity of today's networks

If the network utilizes more than one fiber type, the total end-to-end chromatic dispersion cannot be modeled by a simple equation such as the 5-term Sellmeier, since the actual CD value is therefore a mix of several fitting equations, which makes the calculation much more complex. In such a case, the limit of four data points is even farther from the "truth".

3- The wavelength/length-dependence of dynamic range and attenuation

Attenuation is approximately 50% greater at 1310 nm than at 1550 nm. Consequently, with equivalent dynamic ranges, the fiber is actually 33% shorter. An OTDR using a 1310 nm data point will most likely "lose" it at about 80 km, that is if all splices and connectors are perfect.

Many networks have longer links. In fact, for 10 Gbit/s transmission, CD becomes an issue mainly at 80 km and over. So when the testing becomes the most important, one of the data points is lost, which leaves us with only three data points–even further from the model described earlier–and reduced test accuracy.

4- The "free OTDR" perception

In essence, this CD measurement approach does provide the user with a "free OTDR". However, CD testing requires a DFB laser (narrow linewidth), while quality OTDRs use Fabry-Perot lasers (broad linewidth). A narrow linewidth significantly affects the effectiveness of the OTDR functionality, delivering typical specifications of the order of 6 m event dead zones and 30 m attenuation dead zones.

Today's network requirements call for a much better OTDR than this, with event dead zones below 1 m and attenuation dead zones below 5 m. Accordingly, the free OTDR is most of the time unsuitable for the task.

Improving the Method

We can assume that network operators who need a good OTDR will acquire one. This frees the CD analyzer design from such OTDR-based limitations (including the 1310 nm data point) and enables it to use a tunable laser source covering the S, C and L bands (a wavelength range of 150 nm) and to only "look" at the fiber end, and not the events in-between, which seems to solve the above-mentioned issues.

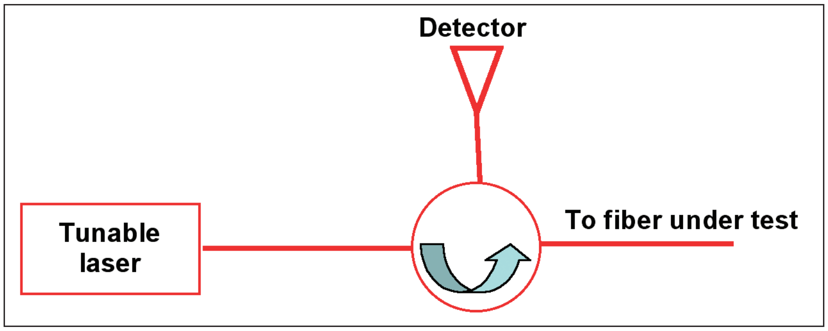


Figure 1. Tunable laser-based, single-ended CD measurement.

With simple electronics, a first pulse is sent to check the attenuation of the link. Then, eight equally spaced signals are sent down the fiber, at wavelengths optimized for the measured attenuation.

- Eight points instead of four allows every fiber–even within complex networks comprising several fiber types–to be calculated, even those requiring 5-term equations.
- Since we only test at the fiber end, and since each wavelength has sufficient dynamic range (the tunable laser automatically selects eight wavelengths optimized for the span loss), testing is much quicker and each wavelength is much more accurate.

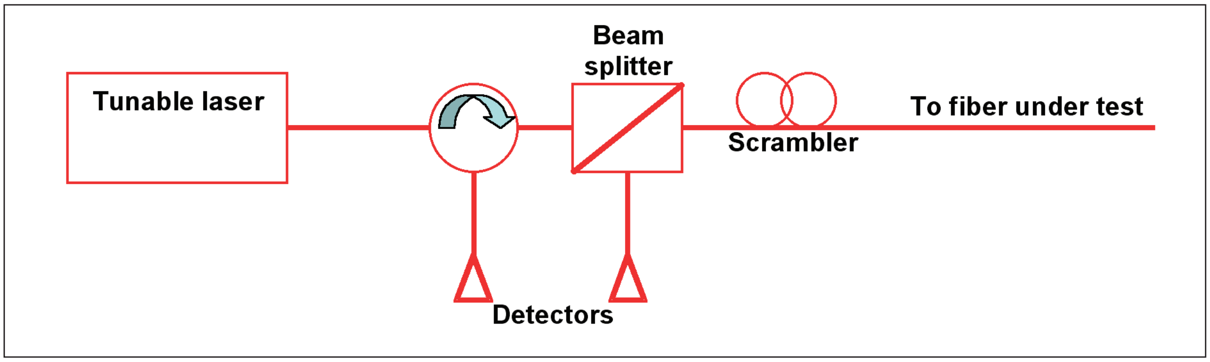
Polarization Mode Dispersion

At this point, we have much more accurate single-ended CD measurement, but we still need two boxes (source and receiver) for PMD testing—which, historically, is a strong area of expertise for EXFO. Indeed, in 1996, EXFO pioneered interferometry-based portable PMD analyzers; in 2000, the Poincaré sphere analysis method for component PMD testing; and in 2003, GINTY-based (generalized interferometric analysis) PMD test modules, by far the most robust for end-to-end testing in the field.

We know that PMD is the average differential group delay over all wavelengths and/or all states of polarization (SOP). As mentioned above, our tunable laser sources cover the S, C and L bands, providing a broad wavelength range. As a result, by simultaneously sending two very closely spaced wavelengths at random states of polarization and monitoring their individual delays, we obtain a local difference.

Repeating this process at several wavelengths along the tuning range and at various SOPs (generated through a polarization scrambler) gives us the mean velocity or, in other words, the PMD. So what we are actually measuring is the local differences of transmission between random pairs of closely spaced wavelengths and for random SOPs.

Therefore, in our tunable reflectometer described in the CD section, we inserted a polarization scrambler to generate random polarizations for each different wavelength pair, and we added a polarization beam splitter on the return path, which transforms the CD analyzer into a PMD analyzer.



Conclusion

In brief, the FTB-5700 is a single-ended, one-box dispersion analyzer that measures both PMD and CD and delivers valuable benefits: no test delays because of equipment shipping or technician synchronization, shortened test cycles, increased accuracy and efficiency and, ultimately, reduced CAPEX and OPEX. The bottom line: precise network qualification does not compromise the budget, and vice versa.

In addition, a single unit means a single software to learn and use, simplifying training and minimizing human errors. The output is also a single test file to manipulate instead of two separate files that need to later be combined to produce test reports.

What's more, using an all-dispersion analyzer avoids having to disconnect the fiber between CD and PMD tests. Since more than 75% of network problems are caused by dirty or damaged connectors, less manipulation is always good.

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