Measuring Ultra-Low PMD with High Reliability

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Introduction

Polarization mode dispersion (PMD) has concerned fiber/equipment manufacturers and service providers (Telco or multiple-system operators [MSOs]) for some time. However, increased transmission speeds and the related PMD-dependent limits have driven field measurement interests from identifying high-PMD values to performing reliable and repeatable high-resolution PMD measurements.

The Requirements

Advanced Fiber Specifications

With every enhancement made over the past few years, fiber and cable manufacturers have significantly improved the performance of fiber and cabling designs and greatly reduced PMD.

They have developed processes for manufacturing optical fibers with ultra low PMD. This ultra low PMD can further be preserved because of modern cabling design. Leading manufacturers now specify the Link Design Value (LDV), which could be less than 0.04 ps/√km, when the cable is installed in the field.

Link Design Value[1]
LDV provides a useful design parameter for calculating the worst-case amount of PMD a fiber contributes toward the overall system PMD for a link. LDV, also referred to as PMDQ, is a term developed in standards bodies used to evaluate the impact of fiber-related PMD where cabled fibers are deployed in concatenated sections. The LDV is the worst-case PMD of the end-to-end link made up of randomly chosen cable sections spliced together and, therefore, represents the worst-case PMD of a fiber path in a deployed cable span. PMD standards suggest calculating LDV from nominally 20 to 24 sections with a maximum cumulative distribution Q of nominally 0.001 to 0.0001, which implies that 0.1 percent or 0.01 percent of all spans (made up of concatenated sections) would be above this level of PMD.

Typical LDV and PMD Values that Fiber Manufacturers Specify
Tables 1 and 2 show PMD parameters extracted from fiber manufacturer data sheets. The associated values indicate that the low level PMD (or LDV) are now the de-facto standard with high performance optical fiber.

Polarization Mode Dispersion	
Fiber PMD LDV	≤0.04 ps/√km
Maximum individual fiber	<0.1 ps/√km

Table 1: ITU-T G.655 fiber types.[2]

Polarization Mode Dispersion	
Fiber PMD LDV	≤0.06 ps/√km
Maximum individual fiber	<0.1 ps/√km

Table 2: ITU-T G.652D fiber types.[3]

High-Speed Transmission Limitations

PMD limits decrease proportionally as bit rates increase; therefore, it is necessary to measure lower and lower values to ensure that today's fiber characterization holds true for future transmission upgrades. Upgrading from 10G to a 40G decreases PMD limits by a factor of 4. The theoretical values then fall between 2 and 2.5 ps of PMD delay and can decrease further with 100G transmission.

Modulation Format	OOK	PSBT	CS-RZ	DPSK
PMD tolerance	1 ps	2.1 ps	2.8 ps	2.5 ps

Table 3: Comparing PMD limits vs. the 40 Gbps modulation scheme.

Modulation Format	OOK	PSBT	DPSK	DQPSK	PM-DQPSK	PM-QPSK
PMD tolerance	1 ps	1 ps	1 ps	2 ps	2.5 ps	2.5 ps

Table 4: Comparing PMD limits vs. the 100 Gbps modulation scheme.[4]

ITU-T Recommendation for Maximum PMD [5,6]

Recommendations specify a maximum PMD coefficient of 0.2 ps/$\sqrt{km}$ for long-haul or high-bit-rate transmission applications of 10 to 40 Gbps, including 10 GbE. Some recommendations mention "common typical values" of 0.1 ps/$\sqrt{km}$, particularly for 40 Gbps intermediate and long reach applications.

Enhancing the Fixed Analyzer Fourier Transform Solution (FA-FT)

Improving Low PMD Measurement Uncertainty and Repeatability

It has been commonly known for years that the accuracy of PMD measurements improves with multiple measurements taken over various polarization launch conditions. The International Electronic Commission (IEC) already recommends using polarization scramblers for the Interferometric method in IEC61280-4-4 which is also well documented in the Generalized Interferometric (GINTY) method.

The Fourier-Transform of an optical spectrum is mathematically equivalent to the interferogram of the same optical signal; therefore, making the IEC61280-4-4 recommendation applicable to the Fixed Analyzer method, resulting in a test setup similar to the GINTY method with the introduction of two polarization scramblers as described in Figure 1.

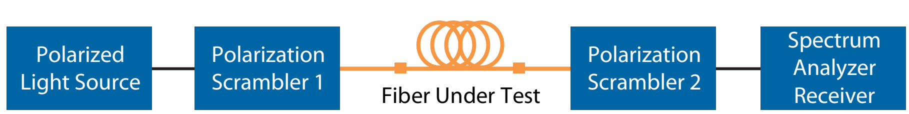

Figure 1: General setup for high repeatability of low PMD value with FA-FT Test method

The Lyot Depolarizer

A Lyot Depolarizer induces rotation of the polarization as a function of wavelength.

- The motion is quasi-periodic with two periods that are directly linked to the two differential group delays (DGDs) introduced by the Lyot device.
- Sufficiently large DGDs make the covering of the Poincaré sphere very high over a given wavelength span.
- This depolarization effect is instantaneous; therefore, it prevents from covering multiple polarization states at the input of the fiber under test.

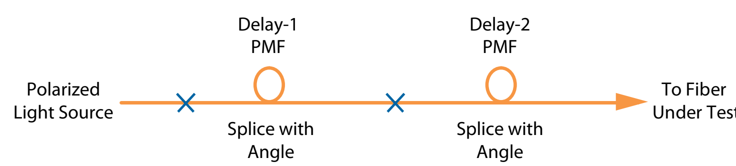

Figure 2: Broadband source with Lyot depolarizer implementation

The JDSU "Enhanced Fixed Analyzer"

The new JDSU solution was specifically designed to measure ultra low PMD values ("0 ps" in strong mode coupling) with high reliability.

This patented innovative configuration, based on the field rugged Fixed Analyzer design, consists of a Polarized Broadband Source with the Lyot depolarizer implementation on the transmitter side and a variable polarization scrambler and an optimized Fixed Analyzer detector on the receiver side.

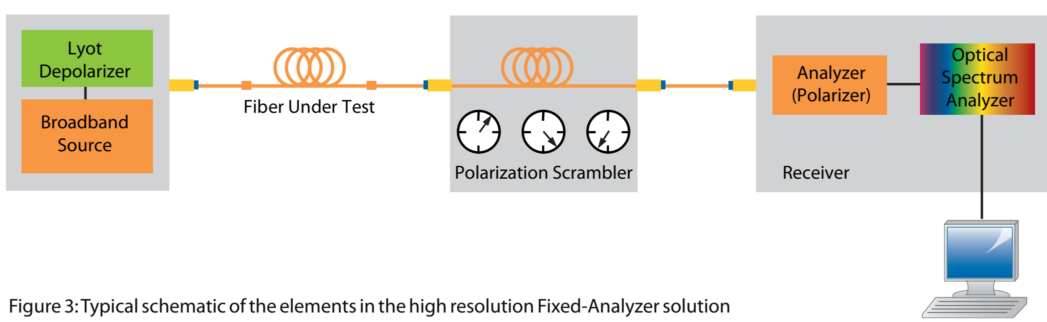

Figure 3: Typical schematic of the elements in the high resolution Fixed-Analyzer solution

Uncompromised Performance in the Field or the Lab

Measuring Optical Fiber with Minimal PMD

Optical fibers have lower and lower PMD values; however, they must be characterized in the field to prove they meet specification after burying them in the ground. Using a suitable measurement tool can provide reliable baseline PMD figures for network and transmission engineers.

Inter-Comparison with the JME Method

The ITU-T G.650.2 indicates that the Jones Matrix Eigenanalysis (JME) method, also known as the PMD reference test method (RTM), for fiber optic testing in manufacturing environment is the method to use for resolving disputes in measurement results. Therefore, comparing the enhanced FA-FT solution and a JME Test Method shows good agreement between both results for low PMD values in strong mode coupling.

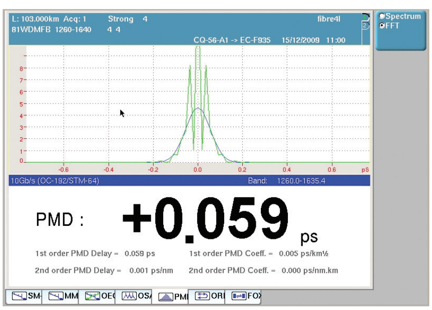

Figure 4: PMD measurement of a 103 km buried fiber link

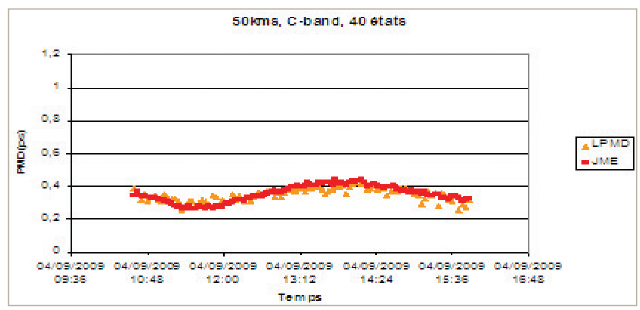

Figure 5: Inter-comparison results between the new JDSU High-Res PMD and a JME-based solution

Conclusion

Measuring PMD on newly installed fibers, therefore, requires new test tools that can provide the right value with the right level of confidence and repeatability.

Most of the current solutions offer relatively low-PMD measurement capabilities, but without indicating or specifying the uncertainty and repeatability in this area.

With the enhanced PMD testing solution, JDSU continues to deliver innovative measurement tools that support the evolution of optical telecommunications and their infrastructures.

Therefore, measuring femtosecond (fs) PMD delay can be best achieved with this field-dedicated test solution when housed in the T-BERD/MTS-8000 platform configured with a dual-slot receptacle.

References

1. Polarization Mode Dispersion—Frequently Asked Questions, R.K. Boncek, A. McCurdy, and A. Sorby
2. OFS AllWave® FLEX ZWP Single-Mode Fiber data sheet
3. Corning LEAF Optical Fiber Product Introduction
4. Can 100 Gbps wavelengths be deployed using 10 Gbps engineering rules? Ross Saunders, Gary Nicholl, Kevin Wollenweber and Ted Schmidt.
5. ITU-T G.652 recommendation–Characteristics of a single-mode optical fiber and cable
6. ITU-T G.655 recommendation–Characteristics of a non-zero dispersion-shifted single-mode optical fiber and cable

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