WHITE PAPER

High Level Dispersion Compensator for Ultra Long-Haul Coherent Detection Links

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Introduction

This paper aims to explain the value proposition in ultra long-haul (ULH) coherent detection systems of the ClearSpectrum™-HLDC, a High Level Dispersion Compensator. We will review its key technical features and pinpoint the main advantages of using such FBG-based compensators.

Figure 1: TeraXion's ClearSpectrum™-HLDC
Generic housing shown above; custom build housing available

What is a HLDC?

The ClearSpectrum™-HLDC is a chromatic dispersion compensator specially designed to compensate large amount of dispersion of up to 150 000 picoseconds per nanometer (~7500 km of G.654) while maintaining a very low insertion loss.

TeraXion's well-established technology in Fiber Bragg Grating (FBG) translates into a reliable and compact solution based on a cascade of several gratings.

Table 1: ClearSpectrum™-HLDC main specifications

Compensation Level	30,000 ps/nm	150,000 ps/nm[1]	15,000 ps/nm	150,000 ps/nm[2]
Channel Spacing	Single Channel		100 GHz	
Operation Bandwidth	> 50 GHz		> 50 GHz	
Typical Insertion Loss	13 dB	65 dB	13 dB	130 dB
Typical Latency	300 ns	1,500 ns	300 ns	3,000 ns

(1): Cascade of five 30,000 ps/nm modules

(2): Cascade of ten 15,000 ps/nm modules

This RoHS-6 solution offers a wide 50 GHz operation bandwidth regardless of the level of dispersion making it perfectly suited for massive dispersion compensation of 40 and 100 Gb/s coherent detection links.

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Why is optical dispersion compensation needed for ULH coherent detection links?

THEN...

The typical way to manage dispersion in repeatered long-haul submarine systems using direct detection was to use cables that mix transmission fiber having positive dispersion (D+ fiber, +20 ps/[nm.km] at 1550nm) with fiber having negative dispersion (D- fiber, -45 ps/[nm.km] at 1550 nm). Both types of fibers are deployed along the links with in-line amplifiers in order to bring down the overall dispersion level close to zero. This configuration works but the dispersion profile over the transmission bandwidth of the D+ fiber never exactly matches (in the opposite direction) the profile of the D- fiber. This slope mismatch brings residual dispersion close to 0 ps/nm for the center channel but to a maximum for the channels located at both ends of the transmitted spectrum. This residual dispersion accumulates throughout the link; the longer the link, the higher becomes the residual dispersion to be compensated at the terminal ends.

Figures 1 and 2 provide a typical example of a long-haul submarine network where the accumulated residual dispersion is – 5000 ps/nm on the first channel and +5000 ps/nm on the last channel while the center channel is close to 0 ps/nm. The residual dispersion slope to be compensated at the terminal depends on the matching between the D+ fiber, the D- fiber and on the total length of the network. This slope variability makes it difficult to compensate this residual dispersion all at once for all the channels; this is why compensation must be done on a channel-per-channel basis as shown on Figure 2.

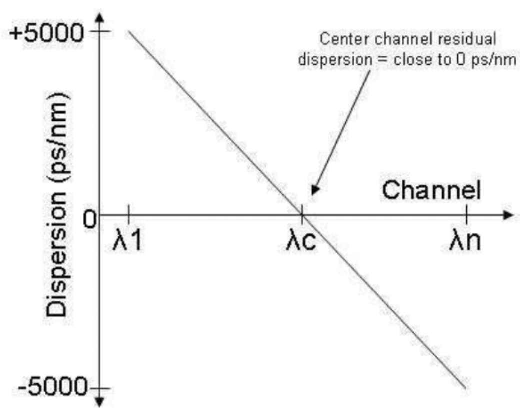

Figure 1: Typical residual dispersion at terminal of long-haul submarine networks

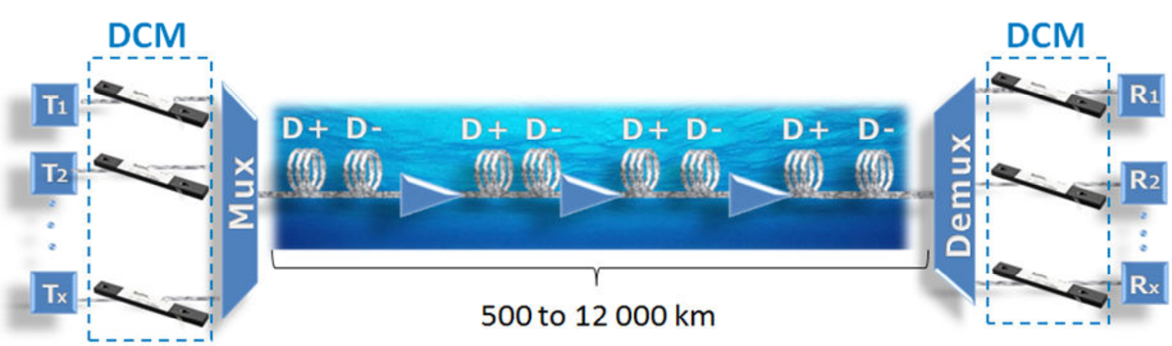

Figure 2: Typical repeatered long-haul submarine configuration based on direct detection

Why is optical dispersion compensation needed for ULH coherent detection links?

...NOW

Now that coherent detection systems are available, it has become the most promising technologies for long-haul and ultra -long haul high speed transmission systems. Advanced digital signal processing (DSP) algorithms are now being used to compensate fiber impairments including polarization mode dispersion (PMD) and chromatic dispersion (CD).

To preserve the systems margins, systems vendors are taking advantage of larger effective area fiber such as G.654 in order to reduce the non-linear effects and reach longer distances. Such fibers offer a much lower attenuation (≤0.17dB/km at 1550nm) but adds up significant amount of chromatic dispersion (≤ 20 ps/[nm.km] at 1550 nm) especially for intercontinental networks where it can reach hundreds of nanoseconds per nanometer. With such amount of dispersion, it becomes obvious that it cannot be all managed by the DSP and that optical compensation becomes a necessity. High Level Dispersion Compensators are therefore used at the terminals in order to get into the optimal dispersion range of the coherent receiver for extended reach networks.

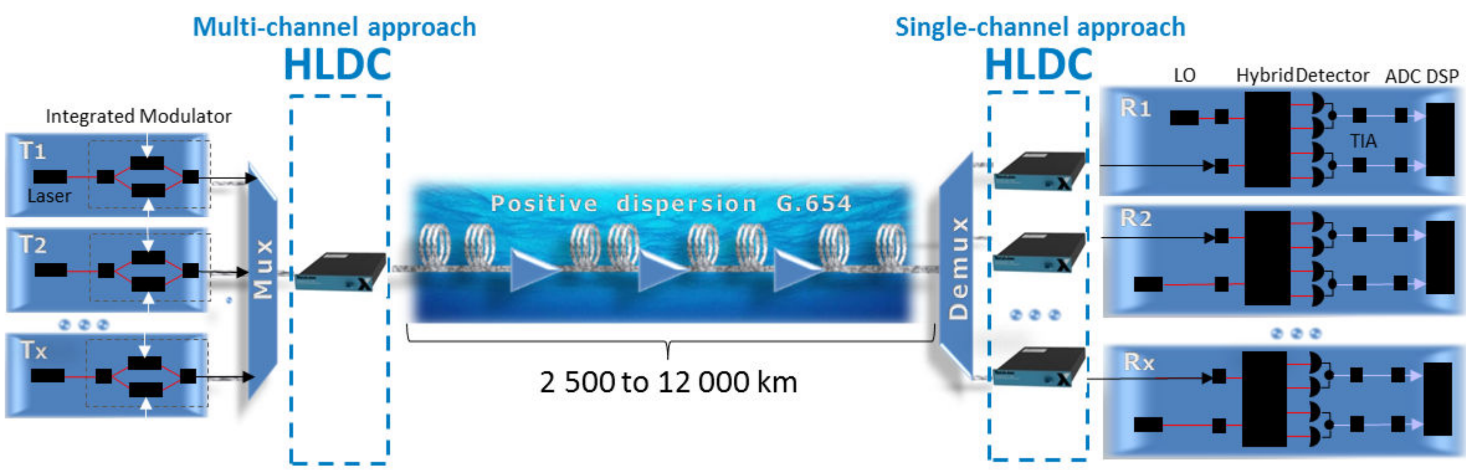

Figure 3: Improved repeatered long-haul submarine configuration based on coherent detection

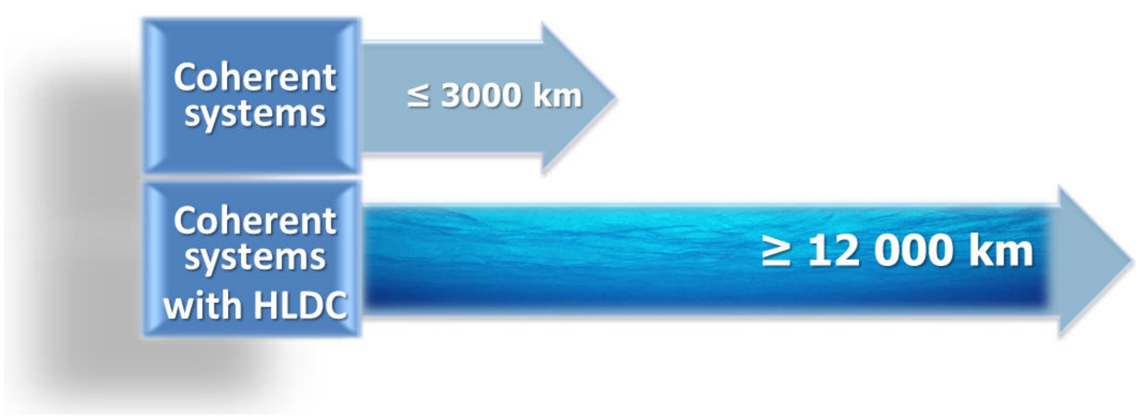

Figure 4: Significant reach extension using High Level Dispersion Compensator

What benefits do optical compensation brings to ULH coherent networks?

Lower > **Complexity**

Large amount of dispersion can be handled using bulk optical dispersion compensation therefore reducing the CD level that needs to be compensated by the DSP. By dealing with dispersion in the optical domain, the complexity of the DSP can be reduced and the system reach can be extended.

Lower > **Power consumption**

Coherent detection requires tens of watts to linearly recover both the amplitude and the phase of each wavelength due to fiber impairments such as chromatic dispersion. Totally passive solutions like bulk optical dispersion compensation are required for ULH networks and important power savings can be made, mainly with a multi-channel approach.

Lower > **Latency**

Complex forward error correction (FEC) schemes are used in ULH coherent networks to improve systems margins. Although it provides great benefits, using such strategy slow down the transmission process the same way the DSP does when electronically dealing with fiber impairments. Those delays directly translate into a higher latency which can be limited by the use of FBG-based optical dispersion compensators. With nanoseconds latency, FBG-based DCM contributes to reduce milliseconds computational delays induced by FEC and DSP processing.

Why use a HLDC?

Ultra-low loss

With guaranteed losses below 18 dB for a module of 30 000 picoseconds per nanometer, it has the best (by a **factor 2**) losses/dispersion level ratio on the market. It represents **5 times less loss** than using any DCF-based module which represents tremendous gain in reach and amplifier cost savings.

Reliable solution

With more than **tens of thousands DCM sold**, TeraXion patented expertise in DCM is well established. All based on Telcordia qualified products, the HLDC is one of TeraXion passive products perfectly suited for submarine application. It doesn't cause any non-linear effects and is **tolerant to high optical power**. Such channelized solutions cause **no fast SOP change** (state of polarization) under vibration thus avoiding unpredictable changes that aren't well compensated by DSPs.

Small form factor

Up to 150 ns/nm can fit in a 1U half-rack and the level of dispersion achievable is directly linked to that available space to fit each of these single gratings.

Efficient solution

By using a single-channel solution, **only what needs to be compensated is compensated**. When it is time to upgrade a system with 40 Gb/s or 100 Gb/s every system is different. Unlike band compensators, the investment is made on a solution that addresses only the channels that needs to be compensated. Therefore upgrades are easier to complete and there is no need to spend extra money on a solution that will help out competitors on the next bidding.

About TeraXion

TeraXion is a leading-edge photonic solutions provider for high-end applications of the optical communications, industrial lasers and optical sensing markets. Its line of OEM chromatic dispersion management solutions includes Telcordia-qualified low-loss static and tunable dispersion compensators for terrestrial and submarine networks. TeraXion offers customized filtering solutions based on advanced FBG technology and narrow linewidth semiconductor laser sources for RF photonic and coherent detection systems.

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