40G/100G SUBMARINE APPLICATIONS

40G/100G WaveLogic™ Coherent Optical Processors

Deployed the world over for high-capacity terrestrial networks, Ciena’s leading 40G/100G WaveLogic technology enables operators to maximize reach and capacity cost-effectively for submarine network applications. Ciena has taken its industry-leading technology and enhanced it to enable 40G/100G overlay of ultra-long-haul submarine systems, including transoceanic links. Using the innovative coherent receiver and Dual Polarization Phase Shift Keying (DP-QPSK) and Dual Polarization Bipolar Phase Shift Keying (DP-BPSK) technology, submarine networks can be seamlessly upgraded to 40G/100G with only the addition of new terminal equipment, significantly extending the life of existing cable plants.

Given the tremendous expenditure required to reengineer or replace submarine cable plants, maximizing the potential of existing networks is essential. Ciena’s 40G/100G solutions offer unparalleled spectral efficiency within the C-band, enabling the upgrade of existing cable plants well beyond maximum designed capacities. Precise electronic Dynamically Compensating Optics (eDCO) enable compensation for all deterministic linear impairments, such as Chromatic Dispersion (CD), and all orders of Polarization Mode Dispersion (PMD). The use of eDCO technology avoids the need for deployment of in-line or terminal Dispersion Compensation Modules (DCMs) to overcome CD and also avoids deployment of optical PMD compensators—both key benefits when old fiber plants are used.

Benefits

→ Enables upgrades to 40G/100G by simply replacing terminal equipment of the link
→ Gives subsea operators the ability to meet surging bandwidth demands in an increasingly competitive environment
→ Allows cost-effective migration without network reengineering
→ Enables deployment on submarine repeatered wet-plants, and extends reach beyond terrestrial limits to nominally 8,000 km on submarine wet-plants

Developing beyond 10G

Market trends

The growth of fiber network bandwidth demand has traditionally been met by achieving increased spectral efficiency through increases in line rate via Time Division Multiplexing (TDM), and increases in the number of carriers via Dense Wavelength Division Multiplexing (DWDM). Cost reduction has been driven in each generation by increasing the number of bits transported per electro-optic device and per optical amplifier. However, the physical impairments due to optical filtering, CD and PMD increase so strongly as a function of reach and TDM rate that only a small portion of desired routes are able to support TDM rates of 40/100 Gb/s or above.

Ciena 40G/100G-based WaveLogic Technology

Several years ago, when competing optical vendors were increasing line rates via TDM and DWDM, Ciena began developing its coherent WaveLogic technology, providing a roadmap to 40G, 100G and beyond. Ciena’s solutions enable upgrade of existing 2.5G and 10G links to 40G and 100G simply by replacing terminal equipment of the link. Ciena has successfully deployed 40G solutions in both unrepeatered and repeatered submarine applications. Commercially available since early 2008, Ciena’s Submarine
40G technology is giving subsea operators the ability to meet surging bandwidth demands in an increasingly competitive and continually changing market environment. Ciena’s 100G technology soon followed offering undersea cable operators the choice to move to 100G channel rates.

**Coherent receiver**

By employing advanced modulation schemes, such as DP-QPSK and DP-BPSK, power budgets and spectral efficiency can be maximized. High-level, phase shift keyed modulation combined with polarization multiplexing lowers the baud rate of the system, using up to four bits per symbol, decreasing the occupied optical bandwidth. At the receiver, coherent detection and complex DSP algorithms are applied. Coherent detection offers the advantage of access to the amplitude and phase of the optical electric field in the electronic domain at the receiver. Ciena’s DSP algorithm then compensates for linear impairments such as CD and PMD without penalty. Nonlinear impairments, such as nonlinear phase noise and four-wave mixing, are also partially compensated. By utilizing DSP-based compensation, receiver adaptation to time-varying impairments and the use of advanced Forward Error Correction (FEC) codes are possible.

**40G/100G for Submarine Applications**

**40G/100G DP-QPSK for regional submarine applications**

Ciena has extended the performance of its 40G/100G DP QPSK terrestrial transponder to enable deployment on submarine repeatered wet-plant. Reach is extended beyond terrestrial limits to nominally 8,000 km on submarine wet-plants (dependent on the vintage and quality of wet-plant components).

Ciena’s 40G/100G DP-QPSK solution was designed to overlay on existing 10G optical line systems, allowing cost-effective migration without network reengineering. Because Ciena’s eDCO technology can compensate for linear impairments, deployment of Ciena’s DP-QPSK transponders does not require fixed CD or PMD compensation, typical of Submarine Line Termination Equipment (SLTE). There is no need for in-line or in-shelf separate DCMs or any additional amplifiers these would require. Ciena’s 40G/100G DP-QPSK solution propagates like a 10G signal, using primarily 10G components, thus fully leveraging existing 10G line infrastructure, and operates with improved tolerance to linear impairments.

**40G DP-BPSK for ultra-long-haul**

In order to meet the demands of ULH repeatered networks and older fiber plants unsuitable for even 10G technologies, a new variant of 40G has been developed. Using a Coherent optical Frequency Division Multiplexing (CoFDM) DP-BPSK solution, Ciena has leveraged the coherent receiver and advanced DSP algorithms of the 40G DP-QPSK design, maintaining all of its advantages, and further improved its reach and performance. The 40G DP-BPSK transponder will provide approximately double the reach of the 40G DP-QPSK variant, depending upon the undersea cable network being upgraded.

The 40G ULH uses two CoFDM subcarriers and BPSK modulation to improve reach and enhance robustness to phase distortion. Because it is based on the same technology as the 40G regional submarine solution, coherent detection and advanced DSP still provide essential benefits such as electronic compensation of impairments. The use of BPSK in place of QPSK provides increased resilience to phase distortion. CoFDM of two DP-BPSK signals allows the transponder to take full advantage of the added phase margin offered by BPSK, while maintaining a 40 Gb/s line rate and high spectral efficiency.
By further improving the reach of Ciena’s ground-breaking 40G/100G DP-QPSK technology ULH submarine cable systems can be upgraded to 40G/100G, yielding capacities well beyond designed maximum. Ciena’s 40G DP-BPSK can approximately double the allowable distance of the 40G DP-QPSK variant allowing for significant capacity upgrades to submarine systems without extensive network reengineering, and consists of a simple installation of the new terminal equipment. Ciena’s 40G DP-BPSK transponder is built on existing WaveLogic technology, and avoids the massive deployment of in-line or terminal DCMs and optical PMD compensators. 40G DP-BPSK not only creates a tremendous opportunity for transatlantic and transpacific service providers to meet bandwidth demands while maximizing the utilization of existing network assets, but also paves the way for extended reach CoFDM 100G and beyond.

Figure 2. Improvements offered by CoFDM DP-BPSK