Development of the Digital Coherent Optical Transmission Technology

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Abstract

Due to the explosive growth of the Internet traffic, the capacity demand of the optical communication has rapidly increased. NEC has developed the packet optical integrated transport system "SpectralWave DW7000" by implementing the digital coherent optical transmission technology. This paper provides an outline of this technology.

Keywords

digital coherent, long-distance optical transmission, large-capacity optical transmission, 100 Gbps, WDM

1. Introduction

The digital coherent optical transmission system has been spotlighted, combined with the high-speed and large-scale semiconductor technology. NEC packet optical integrated transport system "SpectralWave DW7000" provides ultra-high-speed, large-capacity communications across long distances by adopting the digital coherent technology. In this paper, the authors describe the digital coherent optical transmission technology by focusing on its difference from the traditional technology and also discuss the orientation of anticipated future developments.

2. Traditional Optical Communication Technology

The traditional optical communication systems employ the Intensity Modulation - Direct Detection (IM-DD) technology, with which information represents intensity of light and is directly detected by a photodetector device (**Fig. 1**). The IM-DD system can transmit digital information by switching light on and off, it is widely used in the optical fiber transmission up to 10 Gbps because of its simplicity.

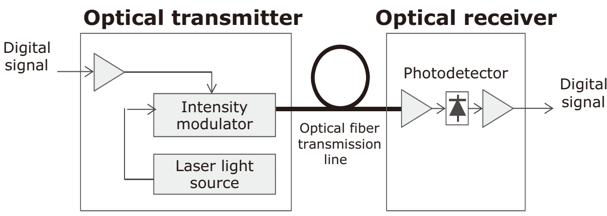

Fig. 1 Example of IM-DD system configuration.

On the other hand, the signal distortion on optical fiber has a negative effect on the long-distance transmission of high-speed signals of 100Gbps-class. As a result, the traditional IM-DD system has difficulties in implementing long-distance, large-capacity transmissions both technically and economically.

3. Digital Coherent Optical Transmission System

The digital coherent optical transmission system can implement long-distance, large-capacity transmissions efficiently by utilizing not only intensity but also phase of

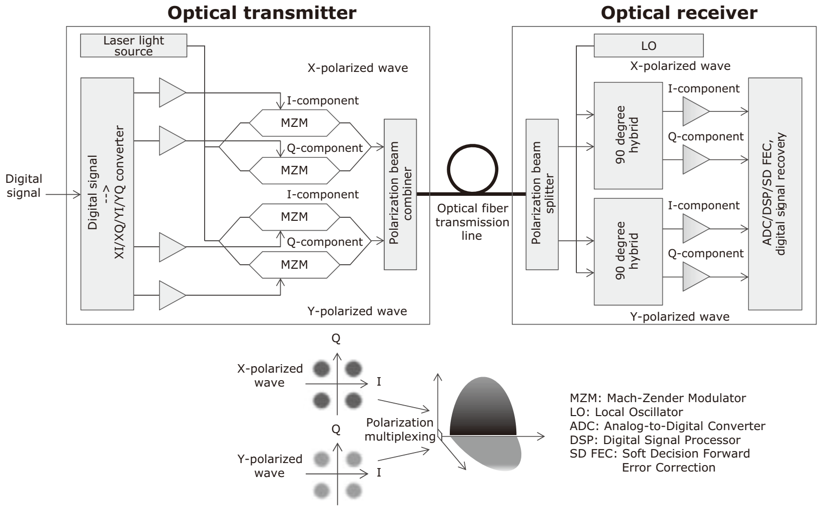

Fig. 2 Example of digital coherent optical transmission system configuration.

light-wave. SpectralWave DW7000 adopts the Quadrature Phase Shift Keying (QPSK) modulation for the transmission at 100 Gbps. The use of light phase information allows this system to transmit twice the amount of information compared to the IM-DD system.

Additionally, the principle that two orthogonal waves do not intersect with each other can be utilized to transmit twice the amount of information by including different information in the X- and Y-polarized waves. This procedure is called the Dual Polarization QPSK (DP-QPSK). It can transmit same capacity only using a quarter signal bandwidth compared with the traditional IM-DD.

Fig. 2 shows the block diagram of the digital coherent optical transmission system. In the optical transmitter, digital signal is converted into four components, that is, the in-phase (I) components and quadrature (Q) components of the X- and Y-polarized waves, respectively. The electrical signals, XI and XQ, drive the Mach-Zender Modulators (MZMs) for X-polarized wave, and the electrical signals, YI and YQ, drive the MZMs for Y-polarized wave, and then the X- and Y-polarized waves are combined to generate an optical signal with phase shift keying and dual polarization (DP-QPSK optical signal).

In the optical receiver, the DP-QPSK optical signal is separated into each polarization and then interferes with a laser light source, Local Oscillator (LO) in order to detect the I- and Q-components of the X- and Y-polarized waves. This process is called coherent detection because it detects signals by causing interference between the signal and the LO.

The detected I- and Q-components of the X- and Y-polarized waves are converted into electrical signals by the photodetectors and then converted into digital sampling data by Analog-to-Digital Converter (ADC). The digital sampling data is subjected to the advanced signal equalization of the Digital Signal Processor (DSP) so that the signal distortions proper to the optical fiber, such as the wavelength dispersion and the polarization mode dispersion, can be compensated.

The digital sampling data before recovery of the 0/1 digital signals can also be used for the powerful error correction procedure of Soft Decision Forward Error Correction (SD FEC). The combination of DSP and SD FEC realizes the long-distance transmission at 100Gbps.

4. Orientation of Future Development

The optical transmission performance can be significantly improved by the advanced digital coherent technology. For example, the Nyquist filtering by means of the DSP in the optical transmitter can decrease the spectral width of the optical signal (**Fig. 3**). Decreasing the optical spectral width in the Wavelength Division Multiplex (WDM) transmission makes it possible to increase the total capacity per optical fiber.

While the QPSK system is currently applied for 100 Gbps, the use of the 16-ary Quadrature Amplitude Modulation (16QAM) is expected to be applied for 200 Gbps because of its higher frequency utilization efficiency. As the 16QAM system represents 16 kinds of values by using the amplitude information in addition to the phase information, it can transmit twice the amount of information compared to the QPSK system. However, as seen in the constellation diagrams in **Fig. 4**, the closer distance between symbols than in the QPSK system makes it susceptible to noise, which leads to the necessity of

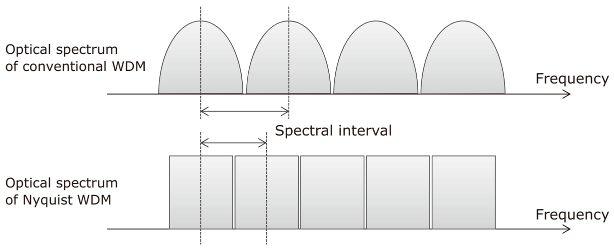

Fig. 3 Nyquist WDM.

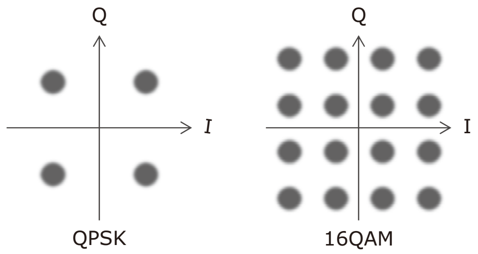

Fig. 4 Constellation diagrams.

applying more advanced signal processing.

5. Conclusion

In the above, we have described the digital coherent optical transmission technology that is adopted by the NEC SpectralWave DW7000 system. This technology enables large capacity, long distance optical transmissions and satisfies further increases in capacity.

Reference

1) K. Kikuchi, "Fundamentals of Coherent Optical Fiber Communications," J. Lightw. Technol., vol.34, no.1, pp.1-23, Jan./Feb. 2016.

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