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Dissertation Abstract:

Study of Multilevel Modulation Formats for High Speed Digital Optical Communication Systems

Selwan Khaleel Ibrahim

Spectrally efficient modulation formats can be used to overcome the problems associated with limited channels and bandwidth of Dense Wavelength Division Multiplexing (DWDM) optical systems. Multilevel modulation formats are considered spectrally efficient and can double the transmission capacity by transmitting more information in the amplitude, phase, polarization or a combination of all. Here we have studied and evaluated different multilevel modulation formats in a practical optical transmission system.

Differential Quadrature Phase Shift Keying (DQPSK) doubles the transmission rate by transmitting more information in the phase of the optical carrier signal. DQPSK receivers require more complex and costly components including delay interferometers and balanced detection photodiode receivers. Combining DQPSK with Polarization Division Multiplex (PolDM) would result into 4 times the transmission rate, but a polarization controller would be needed which results into a more complex receiver.

A 20 Gbit/s DQPSK signal can be generated by combining two 10 Gbit/s Differential Phase Shift Keying (DPSK) signals in quadrature phases using a QPSK modulator. The receiver sensitivity for 20 Gbit/s NRZ- and RZ-DQPSK signals are measured to be -36.8 dBm and -38.3 dBm, respectively. The chromatic dispersion (CD) tolerance for a 1 dB optical signal to noise ratio (OSNR) penalty for a 20 Gbit/s RZ-DQPSK signal is ~360 ps/nm.
When PolDM is used to combine two 20 Gbit/s DQPSK signals, the receiver sensitivity for 40 (2×2×10) Gbit/s NRZ- and RZ-DQPSK PolDM signals become -33.8 dBm and -34.7 dBm, respectively.

Conventional Quaternary Intensity Modulation (4-IM) doubles the data rate by transmitting more information in the amplitude of the carrier signal. This can be achieved by modulating the optical amplitude with an electrical 4-level Amplitude Shift Keying (ASK) signal. A simple receiver consisting of a single photo diode, three decision circuits and a decoding logic can be used to receive and extract the original transmitted data.

The spectral efficiency of this quaternary intensity modulation signal can be increased even more by combining two 10 Gbit/s optical duobinary signals with unequal amplitudes in quadrature phases using a QPSK modulator resulting in a 20 Gbit/s 9-constellation point Quaternary Duobinary signal (QDB). When combined in orthogonal polarizations using a Polarization Beam Combiner (PBC), a 20 Gbit/s 9-constellation point Quaternary Polarization Duobinary signal (QPolDB) is generated. The receiver sensitivity and CD tolerance of a 20 Gbit/s QDB signal generated using a duobinary stub filter with a frequency response dip at 5 GHz, are measured to be -21.2 dBm and ~140 ps/nm, respectively. The receiver sensitivity and CD tolerance of a 20 Gbit/s QPolDB signal generated using the same duobinary stub filter, are measured to be -20.5 dBm and ~340 ps/nm, respectively. When using another duobinary stub filter with a frequency response dip at 6 GHz, the receiver sensitivity and CD tolerance of the 20 Gbit/s QPolDB signal became -18.4 dBm and ~530 ps/nm, respectively.

A polarization and phase insensitive direct detection receiver with a single photodiode has been used to detect all generated quaternary signals as 4-IM signals. The 20 Gbit/s QDB and QPolDB quaternary signals that we have reported for the first time, have a narrow spectrum with a bandwidth similar to that of a single 10 Gbit/s duobinary modulation signal.

These quaternary intensity modulation formats are attractive for DWDM systems applied for short reach (several kilometers) to medium reach (several hundred kilometers) transmission applications (metro applications). However, for long or ultra long haul optical fiber transmission systems, DQPSK and DQPSK PolDM modulation formats featuring better receiver sensitivities are potential candidates.