Simulation Based Analysis of 16-QAM Constellations with Five Circular Shells in Long Haul Optical Links

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Nonlinear phase noise in optical fibers depends on the transmission power and has significant impact on the performance of long-haul transmission links. Many studies have been performed on sixteen quadrature amplitude modulation (16-QAM) constellations to overcome the effects of nonlinear phase noise. This work proposes three new constellations and analyses five different representations of 16-QAM. These representations use five circular shells with different placement of 16 symbols. The constellation diagrams consist of four circular shells with equally phased three symbols and a shell with equally phased four symbols. The shell with four symbols is different for each constellation diagrams.

The simulations were carried out using MATLAB software. A random bit stream was generated and by using the random bits 16-QAM symbols were formed by combining four bits. The symbols were modulated according to the constellations and a model nonlinear optical channel was used to transmit the bit over long distances. The nonlinear optical channel was approximated to a Gaussian distribution with a non-zero mean. Received patterns were rotated by mean nonlinear phase noise and recovered by using maximum likelihood detection techniques. The performances were compared in terms of bit error rate with different transmission powers at 3000 km and with different transmission distances at -2 dBm launch power.

The simulated results with different transmission powers show that the constellation diagrams with four symbol shell in the inner circle (4-3-3-3-3) and the outer circle (3-3-3-3-4) provide considerably high bit error rate compared to the other three constellation diagrams. However, the constellation diagram with four symbols in the outer shell (3-3-3-3-4) provides the performance of four symbols in the inner shell (4-3-3-3-3) with 4 dB reduction of power. Meanwhile, the constellation diagram with four symbols in the middle shell (3-3-4-3-3) provides the best performance for 3000 km link with the transmission power of -2 dBm. The constellation diagrams with four symbols in the second shell (3-4-3-3-3) and fourth shell (3-3-3-4-3) provide slightly increased bit error rates than four symbols in the middle (3-3-4-3-3). The simulation results with different transmission distances shows that the constellation with four symbols in the third shell (3-3-4-3-3) provides the best results over the analysed distances. The constellations with four symbols in the second shell (3-4-3-3-3) and fourth shell (3-3-3-4-3) provides slightly higher bit error rates and the constellation diagrams with four symbols in the inner shell (4-3-3-3-3)and outer shell (3-3-3-3-4) provides high bit error rates comparatively.

The simulated results suggest that the five shell circular constellation with four symbols in the middle shell (3-3-4-3-3) is the best option for a long-haul optical communication link within these five shell circular constellation diagrams. Meanwhile, constellation diagrams with four symbols in the second shell (3-4-3-3-3) and fourth shell (3-3-3-4-3) give slightly lower performances compared to the one with four symbols in the middle (3-3-4-3-3) and can be used according to the circumstances.