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Performance analysis of mode division multiplexing system in presence of nonlinear phase noise

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Abstract

The potential for higher spectral efficiency has increased interest in mode division multiplexing (MDM) systems. However, the sensitivity of MDM to fiber nonlinearity and mode coupling, which induces nonlinear phase noise (NLPN), forms the main penalty. In this work, we developed an analytical model that describes the effects of fiber nonlinearity on the performance of m-array quadrature amplitude modulation (mQAM) MDM system based few-mode fiber (FMF). The random NLPN is mainly induced when Kerr nonlinearities such as self-phase modulation (SPM), cross-phase modulation (XPM) and four-wave mixing (FWM) as well as their interaction with optical amplifiers noise occur over an optical fiber link. FMF is proposed and designed to carry six spatial modes. The parameters of proposed FMF are used with the analytical model for evaluating the NLPN versus power and distance. To verify the analytical results, an MDM system, that uses proposed FMF without any nonlinear compensation, is demonstrated by numerical simulation. Each spatial mode is modulated by a 4QAM format with a symbol rate of 20 Gsymbol/s. The results are obtained for single-, two- and six–mode propagations to show the influence of fiber nonlinearity on the system performance. The results reveal that the XPM phase noise is the dominant effect that degrades the system performance, specifically when two degenerate spatial modes or modes within the same mode group are co-propagated. In addition, for six-mode transmission, FWM insignificantly induces the NLPN. Finally, the results confirm that the numerical and analytical results in good agreement