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Performance analysis of polarisation shift keying modulation format for optical networks

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Recent studies show that the polarisation shift keying (PolSK) is regarded as one of the most promising modulation formats for future optical networks. Therefore, a novel architecture of PolSK modulation format is presented in this study. This paper also includes performance comparison of PolSK with the conventional Duobinary and non-return-to-zero on-off keying (NRZ-OOK) modulation formats. The obtained results show that the proposed PolSK modulation format can bring significant improvement of about 40% and 52%, respectively than the results obtained by using the conventional Duobinary and the existing NRZ-OOK modulation format.

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1. Introduction

One of the most promising modulation formats for future optical networks is polarisation shift keying (PolSK) [1]-[7] that guarantees a constant power level using polarisation diversity by distributing complementary data streams between two orthogonal polarisation states. The polarisation can be used to improve the propagation properties of a format by pseudo-multilevel or correlative coding, similar to an auxiliary optical phase modulation. Furthermore, the polarisation can be used to increase the spectral efficiency, either by transmitting two different signals at the same wavelength but in two orthogonal polarisation states (polarisation-multiplexing), or by transmitting adjacent WDM (wavelength-division multiplexing) channels in alternating polarisation to reduce the coherent WDM crosstalk or non-linear interactions between the channels (polarisation-interleaving) [8].

Therefore, in this paper, a new architecture of PolSK is proposed. The remaining part of this paper is organised as follows. In Section 2, the setup of PolSK is included. In Section 3, the simulation results and analysis will be presented to ensure the successful implementation of PolSK. This section also includes a comparative study with other known modulation formats to evaluate the performance of the proposed system. Finally, Section 4 provides the concluding remarks and future guideline.

2. Methodology

Fig. 1 below shows the schematic setup of PolSK modulation format. The implementation of PolSK is relatively simple in OptSim™. The important components involved in generating PolSK signals are polarisation driver, polarisation modulator, polarisation rotator, and polarisation receiver as shown in Fig. 1. These components are available from OptSim™ component library. Refer to Fig. 1, 10Gbps data source is fed into the polarisation driver. As a result, the driver changes the data source of logical signal into equivalent electrical signals. These electrical signals will be then fed into the polarisation modulator together with the laser source with 1550nm wavelength and optical power of 0dBm. The state of polarisation (SOP) of the laser source will be changed accordingly to the input electrical signal from the driver at the modulator.

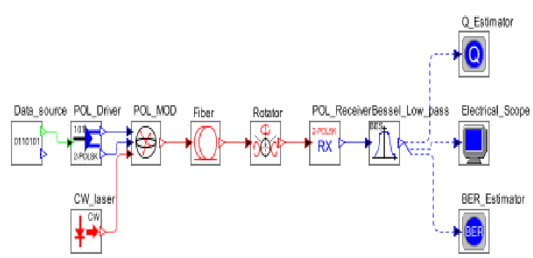

Fig. 1. Setup of PolSK modulation format.

Table 1. The components used for PolSK setup.

Component Symbol	Component Name	Description
0110101	Data Source	Simulates a pseudo-random bit sequence or a deterministic logical signal generator of arbitrary level (number of bits per symbol).
101 2-POLSK	POLSK Driver	This component simulates an electrical driver for binary POLSK modulation. It should usually be used together with the components Data Source and Polarisation Modulator.
	Polarisation Modulator	This component simulates a polarisation modulator, i.e., a component that changes the State of Polarisation (SOP) of the input optical signal as a function of the electrical driving voltages.
CW	Continuous-Wave Lorentzian Laser (CW laser)	This model implements a simplified continuous wave laser. Laser phase noise is taken into account by generating a Lorentzian emission line shape whose FWHM is specified by the parameters.
	Optical Fiber Link	This component models the propagation of the optical signal along an optical fiber span.
	Polarisation Rotator	This component simulates a polarisation rotator, i.e., a component that changes the state of polarisation (SOP) of the input optical signal. The parameters to be specified for this component are related to the Stokes representation of polarisation, and correspond to the angles of rotation around the three axes in the Stokes space.
2-POLSK RX	POLSK Receiver	This component simulates a receiver for a binary POLSK system. Parameters are read from a file. The output signal is obtained as scalar product between the Stokes parameters of the received optical signal and an internally calculated reference vector.
	Electrical Bessel Filter	This component simulates an electrical filter. This component implements low-pass, high-pass, and band-pass Bessel filters. This is a standard family of filters that are also sometimes called "Maximally Flat Delay" filters.
Q	Electrical Q Estimator	Measures the Q value: a pattern length for system affected by the inter-symbol interference (ISI) can be specified. Besides the Q value, the following information are provided: optimal threshold, eye closure, average eye opening, eye opening, tolerance to sampling instant variation, jitter measurement for RZ signal, diagram of Q value versus sampling instant, and diagram of eye closure versus sampling instant.
	Electrical Scope	Simulates an oscilloscope for electrical signals. It collects data for diagrams, such as amplitude, eye diagram, histogram at the optimum sampling instant, and power spectrum of the electrical signal.
BER	BER Estimator	This component estimates the bit-error-rate (BER) of an electrical signal.

Table 1 illustrates and describes all the components (symbol, name, and description) used in the simulation for PolSK setup. The polarised optical signal will be coupled into the fiber link. Before the optical signal could be detected by the polarisation receiver, it needs to go through the polarisation rotator, where the SOP will be changed accordingly in order to be detectable by the polarisation receiver. The detected signal will pass through the electrical low-pass Bessel filter to filter the excessive noise before it is analysed by the measurement components. The obtained results are presented at the following figures.

3. Results and analysis

3.1 BER versus distance analysis

The diagram of bit-error-rate (BER) versus distance transmitted for 10Gbps PolSK modulation format is shown in Fig. 2. At the desired BER of 10^{-9}, it corresponds to 150km of transmission distance. The transmission further than this distance will not comply with the communication link requirement. The thresholds BER for all the modulation formats are set to 1×10^{-9} as this BER value is the typical error rate for most of the optical fiber communication systems [9]. It is noted that the PolSK modulation format is capable of delivering signals up to a distance of 150km.

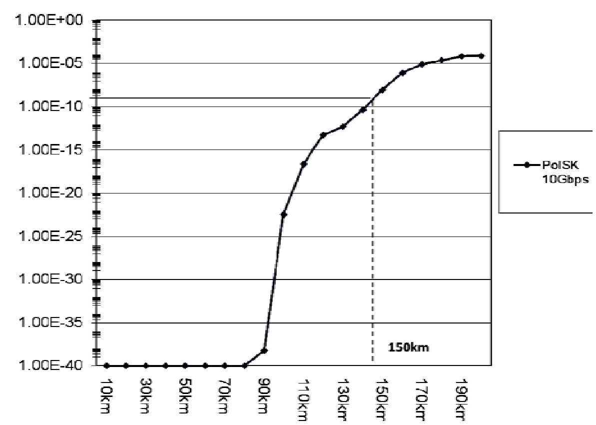

Fig. 2. BER versus distance (km) for PolSK modulation format.

The results obtained from the proposed PolSK are compared with the existing non-return-to-zero on-off keying (NRZ-OOK) modulation format and the conventional Duobinary modulation format. Thus, the results of NRZ-OOK and conventional Duobinary modulation formats are deemed to be a reference point for the performance comparison of the proposed PolSK modulation format. From the results obtained from Fig. 3, it can be noticed that the maximum distance achieved by the proposed PolSK modulation format is 150km. It is further observed that, the maximum transmission distance is limited to 90km by the conventional Duobinary modulation format. Besides, the NRZ-OOK modulation format can reach up to a distance of 72km.

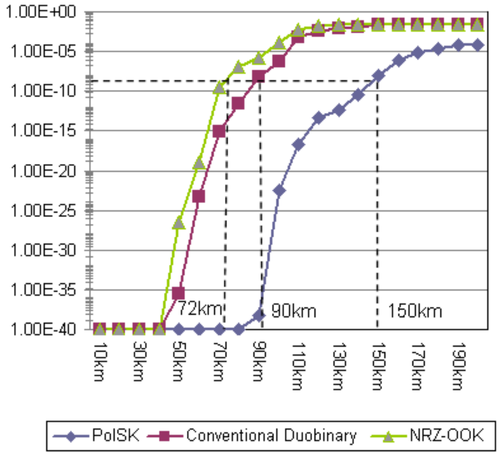

Fig. 3. Performance comparison among NRZ-OOK, conventional Duobinary, and the proposed PolSK.

3.2 Eye diagram analysis

Fig. 4 shows the received signal of the eye diagram for PolSK modulation format at 10km, 50km, 100km, and 200km, respectively. At 10km of transmission distance, the eye opening is wide and easily distinguishable. At 50km, the eye diagram of this PolSK modulation format is still clearly depicted; however, little noise is noticeable at the upper and lower levels of the eye diagram. At 100km, the eye diagram starts showing the indistinct pattern, where the eye diagram starts accumulating higher level of noise; however, the eye opening still can be distinguished. At 200km, the eye opening is severely distorted, where high level of noise accumulating at the upper and lower part of the eye diagram. Thus, from the eye diagram analysis, the performance of an optical network system setup can also be justified.

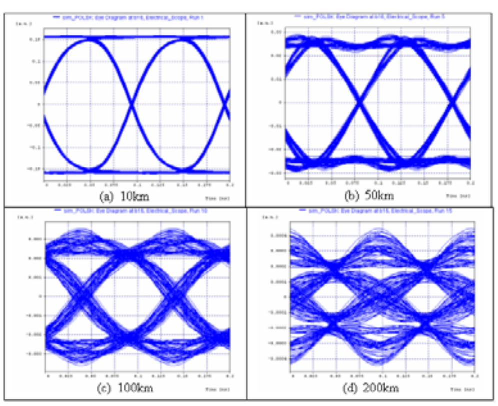

Fig. 4. Eye diagram of PolSK modulation format at (a) 10km; (b) 50km; (c) 100km; (d) 200km.

4. Conclusions

This study has successfully demonstrated that the PolSK modulation format can achieve better results compared to the conventional Duobinary and existing NRZ-OOK modulation formats in terms of the transmission distance. The obtained results reveal that the PolSK modulation format can significantly improve the transmission distance by 40% over the conventional Duobinary and 52% over the existing NRZ-OOK modulation format at a given BER = 10^{-9}.

As stated earlier, the PolSK has advantages of higher spectral efficiency, capability of reducing coherent WDM crosstalk, and non-linear interactions between the WDM channels. The PolSK modulation format can be integrated with the intensity modulation in order to gain popularity in real time implementation. Thus, by integrating of PolSK with the intensity or phase modulation, the advantages of PolSK can be maintained while reducing the complexity of the component design for the receiver. Therefore, in future, such integration can be implemented through the well-known Duobinary modulation format with the PolSK modulation format. The integrated scheme can be termed as Duobinary-PolSK modulation format.

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