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Performance Analysis and Comparison of QPSK and DP-QPSK Based Optical Fiber Communication Systems

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ABSTRACT

In this paper, the comparison between advanced modulation schemes i.e. Quadrature Phase Shift Keying (QPSK) and Dual Polarization Quadrature Phase Shift Keying (DP-QPSK) is carried out on single mode optical fiber cable. Models are simulated for long distance communication and high data rates. Different scenarios such as effect of dispersion, optical fiber length, data rate and wavelengths are tested to check the performance of models. The simulations and investigation are done using licensed version of OptiSystem 14.0.

Keywords: *QPSK, DP-QPSK, Single-mode fiber, Dispersion, Long haul communication, High data rate.*

1. INTRODUCTION

The Optical fiber communications has played a huge part in changing our ways of life over the past few decades. The tremendous approval of optical communications technology is due the low-loss optical transmission fibers [1, 2]. The developing interest of optical communication networks generally relies upon a high-speed transmitter, a high-capacity optical fiber [3, 4]. It is widely used for long distance communication (few hundred feet to hundreds of miles) due to less attenuation during light propagation through the fiber compared to electric cables [5].

To achieve high spectral efficiencies, much consideration has been given in identifying advanced modulation schemes which can meet the increasing capacity demands, keeping in mind the bandwidth limitations of optical fibers and amplifiers [6]. One of the most outstanding approach is the use of advanced modulation formats and coherent detection combined with multiplexing techniques. However, as the modulation level increases, system implementations become troublesome accordingly, specifically in terms of transmitter structure and digital signal processing hardware [7].

The current deployment of 100 Gbit/s including some more optical fiber communication systems follows orthogonal phase modulation method (quadrature phase shift keying, QPSK). It reduces the baud rate to half of that of binary modulation type, in order to obtain greater tolerance chromatic dispersion and polarization mode dispersion tolerance [8, 9]. The focus of this paper is to directly compare QPSK with DP-QPSK based on different parameters such as optical fiber length, different data rates, different wavelengths etc. It is evident from figure1 that in QPSK, the input binary data is split into two streams, in-phase and orthogonal, using serial to parallel converter. Local oscillator generates cos(ωt) and 90-degree phase shift of this gives sin(ωt).

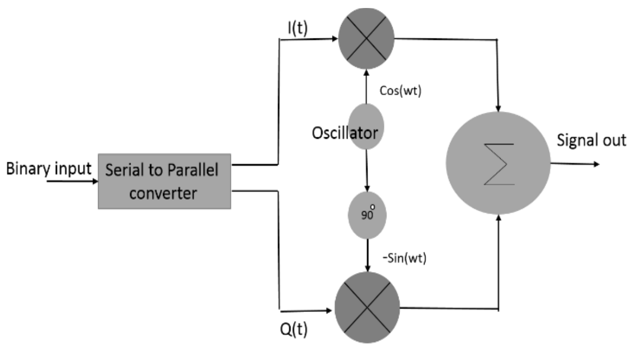

Fig.1. QPSK modulation [10]

Both I and Q signals are combined to produce QPSK signal. QPSK represents two bits per symbol. This modulation technique finds its applications in RF and wireless communication.

DP-QPSK modulation uses two polarizations, horizontal polarization and vertical polarization, with the same original QPSK constellation to represent four bits per symbol represents four bits per symbol.

Fig. 2, shows that power of laser source is split using beam splitter. The continuous light input is described by eq. (1), where Po stands for input light intensity and ω stands for angular frequency of the input light: [9]

$$Ein = \sqrt{Po}\, e^{-j\omega t} \quad (1)$$

Beam splitter produces two signals having same polarization and power and are as:

$$Ea = \frac{\sqrt{2Po}}{2}\, e^{-j\omega t}\, \vec{e}_x \quad (2)$$

$$Eb = \frac{\sqrt{2Po}}{2}\, e^{-j\omega t}\, \vec{e}_y \quad (3)$$

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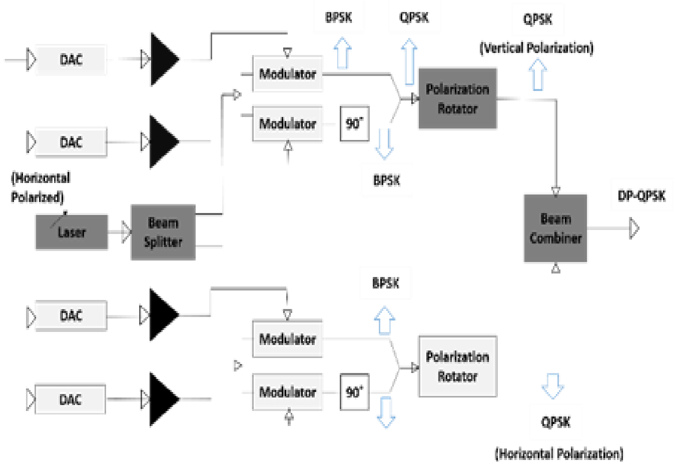

Fig. 2. DPQPSK modulation [10]

One signal is given to upper QPSK modulator part while the other is given to lower QPSK modulator part. In the upper part, QPSK signal polarization is rotated to make vertical polarized signal which is then combined with horizontal polarized QPSK signal from the lower part to obtain DP-QPSK modulation signal.

2. SIMULATIONS WORK

QUADRATURE PASE SHIFT KEYING

Fig. 3 shows the block diagram of fiber communication system using QPSK modulator. Pseudorandom binary sequence is fed to optical QPSK transmitter, a built-in block in OptiSystem 14.0 that simulates a single channel optical coherent transmitter with an optical QPSK signal. Optical output of transmitter is then given to DCF which compensates the dispersion of signal in fiber medium. Signal after DCF is received by optical QPSK receiver, which after processing the received signal, forwards it to electrical amplifier. This signal is then passed through low pass filter and decoder, which decodes the signal that can be visualized on eye diagram analyzer.

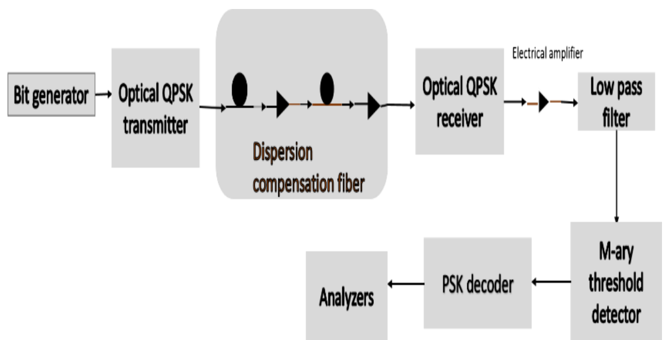

Fig. 3. QPSK based communication model block diagram

For the proposed QPSK setup, the considered parameters are given in Table 1:

Table. 1 Simulation Parameters of QPSK Model

Parameter	Value
Data rate	120 Gbit/s
Wavelength	1550 nm
Fiber length	100 Km
Sequence length	1024 bits
Samples per bit	64
Modulation	QPSK
Optical QPSK transmitter power	10dBm
Line width of optical Transmitted power	0.01 MHz
Attenuation	0.2 dB/km

DUAL POLARIZATION QUADRATURE PHASE SHIFT KEYING

Fig. 4 shows the block diagram of optical fiber communication system using DP-QPSK modulation scheme. The proposed model consists of a transmitter, optical fiber channel receiver and a few numbers of visualizers and constellation diagrams. The transmitter consists of a pseudo random bit sequence generator that feeds the bits sequence to optical DP-QPSK transmitter that simulates a single channel optical coherent transmitter with an optical dual polarization QPSK signal.

Fiber Losses are taken into account and are being compensated through dispersion compensation fiber and amplifiers. Receiver consists of an optical DP-QPSK receiver, electrical amplifier, low pass filter, M-ary threshold detector, PSK decoder and parallel to serial converter.

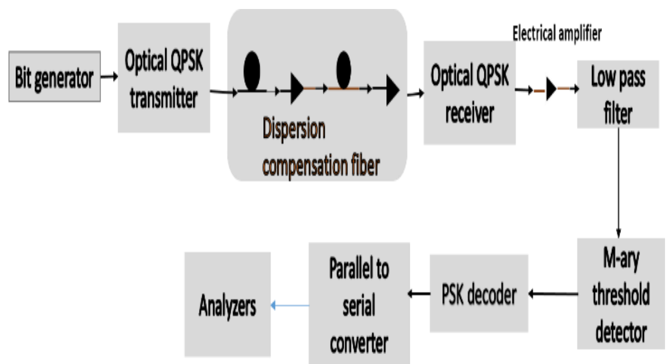

Fig. 4: DP-QPSK based communication model block diagram

PSK decoder is used here, for reproducing 0s and 1s from the received signal. Visualizers are used to find the Eye diagram, signal constellation diagram and the transmitted and received signal in time and frequency domain. For proposed DP-QPSK system, the considered parameters are given in Table 2:

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Table. 2 Simulation Parameters of DP-QPSK Model

Parameter	Value
Data rate	120 Gbit/s
Wavelength	1550 nm
Fiber length	100 Km
Sequence length	1024 bits
Samples per bit	64
Modulation	DP-QPSK
Optical QPSK transmitter power	10dBm
Line width of optical Transmitted power	0.01 MHz
Attenuation	0.2 dB/km

3. RESULTS & DISCUSSION

The parameters for both communication models, QPSK based and DP-QPSK based, are kept same for comparison. Both the systems are evaluated, and the results are compared. Fig. 5 shows the constellation diagram of QPSK based communication model over the parameters specified in Table 1. Fig. 6 shows the constellation diagram of DP-QPSK based communication model over the same parameters as QPSK based model, specified in Table 2. Fig. 7 and 8 depicts the eye diagrams for QPSK based model and DP-QPSK based model respectively. The large eye-opening shows that DP-QPSK performs signal better than QPSK signal

From the Fig 5 and 6, it is evident that at 120 Gbit/s data rate, fiber length of 100 km and fiber medium lineraties being controlled, DP-QPSK performs better than QPSK.

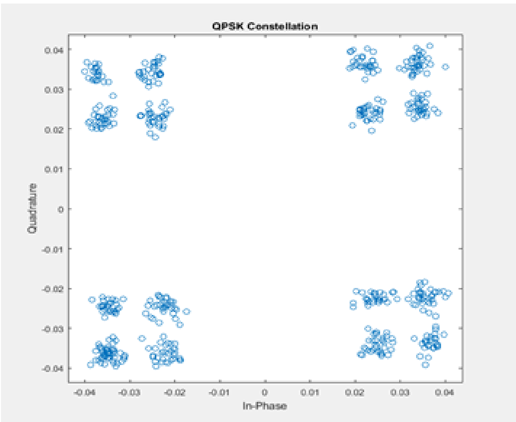

Fig. 5: Constellation Diagram of QPSK based model

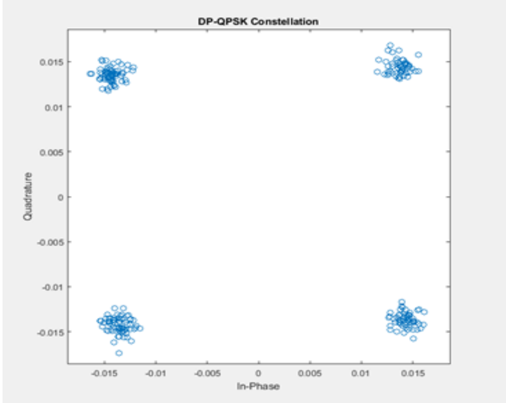

Fig. 6: Constellation Diagram of DP-QPSK based model

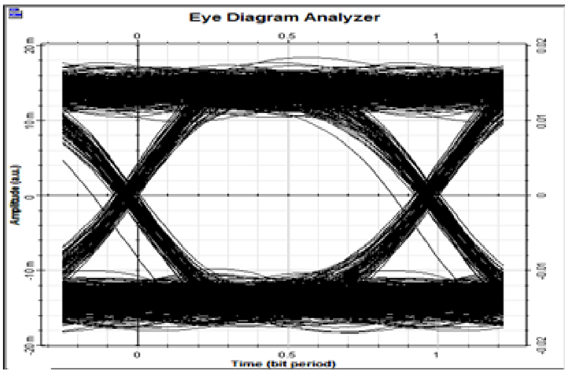

Fig. 7: Eye diagram of DP-QPSK based model

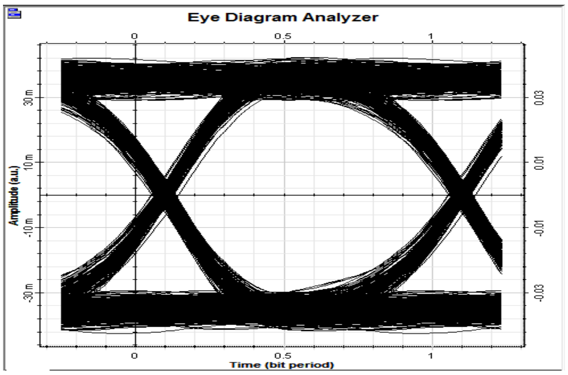

Fig. 8: Eye diagram of DP-QPSK based model

QPSK suffers severe dispersion and error issues over long distance and high data rate than DP-QPSK, which can be clearly seen from the Fig. 5 and 6.

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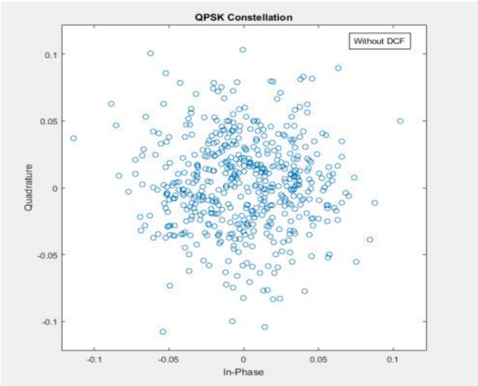

Fig. 9(a) At distance 160 km without DCF (QPSK)

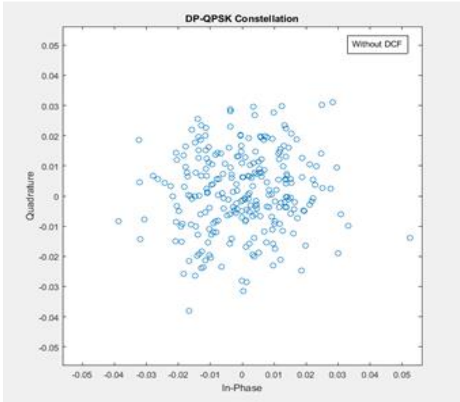

Fig. 10(a) At distance 160 Km without DCF (DP-QPSK)

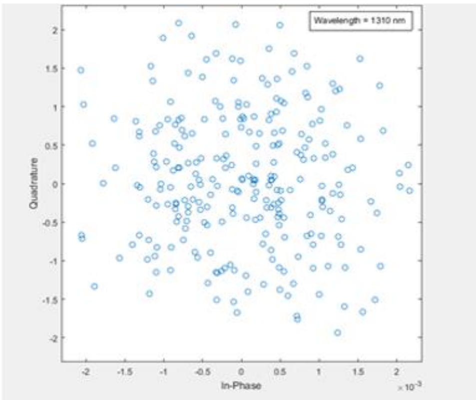

Fig. 9(b) At distance 160 km using DCF (QPSK)

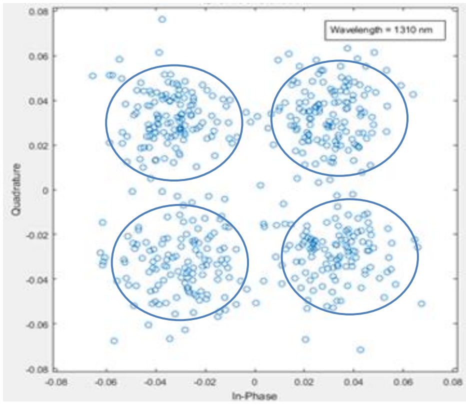

Fig. 10(b) At distance 160 km using DCF (DP-QPSK)

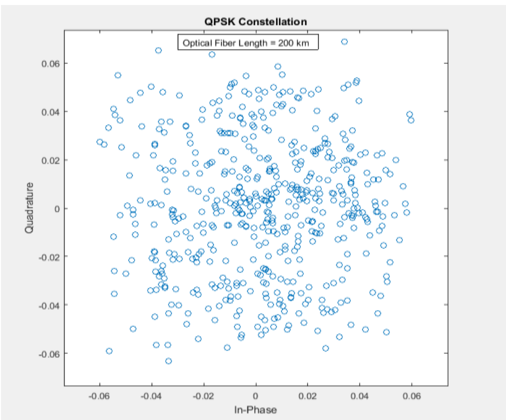

Fig. 9(c) At distance 200Km (QPSK)

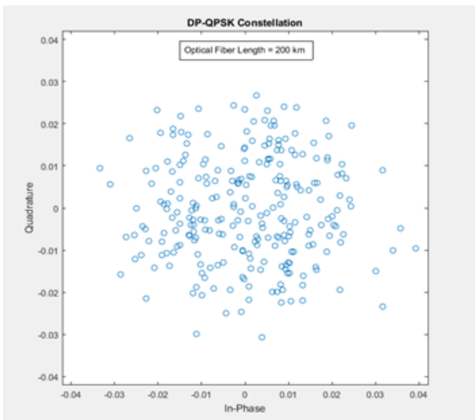

Fig. 10(c) At distance 200 km (DP-QPSK)

Fig. 9 and 10 shows the constellation diagram and of QPSK based model and DP-QPSK based model over different parameters.

It is clear from Fig. 9 and 10, DP-QPSK performs better than DP-QPSK even at very long distance, high data rate and without dispersion control.

4. CONCLUSION

We have compared the performance of QPSK based optical fiber communication system with DP-QPSK based optical fiber communication system which proves that DP-QPSK based system performs better than QPSK even at very high data rates upto 120 Gbit/s and distance of 200 km. This is due to the fact that DP-QPSK represents four bits per symbol, while QPSK represents two bits per symbol which makes DP-QPSK more bandwidth efficient that can handle high data rates as compared to QPSK. This work also proves that DP-QPSK based system is still a better performer than QPSK even without using dispersion compensation techniques which makes DP-QPSK better choice for optical fiber communication.

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