A Novel All-Optical Signal Regeneration Technique for 10Gb/s Differential Phase Shift Keying Signal

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Summary
Nonlinear signal processing became fascinating field for the researchers for high speed optical communication. One of the significant application has been came up is optical signal regeneration. There are different signal regeneration techniques have proposed by different researchers. However, the achieving the low power consumption along with Bit Error Rate (BER) is still challenging. This paper proposed the signal regeneration technique via PSA and locked signal technique. The designed technique achieved BER of 10^{-14} at -14 dBm for degraded Differential Phase Shift Keying signal.

Key words:
Bit Error Rate (BER); Optical Signal Regeneration; Highly Nonlinear Fiber (HNLF); Phase Sensitive Amplification (PSA); Constellation Diagram.

1. Introduction

During transmission, several noises are incurred in the signal. The signal regeneration enables the restoration of the signal fidelity or to transmit the signal even at a longer distance [1]. Recently, various signal regeneration techniques and methods have been reported for diminishing the signal noise i.e. phase and amplitude noises [2] for different modulation schemes [3, 4].
PSK has lately is widely used modulation scheme due to its benefits of 3-dB receiver sensitivity enhancement [5]. The techniques discussed various research before in [1-5] has developed solution for signal regeneration using dual pump configuration, clock recovery, inject locking and others in [6].
Furthermore, the present techniques yields 10^{-9} BER in real-time at less than -11 dBm [2]-[6]. In this paper, developed technique enables regeneration of optical signal along with diminishing of noise for noisy 10Gb/s DPSK signals. The developed method of signal regeneration offers the minimum BER at minimum power consumption compared to signal regeneration in [2]-[6].

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2. The design and development of of proposed signal regeneration Scheme

In the Figure 1, the proposed signal regenenration is demosnatarted. The system is designed in such a way that noisy DPSK of 10Gb/s signal is iput to HNLF fiber. The FWM operation is proposed using PSA to amolify and regenenrtate the signal using degenerated FWM [7];

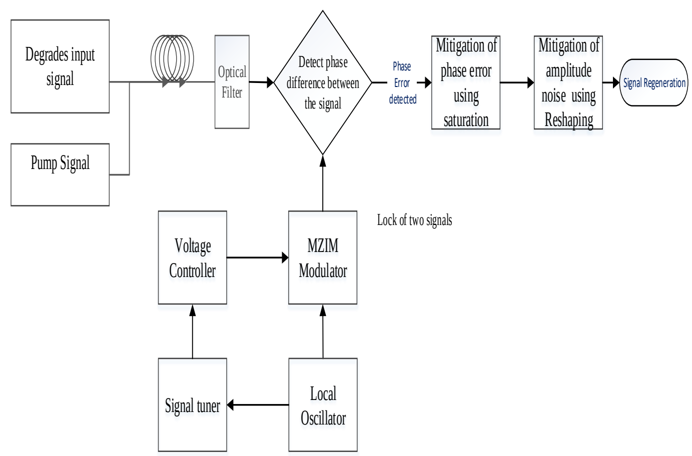

Fig. 1 Design of proposed signal regeneration method.

During PSA, degraded signal receives the hase gain. The pump signal along with noisy signal is regenerated at the diverse wavelengths as shown in Eq. 1;

$$X(\phi) = (2z^2 + 1) - 2z^2 \cos(\phi_n + 2\phi) + 2z\cos(\phi_n) - 2\cos(2\phi) \quad (1)$$

And;

$$z = \bar{\gamma} P_p / a(-\Delta k + \bar{\gamma} P_s - 2\bar{\gamma} P_p),$$

In terms of phase,

$$z = \theta - (\Delta k + 2\bar{\gamma}P_p - \bar{\gamma}P_s)z \quad \text{and} \quad \theta = 2\phi_p - \phi - \phi_i \,,$$

X(ϕ) defines the gain signal, Pp is power of pump signal, Ps is the power of signal, ϕ the is signal's phase. $\bar{\gamma}$ is the coefficient of nonlinearity. This directly relative to kerr nonlinearity. PSA signal also accompanied with other signals such as; pump, idler and different harmonics generated. All these signal components are passed to optical filter that separate the other signals from PSA signal. The PSA regenerated signal passed to phase error detection, where the PSA signal and phase of the generated optical locked signal's phases are compared using (2) [8];

$$A = 2R\sqrt{P_R P_{LO}}\cos(\pi a_k s(t)) \qquad (2)$$

The phase comparison produces the phase alteration among the regenerated signal using the developed technique and the optical carrier signal that has the same carrier characteristics as of input original signal. The perceived phase difference is diminished via threshold of using Simulink model's limit function. The diminished phase difference signal is sent for smoothing of signal to reshape function that further reduce the amplitude noise spikes.

3. Simulation Setup

The designed system is developed via Simulink model as shown in Fig. 2. DPSK signal of 2^{31}-1 of noisy pseudo random GB/s PRBS signal at1551 nm. These are 17 dB for amplitude noise and 23 dB of phase noise is considered to verify the developed signal regeneration method.

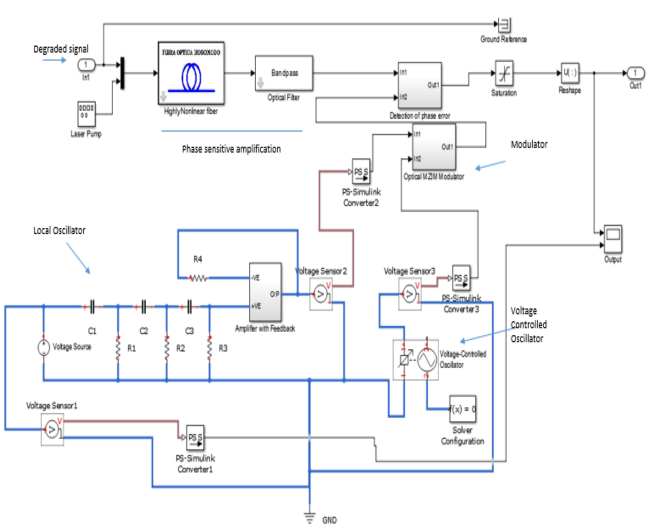

Fig. 2 Simulink model of the designed signal regeneration method.

The input degrades signal is characterized using different parameters such as; 1550nm in wavelength is launched in nonlinear fiber together with the carrier or pump signal. The nonlinear fiber furthermore is characterized using different parameters having length of 0.45 km with effective area of 14 μm^2. The characterized nonlinear fiber generates different spectral components or harmonics for input degraded DPSK test signals and carrier signal combination at 1552 nm, 1549 nm, 1552 nm and 1548 nm. Among these spectral components the signal is renewed at 1552 nm at the signal gain 3.7 dB. The rest of the spectral components such as; pump, idler and other harmonics are eliminated using optical filtering except the regenerated signal.

In the next, the optical carrier is generated using MZIM having carrier frequency of 500 GHz. The phase difference between the signal regenerated and the optical carrier is calculated at locked frequency. The optical modulator bandwidth decides the range of optical carrier. The phase difference between two is compensated by modification the voltage level of crystal oscillator i.e. VCO. This will generates the sinusoidal wave that will control the modulator output.

4. Results and Discussion

In this paper, the new regenerated signal method is developed using phase sensitive and locking of phase. The developed signal regeneration method is able to achive the low BER for degraded signal of BER of 10^{-8} at -8.3 dB. It has been demonstrated that using the developed method BER of 10^{-14} at -14 dBm is attined for the noisy input signal as shown in Fig. 3;

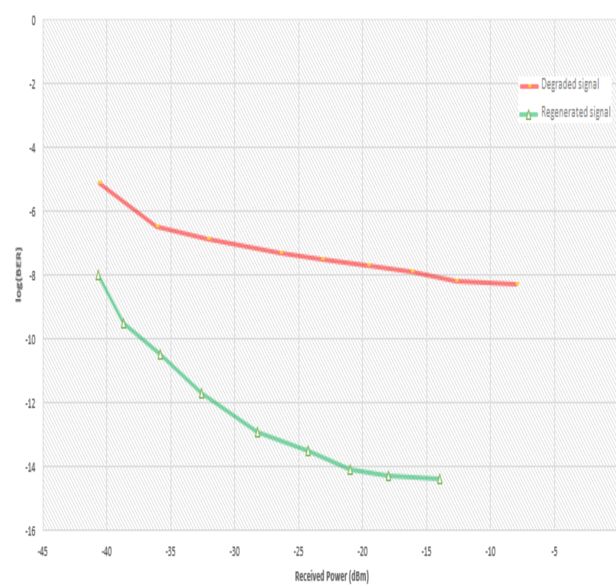

Fig. 3 BER and Power curves for before and after signal regeneration method.

It is discussed that the amplitude and noise is recorded in the regenerated signal is 0.1 dB and 0.35 dB respectively. Figure 4 shows the constellation diagram that shows the phase response of the developed technique at different stages (a) represents response of degraded DPSK signal; (b) signifies the response after deploying PSA technique; (c) illustrates the response at end saturation block that mitigates the phase error and (d) shows the response at the end of reshaped function that mitigates the amplitude noise.

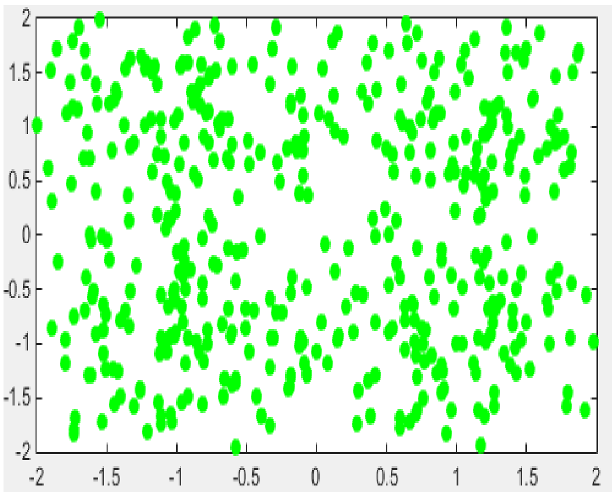

Fig. 4(a) Constellation diagram of Degraded DPSK.

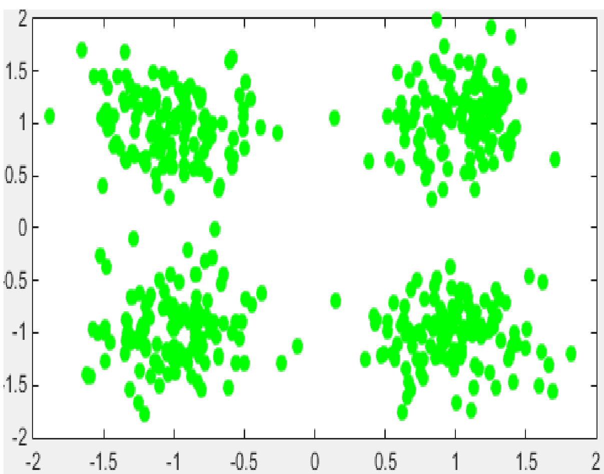

Fig. 4(b) Constellation diagram after PSA.

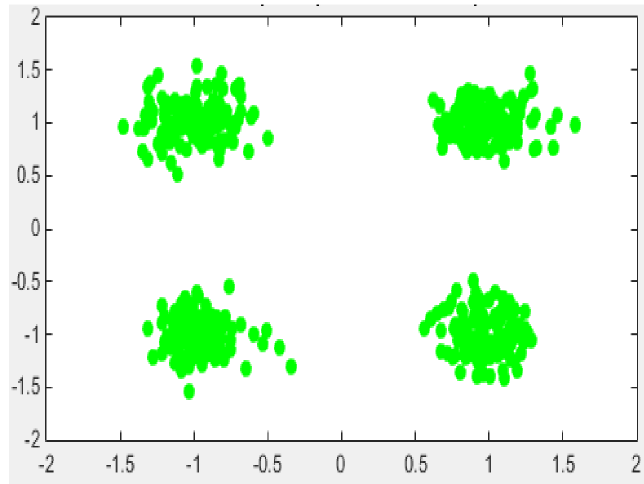

Fig. 4(c) Constellation diagram after mitigating phase noise.

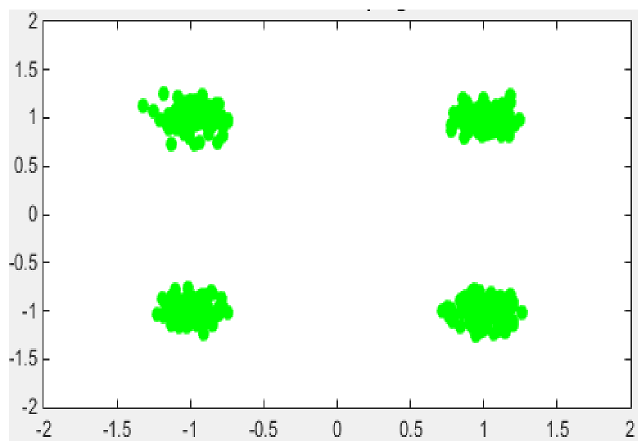

Fig. 4(d) Constellation diagram after mitigating amplitude noise.

5. Conclusion

In this work, using Simulink model a new signal regeneration method has been developed and validated. The proposed technique demonstrates the possibility of regenerating the signal with noise mitigation from 10Gb/s DPSK degraded test signals. The developed technique yields signal fidelity i.e. approximate BER of 10-14 at -14 dBm. The performance of existing regeneration system can be enhanced with low BER with power efficient output.

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