ASEC 2024 Conference
The 5th International Electronic Conference on Applied Sciences
04–06 December 2024 | Online
MDPI

# Optimizing High-Bit-Rate Optical Transmission with Advanced Technique

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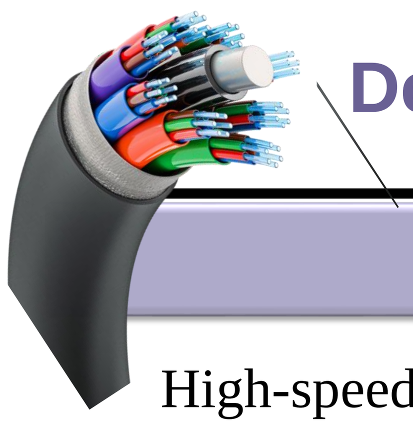

## INTRODUCTION & AIM

High-speed optical communication systems are essential for modern digital networks, enabling the transmission of vast amounts of data over long distances. However, challenges such as power consumption, system complexity, linear-nonlinear effects can significantly limit their performance. To address these limitations, advanced techniques are required to optimize system performance.


This research aims to optimize high-rate optical transmission by employing advanced chromatic dispersion and nonlinearity compensation CDC/NLC techniques through Digital Signal Processing algorithms to mitigate these impairments and enhance system performance metrics such as BER and reach.

## METHOD

### A. System Setup

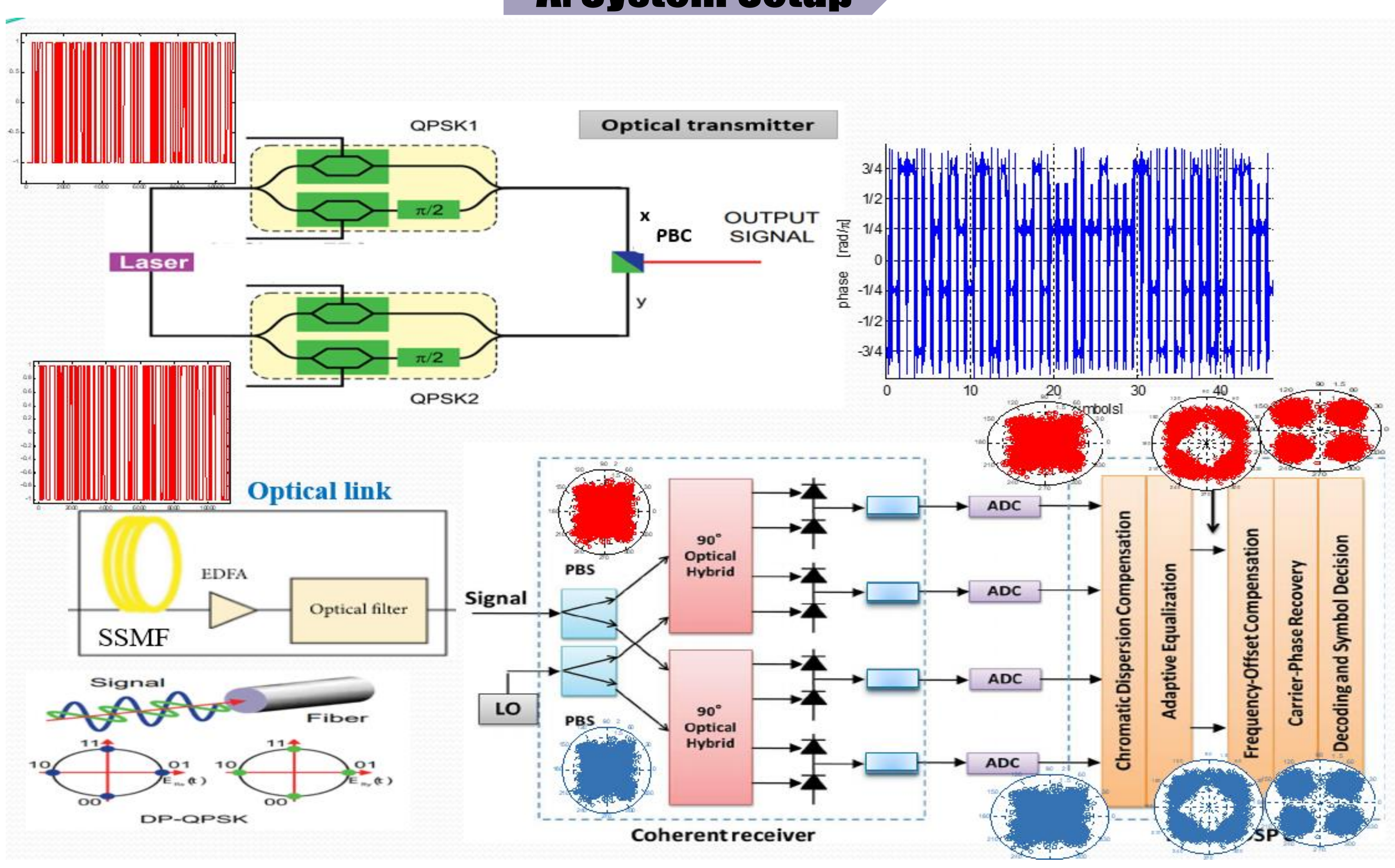


***Figure 1.1:*** *DP-QPSK Coherent Optical System configuration.*

The simulation setup of the signal channel different bit rates optical coherent ***Dual Polarisation-Quadrature Phase Shift Keying*** system is illustrated in Figure 1.1. The system consists a transmitter, transmission link (multi-span of optical fiber and the optical amplifier while the impact of the linear and nonlinear effects are presented, and finally coherent receiver with digital signal processing. The parameters of the link are summarized in Tables below.

**Table 1.1: Set of system simulation parameters.**

| Format | PDM-0.3RZ- QPSK |
|---|---|
| $R_{bit}$ | 56-112-224 Gbps |
| $R_{sym}$ | 14-28-56 Gbaud |
| $N_{bit}$ | $2^{12}$ |
| Samples / bit | 64 |
| Number of samples | 262114 |
| Wavelength (λ) | 1550 nm |
| N steps/span | 4 |

**Table 1.2: Transmission line parameters.**

| Parameters | SSMF |
|---|---|
| Span length (L) [km] | 75 |
| Attenuation (α) [dB/km] | 0.22 |
| Dispersion (D) [ps/ nm /km] | 17 |
| Dispersion slope (S) [ps/$nm^2$/km] | 0.08 |
| Nonlinear refractive index ($n_2$) [$m^2$/W] | $2.6\times10^{-20}$ |
| Nonlinear coefficient (γ) | 1.31 |
| Core effective area ($A_{eff}$) [$\mu m^2$] | 80 |
| EDFA Gain | 15 dB |
| EDFA noise figure | 5 dB |

### B. The principle of linear and nonlinear compensation

Digital Back Propagation (DBP) is a channel inversion technique that aims to remove fiber effects by digitally emulating the propagation of the received signal through a fictitious fiber link.

D :linear operator, N :nonlinear operator, A: complex envelop of optical signal.

Z: size step.

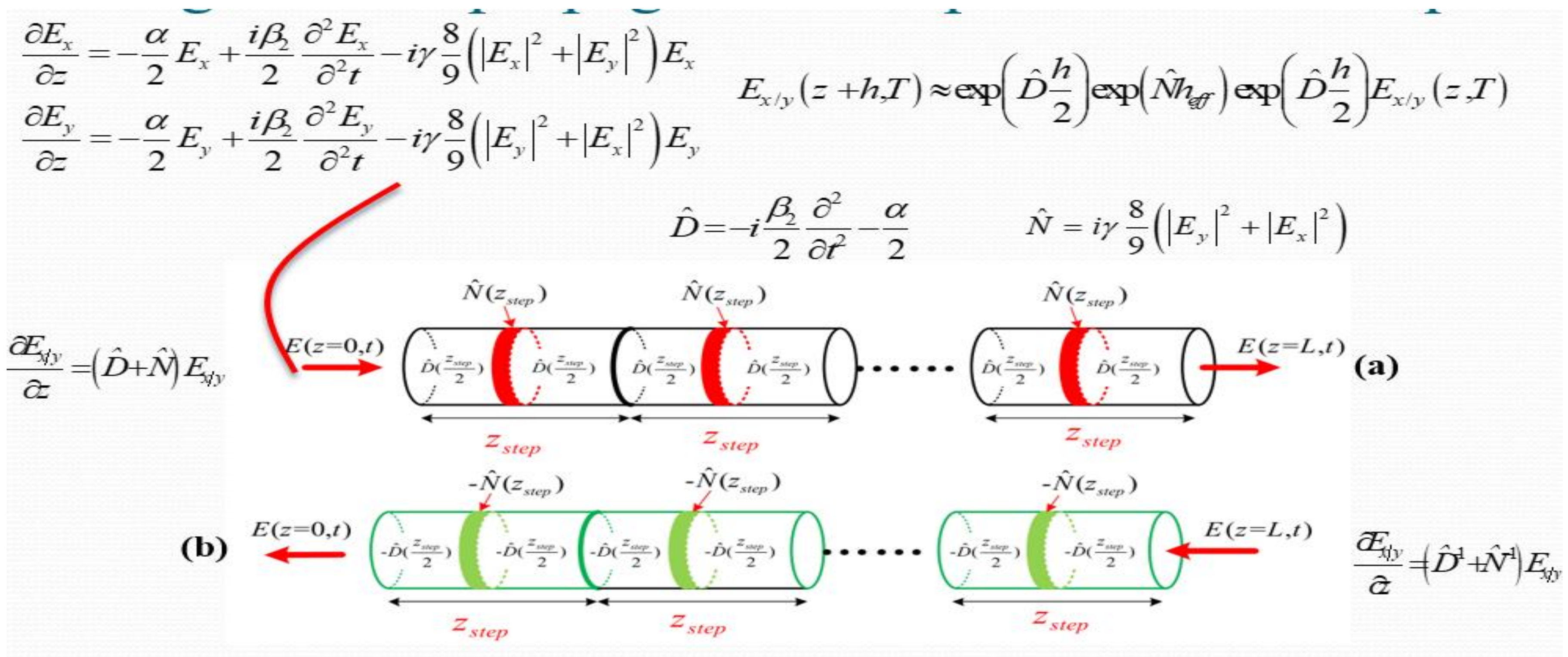


**Figure 1.2: (a) Forward propagation process through the fiber, (b) Digital backpropagation propagation through the virtual fiber.**

## RESULTS & DISCUSSION

(a) shows the bit error rate (BER) performance curves versus the optical signal-to-noise ratio of the DP-QPSK system under various transmission situations for bit rates (56-112-228) Gbps. The required OSNR values is presented in Table 1.3.

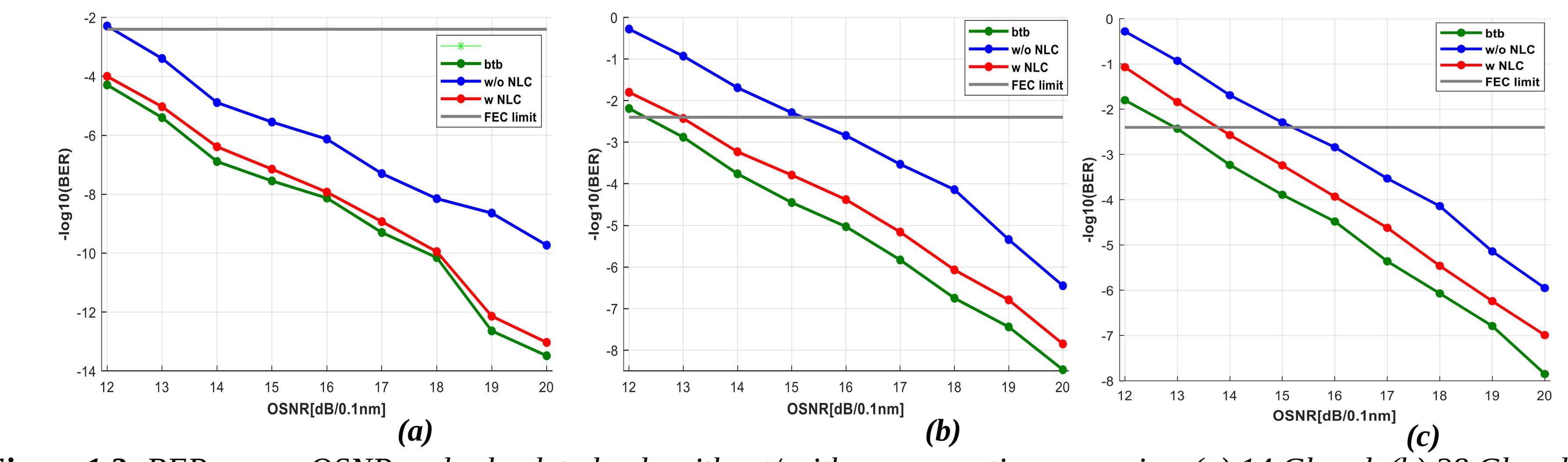


***Figure 1.3:*** *BER versus OSNR under back to back, without/ with compensation scenarios, (a) 14 Gbaud, (b) 28 Gbaud, (c) 56 Gbaud.*

***Table 1.3:*** *OSNR required values at the limit of FEC (BER of 3.8×10-3).*

| Configuration | 14 Gbaud | 28 Gbaud | 56 Gbaud |
|---|---|---|---|
| Btb transmission | Above FEC limit | 12.3 dB | 13 dB |
| W NLC compensation | | 13 dB | 13.8 dB |
| w/o NLC compensation | 12 dB | 15.2 dB | 16.6 dB |

(b) calculate the optimal injected power and system reach for the three different symbol rates using a CDC/NLC techniques (Figures 1.4 a-b).

Transmission is linear at low power, so a doubling of power permits a doubling of reach. However, as the power increases further, the system experiences the NL transmission regime, resulting in curves that initially reach a maximum before descending.

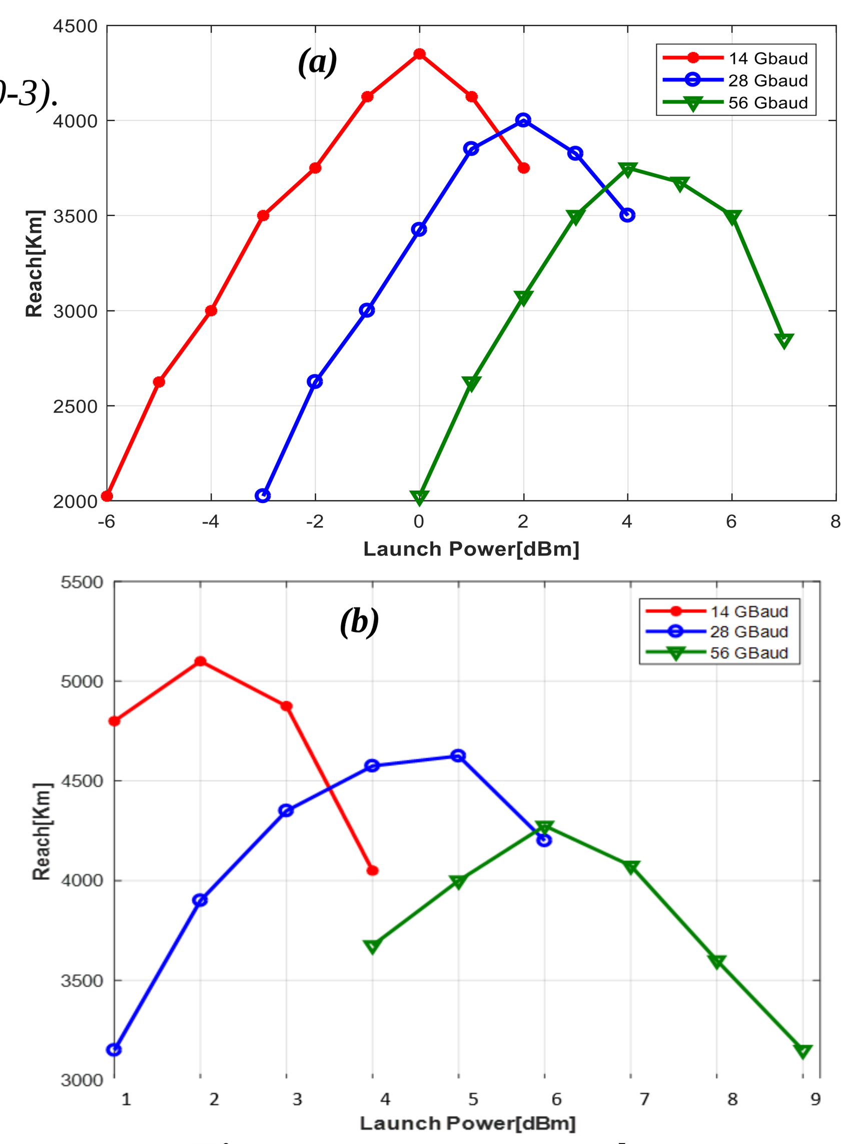


***Figure 1.4:*** *system reach*

## CONCLUSION / FUTURE WORK

The compensation of system performance between DSPs with and without dispersion and nonlinearity compensation, evaluating it in terms of optimal launch power and binary error rates. The results show that performance improved after DBP configuration.

- Reduce the computational load of single-polarization DBP.
- The nonlinear threshold power was extended by 2 dB with the compensated case.
- Reach BER of 1.54×10-4 and a 2.50 dB improvement in the Q-factor (10.25 dB).
- Increase the transmission reach up to 5000 km.

As suggested future research, Higher-order modulation (16-QAM, 64-QAM) and SDM can boost capacity, but introduce complexities. Machine learning can optimize nonlinear compensation, simplifying the process and extending range.

## REFERENCES

[1] Agrawal, G. P. (2016). Optical Communication : Its History and Recent Progress. Springer eBooks, p. 177-199.

[2] Faruk, M. S., & Savory, S. J. (2017). Digital Signal Processing for Coherent Transceivers Employing Multilevel Formats. Journal Of Lightwave Technology, 35(5), 1125-1141.