Comparison of NRZ and RZ Modulation in WDM Optical Systems Using Eye Diagrams and CNN Classification

Type of project: Software

Students' Signatures

Date:

Supervisor Signature

Date:

1. TEAM DETAILS

Sr. No.	Team Member	SID	Supervisor
1.	Swastik Kalsi	23105129	Prof. Jasbir Kaur (ECE Dept.)
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2. TITLE & BROAD AREA OF PROJECT

Comparison of NRZ and RZ Modulation in WDM Optical Systems Using Eye Diagrams and CNN Classification

Type of project: Software

This research investigates the design and performance analysis of a WDM system employing a Mach–Zehnder Modulator, with specific focus on Return-to-Zero (RZ) and Non-Return-to-Zero (NRZ) modulation formats. A dual-approach methodology is adopted: regression models are used to quantitatively predict critical performance parameters (Optical Signal-to-Noise Ratio (OSNR), Bit Error Rate (BER), and Q-Factor) based on system configurations, while Convolutional Neural Networks (CNNs) are employed to classify and interpret eye diagrams, offering a data-driven understanding of signal integrity and modulation quality.

3. OBJECTIVES OF THE PROJECT

1.	To design and simulate a Wavelength Division Multiplexing (WDM) system using a Mach–Zehnder Modulator (MZM)
2.	To analyse and compare the performance of Return-to-Zero (RZ) and Non-Return-to-Zero (NRZ) modulation schemes within the WDM framework and collect data for model training
3.	To implement regression models for predicting key performance metrics such as Eye Height, BER, and Q-Factor
4.	To apply Convolutional Neural Networks (CNNs) for classification and analysis of eye diagrams, enabling intelligent signal quality assessment

4. PROPOSED METHODOLOGY & WORKFLOW

4.1 System Simulation (OptiSystem):

o A WDM system is designed using a Mach–Zehnder Modulator (MZM) for high-speed optical communication.

o Multiple channels (four) are transmitted over a single optical fibre (1550 nm) , incorporating PRBS data, RZ/NRZ modulation, and realistic impairments (noise, dispersion, non-linearities).

4.2 Data Collection:

o Performance metrics (Q-Factor, BER, decision threshold, and eye height) are recorded at 2 km intervals from 1 km to 100 km.

o Eye diagram images are collected at 5 km intervals to capture signal quality variations.

4.3 Regression Modelling:

o Machine learning regression models (Linear, Ridge, Lasso, Random Forest, XGBoost, and MLP Regressor) are trained to predict Q-Factor, BER, and related metrics.

o This enables quick estimation of performance without full simulations.

4.4 CNN-Based Eye Diagram Analysis:

o Collected eye diagrams are used to train a Convolutional Neural Network (CNN).

o The CNN classifies signal quality, detecting eye closure, jitter, and noise.

o Provides intelligent quality assessment to complement OSNR, BER, and Q-Factor analysis.

4.5 Workflow:

o Simulation → Data Extraction → Regression Model Training → Eye Diagram Collection → CNN Training → Performance Comparison → Final Evaluation.

5. SOFTWARE & HARDWARE REQUIREMENTS

5.1 Software Requirements

- **OptiSystem** – For simulation of WDM system, PRBS data generation, modulation (RZ/NRZ), and fiber channel modelling.
- **Python (VS Code or Google Colab)** – For data preprocessing, regression modelling, and CNN implementation.
    - o Libraries: Scikit-learn (Linear, Ridge, Lasso, RF, XGBoost, MLP), TensorFlow/Keras or PyTorch (for CNN), Pandas, NumPy, Matplotlib.
- **MS Excel / CSV tools** – For dataset organization and intermediate analysis.

5.2 Hardware Requirements

- **Processor:** AMD Ryzen 7 or higher (multi-core recommended).
- **RAM:** Minimum 8 GB (16 GB preferred for faster simulations and ML training).
- **Storage:** 20 GB free space (for OptiSystem projects, datasets, and ML models).
- **GPU:** NVIDIA GPU with CUDA support for CNN training and image processing.
- **Operating System:** Windows 11

6. TIMELINE & MILESTONES