International Journal of Innovative Research in Engineering
Volume 3, Issue 3 (May-June 2022), PP: 144-151.
www.theijire.com
ISSN No: 2582-8746

# Capacity Enhancement of 16 Channel DWDM

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**How to cite this paper:**
Dr. Yugnanda[1], Sarvagya Kumar[2], Shresht Gupta[3], Shivam Aggarwal[4], Vishnu Ramesh[5] , "Capacity Enhancement of 16 Channel DWDM", IJIRE-V3I03-144-151.



***Abstract:*** *This paper discusses the data transmission using Dense Wavelength Division Multiplexing (DWDM) for 16 optical channels in an optical transmission system. The decision problem is to find the most cost-effective combination of WDM equipment and fiber that increases the capacity of the network to an extent where we can handle all our expected demand. We have applied various hybrid methodology like varying bit rates, different modulation formats like RZ, NRZ and Duo-binary as a tool for the capacity enhancement. We discuss the concept of optical amplifiers and dispersion compensated fibers. More emphasis has been given to Erbium doped fiber amplifier as its combination with WDM technology emerges as a vital solution to speed and bandwidth problem. In this proposed work Optisystem 7.0 software has been used to design and analyse the performance of the system. The simulation results are also discussed. The results are characterized in terms of parameters like Q-factor, Bit Error Rate (BER), etc. deduced from the eye diagram analyzer.*
***Keywords:*** *Photonics, DWDM, MZIM, EDFA, BER, WDM, RZ, NRZ, Duobinary*

## I. INTRODUCTION

Optics is a field of physics covering a plethora of topics associated with study of light which incorporates many subfields. The term "Optics" came into wider use in 1970s with the invention of optical laser and later the optical laser diode. These inventions shaped the idea for the telecommunications revolution of the late twentieth century and provided the infrastructure for the web. At the start, it was meant to use within the fields wherever the goal was to use light to perform functions that were initially accomplished by electronics. It comprises- the particle properties of light, the potential of making signal process device technologies by photons, the application of optics, and an analogy to electronics.

This feature made fiber optical communication system an attractive alternative for the future, thus the first generation of fiber optic system was born. The desire to reduce the number of regeneration units by increasing the repeater spacing, the first-generation systems quickly reach to the second-generation system in the early 1980s. The development of Erbium Doped fiber Amplifier (EDFAs) during the 1990s, provided a breakthrough which allowed the pulses to be optically amplified thus reducing the need of many regeneration stations. The third-generation systems boosted capacity to terabits per second (Tb/s). The simplest model of a light wave system consists of a transmitter, a transmission medium such as an optical fiber, and a detector or estimator. Information is transmitted in digitized form as such as 1's or 0's and the optical pulses representing this information and it is then send using a laser and a modulator.

## II. WAVELENGTH DIVISION MULTIPLEXING

Wavelength Division Multiplexing (WDM) is a technique in which we can multiplex many signals and transmit into fiber optical cable. WDM, work like FDM which use the radio frequency (RF), here we have infrared (IR) wavelength from the electromagnetic spectrum. Each channel carries a different wavelength separated and combined data which transmit by one only fiber.

But instead of taking place in radio frequency (RF), WDM under the IR section of the electromagnetic (EM) spectrum. Each multiplexed wavelength can be separated, or demultiplexer, the initial signals to the destination. usage of Frequency Division Multiplexing (FDM) or Time Division Multiplexing (TDM), information in each channel, along with many channels of data in different forms at different speeds and can be transmitted simultaneously on a single fiber. In early WDM systems, there are two wavelengths per fiber. At destination, the wavelengths were demultiplexer by two wavelength filter cut-off wavelengths approximately midway between the wavelengths of the two channels.

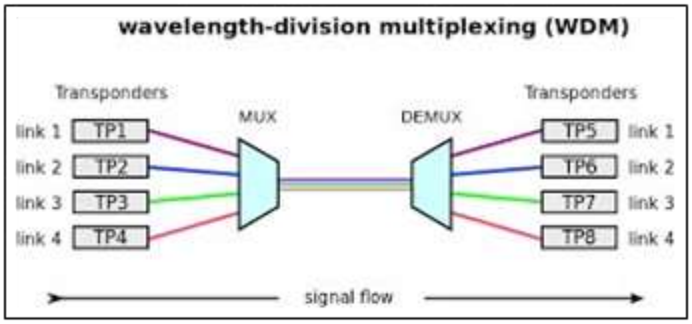


*Figure 1: WDM*

**Dense Wavelength Division Multiplexing**

DWDM stands for Dense wavelength division multiplexers. These are modules that put data from different sources together on a fiber optic cable. There modules further increase system bandwidth and capacity by using closely spaced wavelengths to carry multiple signals on the same cable. DWDM based networks create a lower cost way to quickly respond to customer's bandwidth demands and protocol changes. In DWDM systems, the number of multiplexed channels is much denser as compared because DWDM uses tighter wavelength spacing to fit more channels onto a single fiber.

**Coarse Wavelength Division Multiplexing**

CWDM stands for Coarse wavelength division multiplexers. These are modules that increases the amount of bandwidth the fiber optic system will carry by transmitting multiple signals at various wavelengths along the fiber optic cables. Generally, CWDM is used for lower cost, wider range frequencies, lower capacity (sub-10G) and shorter distance applications where cost is an important factor

**Erbium Doped Fiber Amplifier**

Erbium-Doped Fiber Amplifier (EDFA) is an optical amplifier used in the C-band and L-band, where loss of telecom optical fibers becomes lowest in the entire optical telecommunication wavelength bands. EDFA is now most commonly used to compensate the loss of an optical fiber in long-distance optical communication. Another important characteristic is that EDFA can amplify multiple optical signals simultaneously, and thus can be easily combined with WDM technology.
EDFAs are used as a booster, inline, and pre-amplifier in an optical transmission line. The booster amplifier is placed just after the transmitter to increase the optical power launched to the transmission line. The inline amplifiers are placed in the transmission line, compensating the attenuation induced by the optical fiber. The pre-amplifier is placed
just before the receiver, such that sufficient optical power is launched to the receiver. A typical distance between each of the EDFAs is several tens of kilometers.

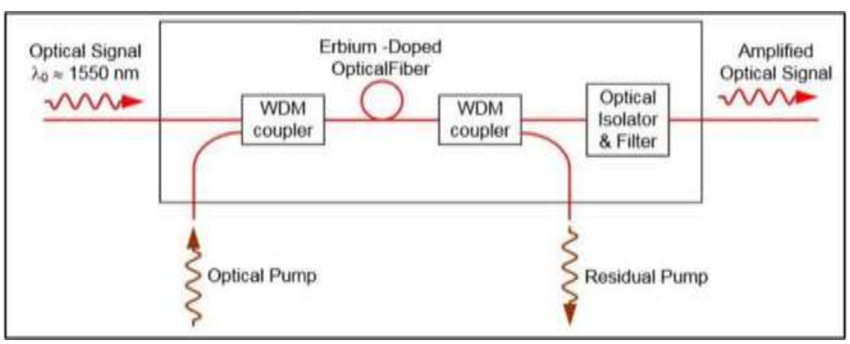


*Figure 2: Working of EDFA*

## III. LITERATURE REVIEW

In [1] author discusses the implementation of DWDM in an optical communication link which requires special optical devices and optical modules such as low chirp integrated laser, EDFAs, multiplexer and demultiplexer.
The results obtained further revealed that the launched power of the system must be reduced for better performance of the DWDM system and improved immunity against identified limitations.
In [2] author discusses data transmission using Wavelength Division Multiplexing (WDM) for five optical channels in an Optical transmission system. All the results are analyzed using OPTISYSTEM simulation at 10 Gbps transmission systems.
In [3] author wavelength division multiplexing allows the multiple channels to transmit the data at high speed at the same instant.

For large distance communication, Single mode fiber is preferred over Multimode fiber.

In [4] author presents an overview about WDM technology and recent developments in this field and how the overall capacity of the communication network can be incremented using this technology. As speed & bandwidth has always been a cause of concern in communication network, WDM emerges as a vital solution to these problems. In [5] author presents Dense Wavelength Division multiplexing (DWDM) is a novel technology that can improve the channel capacity and meet growing demands for bandwidth of the optical fiber communication system. This technology utilizes a composite optical signal carrying multiple information streams. Each information streams transmitted on a distinct optical wavelength onto a single fiber.

## IV.IMPLEMENTATION

### A. HYBRID BIT RATE (10 & 20 GBPS)

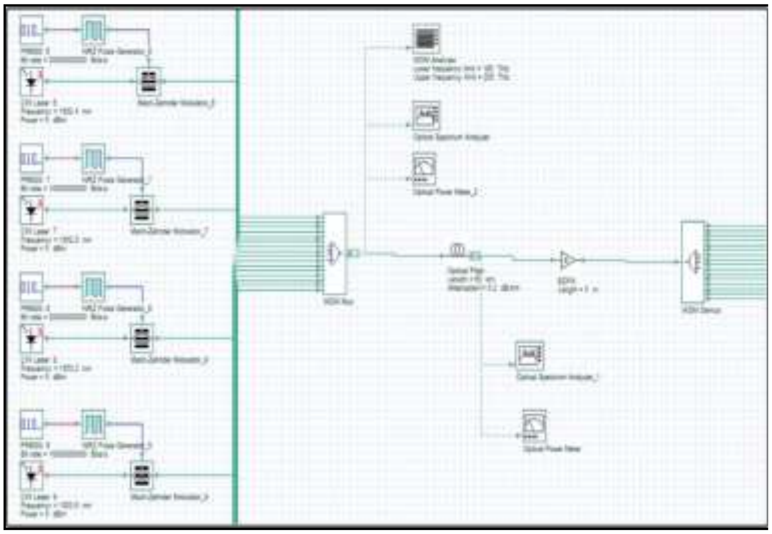

*Figure 3: Transmitter Section*

This is the transmitter section of optical transmission system consisting of 16 channels. Each channel includes PRBSG, NRZ Encoder, CW Laser, MZI Modulator. We have used alternate bit rate i.e., 10 Gbps and 20 Gbps as data stream for each PRBSG. The basic idea behind this is to improve the capacity of the system. The starting frequency is 1550 nm and the subsequent channels have a 0.4 nm spacing between them. All channels are multiplexed by WDM technique and sent for further transmission through a single fiber. The length of fiber is 60 km. Demultiplexer separates each data stream and send to corresponding receiver branch.

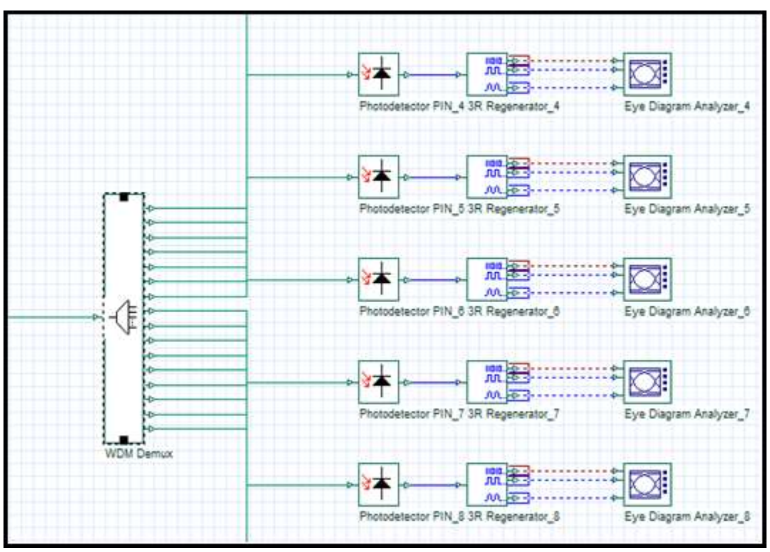


*Figure 4: Receiver Section*

The receiver section consists of PIN photodiode, 3R Re-generator and Eye diagram Analyser. PIN photodiode converts the received optical signal to electrical pulse. 3R regenerator stands for re-shaping, re-amplification and re-timing. So, the regenerator limit signal degradation by noise sources in optical communication systems and the final eye diagram can be observed in the analyser.

**EYE DIAGRAM ANALYSER**

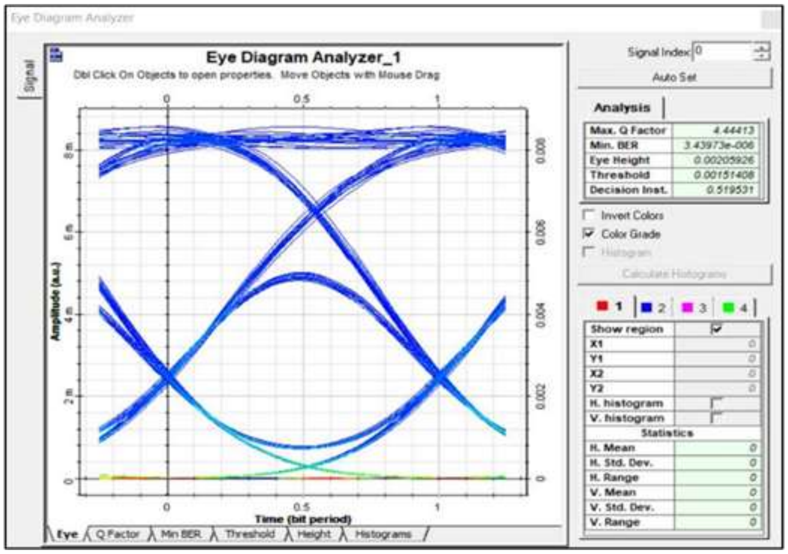

*Figure 5: Eye Diagram*

The eye diagram is a simple but powerful measurement method that is extensively used for assessing the data handling ability of a transmission system. The quality factor of our circuit came out to be 4.44 dB and bit error rate was 3.43x10-6. The opening of eye is inversely related to the noise present in the signal. If there is more noise, more inter- symbol interference, then the eye opening would decrease.

**B. ALTERNATE RZ-NRZ MODULATION**

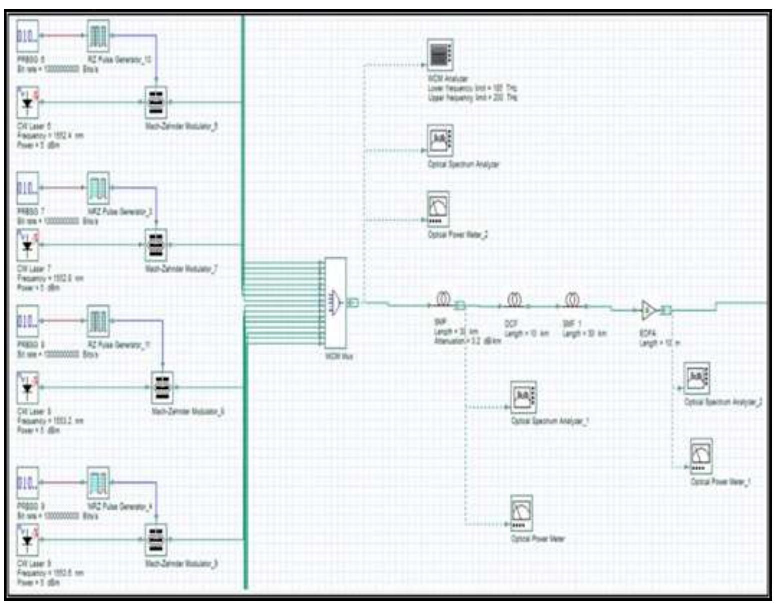
*Figure 6: Transmitter Section*

In this simulation model, we have used RZ and NRZ modulation format alternately in the transmitter section. It also consists of 16 channels. For long distance repeater less transmission, the dispersion will go on accumulating and will limit the number of bits one can send at each wavelength. Properly designed dispersion compensating fibers can overcome this difficulty, whose dispersion coefficient (D) is negative and large at 1550nm. So, in the fiber section we have introduced a dispersion compensated fiber between two single mode fibers. Then the signal is passed through erbium doped Fiber Amplifier.

Among various optical amplifiers, a great preference is given to EDFA because of its high gain, low noise insertion, compensation of loss during long distance communication and ability to amplify multiple signals simultaneously. We can use an optical amplifier in pre, post or inline configuration. We can also use an amplifier individually with each channel. Although that would lead to an increase in complexity of the system.

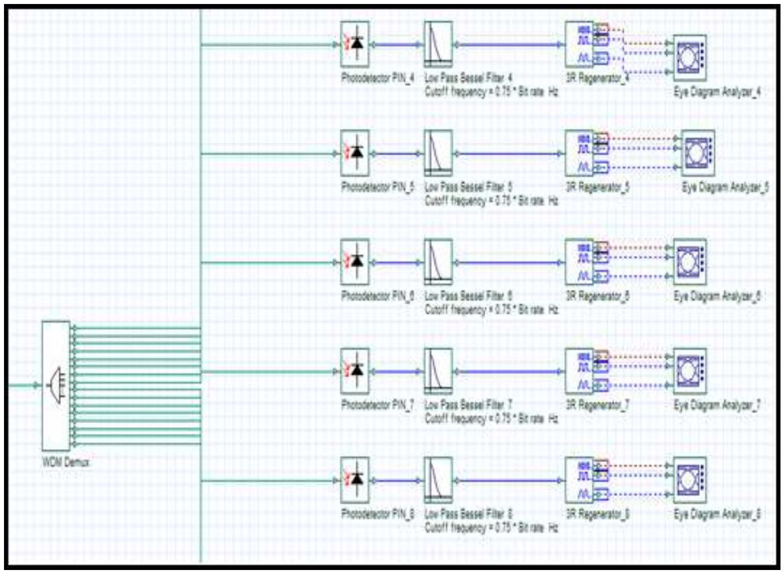


*Figure 7: Receiver Section*

The receiver section consists of same components as earlier. Only we have placed a low pass filter between PIN photodiode and the regenerator. LPF removes noise and interference from the signal. Noise is a high frequency signal and when it is passed through LPF, the distortions are removed corresponding to the frequency higher than the cut-off frequency.

**VARIATION OF EDFA LENGTH**

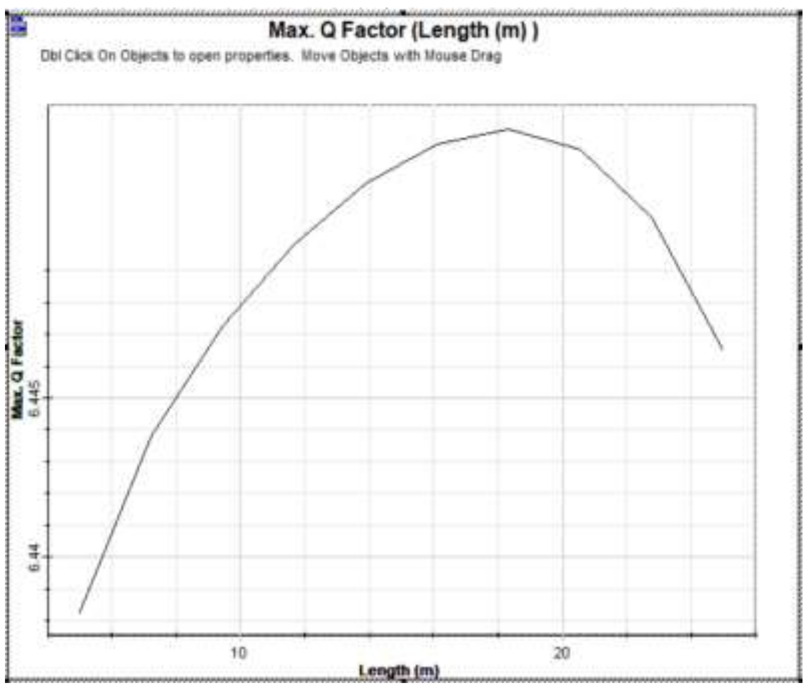


*Figure 8: Plot of EDFA length vs Q-factor*

The length of the erbium doped fiber is varied from 5 to 25 m. The Q-factor is measured by varying the length of erbium doped fiber. The optical fiber length is kept constant at 60 Km. As the erbium doped fiber length increases, the erbium ions will excite to higher evel but after reaching at certain length, the unexcited ions will cause decrease in Q-factor. The maximum Q-factor is obtained at 18 m length of amplifier. So, this is the length of erbium doped amplifier where maximum Q-factor and minimum BER is achieved.

**EYE DIAGRAM ANALYSER**

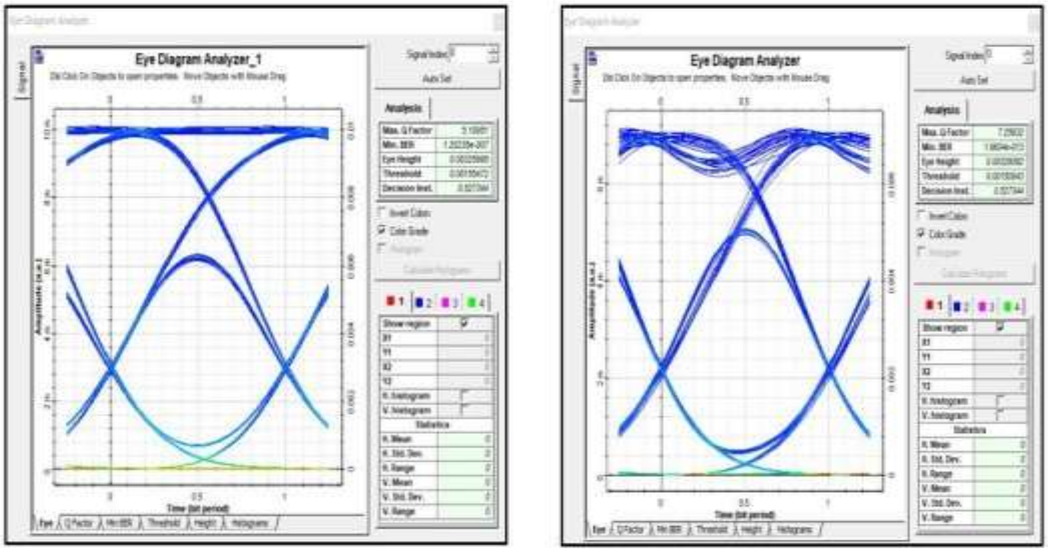


*Figure 9: Eye Diagram (NRZ & RZ)*

The two eye diagrams shown above depicts the performance of the system using NRZ and RZ coding schemes respectively. In the left eye diagram (NRZ), the quality factor came out to be around 5.1 dB and min bit error rate was 1.2x10-6. We also used RZ coding scheme and found an increase in the quality factor and bit error rate. From the eye diagram, it can be observed that the quality factor was increased to

7.25 dB and min bit error rate was 1.6x10-13. The reason for this increase is that RZ does not degrade rapidly under transmission, and it is also not as susceptible to inter-symbol interference as NRZ. The trade-off is that RZ requires more bandwidth as compared to NRZ.

**C. DUOBINARY MODULATION**

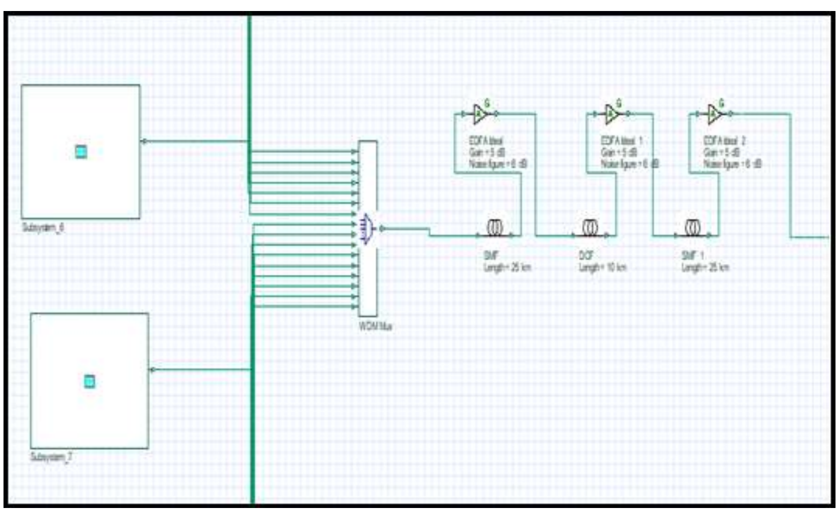

*Figure 10: Transmitter Section*

In the above simulation model, we have used duobinary modulation technique in the transmitter section. We have used this technique to enhance the performance of our system. Now in duobinary encoding, because every bit depends on its previous bit, we have increased the time period of a bit or reduced the frequency. So, the required bandwidth is half of a normal sequence. The fiber section consists of the combination of SMF-DCF-SMF as explained earlier.

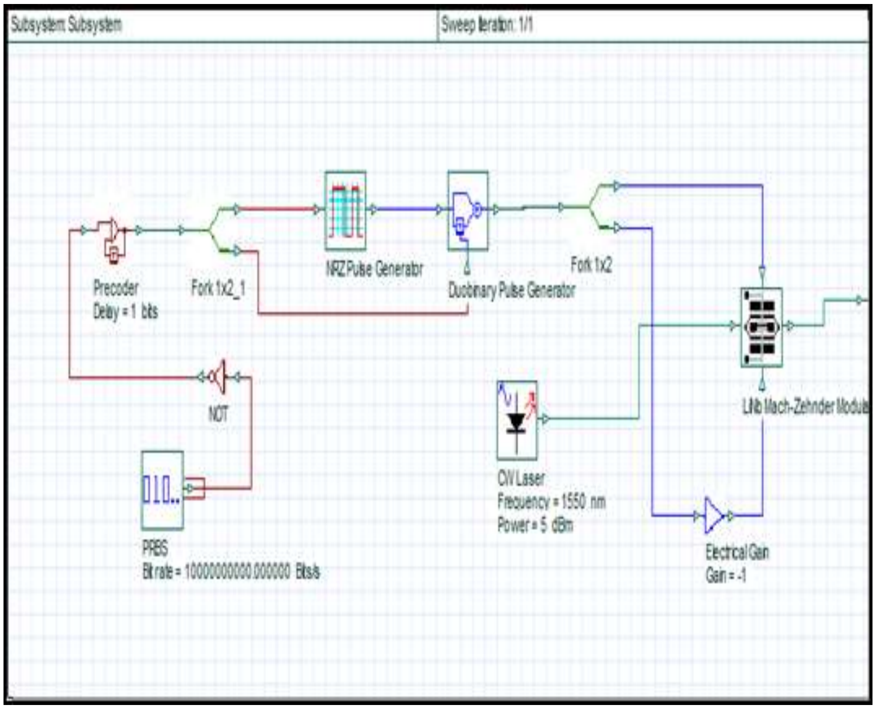


*Figure 11: Duobinary Signal Generator*

This is the duobinary signal generator. Here, we have used a pseudo random bit generator that would generate our bit sequence. First it will pass through a NOT gate. Then a precoder is used that will generate our precoded sequence. That sequence is converted into bipolar NRZ signal and the sequence is also used as a clock signal in duobinary pulse generator. At the end, we have used a LiNb Mach Zender Modulator to generate our optical signal.

**EYE DIAGRAM ANALYSER**

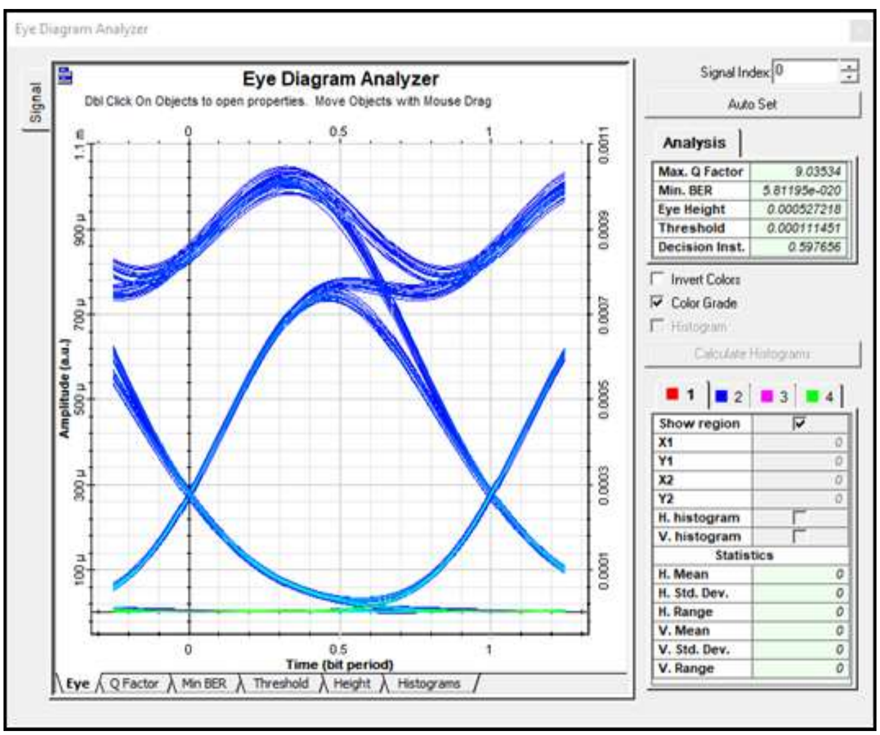


*Figure 12: Eye Diagram*

**PERFORMANCE COMPARISON**

| CODING SCHEMES | Q FACTOR | BER |
|---|---|---|
| NRZ | 5.10 | 10 e-07 |
| RZ | 7.25 | 10 e-13 |
| DUO BINARY | 9.03 | 10 e-20 |

*Table 1: Performance Comparison*

The table here shows that a duobinary encoding performs better with respect to NRZ and RZ. This is because the bandwidth used by the duobinary signal is less than that of original signal. Now as of this, the inter-symbol interference is also less. So, performance gets improved. In duobinary encoding, instead of trying to remove ISI, we introduce controlled ISI.

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