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وزارة التعليم العالي والبحث العلمي
جامعة أكلي محند أولحاج
- البويرة -

Faculté des Sciences et des Sciences Appliquées

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Title

Implementation and Simulation of DWDM Technology

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Dedication

I want to dedicate this work to my beautiful family, mom, dad, my brothers and sister, and also to my entire friend who has been there all the time. I’m so grateful to have all of you; thank you.

-Ayache Abdelbaki-

Je dédie ce modeste travail à :

Mes chers parents. Pour leur soutien, leurs sacrifices et tous ses efforts qu’ils ont fait pour mon éducation Mes sœurs. Tous mes amis. Tous ceux qui m’ont aidé pour accomplir ce mémoire. Tous les professeurs qui doivent voir dans ce travail la fierté d'un savoir bien acquis, donc un grand merci pour vous.

-Boudiaf Khalil-

Abstract

The increasing demand for communication in a limited bandwidth has led to the application of DWDM (Dense Wavelength Division Multiplexing) in different topologies or point-to-point networks. It is a technology that simultaneously transmits several information streams over long distances via a single optical fiber. It provides a cost-effective method to increase channel capacity, increasing the bit rate of existing networks without adding additional fiber and reducing the cost of fiber. In this Master project, we designed and simulated a 32-channel DWDM network to simulate the characteristics of the DWDM network. We used bit error rate (BER) as a test tool for different modulation formats using Optisystems simulation tools.

Keywords: Dense Wavelength Division Multiplexing (DWDM), BER, Optisystem.

Résumé

La demande croissante de communication dans une bande passante limitée a conduit à l'application de la DWDM (Dense Wavelength Division Multiplexing) dans différentes topologies ou réseaux point à point. C’est est une technologie qui permet la transmission simultanée de plusieurs flux d'informations sur de longues distances via une seule fibre optique. Cela offre une méthode rentable pour augmenter la capacité des canaux, ce qui à son tour augmente le débit binaire des réseaux existants sans ajouter de fibres supplémentaires, tout en réduisant également le coût de la fibre. Dans ce projet de Master, nous avons conçu et simulé un réseau DWDM à 32 canaux pour simuler les caractéristiques du réseau DWDM. Nous avons utilisé le taux d'erreur binaire (BER) comme outil de test pour différents formats de modulation en utilisant des outils de simulation Optisystems.

Mot Clé : DWDM, taux d’erreur binaire, Optisystem

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List of Abbreviations

APD:	Avalanche Photodiode Receiver
BER	Bit Error Rat
CWDM:	Coarse Wave Division Multiplexing
DCF:	Dispersion Compensating Fibers
DWDM:	Dense Wavelength Division Multiplexing
EDFA:	Erbium-Doped Fiber Amplifier
ISP:	Internet Service Provider
LAN:	Local Area Network
LD:	Laser Diode
LED:	Light-Emitting Diode
MMF:	Multi-Mode Fiber
NRZ:	No Return to Zero
OA:	Optical Amplifier
OADM:	Optical Add-Drop Multiplexer
OF:	Optical Fiber
OSNR:	Optical Signal to Noise Ratio
PDL:	Polarization Dependent Loss
PMD:	Polarization Mode Dispersion
ROADM:	Reconfigurable Optical Add-Drop Multiplexer
RZ:	Return to Zero
SMF:	Single Mode Fiber
WDM:	Wavelength Division Multiplexing

General Introduction

An optical network is a telecommunications network that uses optical fibers to transmit data through light signals. These networks are designed to provide high-performance, fast and reliable communication links for various applications, including Internet access, telephony, video streaming, and more.

DWDM (Dense Wavelength Division Multiplexing) technology has revolutionized long-haul and ultra-long-haul optical communication networks, dramatically increasing their capacity and efficiency. It is widely used in telecommunications, Internet service providers, data centers, and other applications where high-speed data transmission over long distances is critical.

The remainder of this master's dissertation is planned as follows:

The first chapter presents the theoretical background of optical networks and the transmission with optical fibers, including the components used and their roles, advantages, and disadvantages.

In the second chapter, we present the WDM Technology description, working principle and their different types. In addition, we describe the DWDM technology, stricture, and technical transmission, including its applications.

The third chapter is reserved for the simulation part. We have simulated the DWDM network with RZ (Return to Zero) and NRZ (No Return to Zero) modulation formats at a data rate of 40 Gbit/s.

Finally, the master dissertation is concluded with a general conclusion.

Chapter I: Theoretical background of optical network

I.1 Introduction

Optical networks are communication networks that use light to transmit information over long distances. Today, optical networks continue to evolve and improve new materials, such as photonic crystals, are being developed that could enable even faster and more efficient optical communication. Additionally, optical networks are being integrated with other technologies, such as wireless networks and cloud computing, to create seamless and highly responsive communication systems. In this chapter, we will present a theoretical background of optical networks.

I.2 Optical Transmission

The most straightforward optical transmission system is a point-to-point link, using a single wavelength of light travelling through an optical fiber. An upgrade to this topology uses wavelength division multiplexing (WDM) technology, which combines multiple optical wavelengths for propagation on the same physical route. Optical fiber is a type of high-speed data transmission cable made up of very thin strands of glass or plastic that can transmit digital information over long distances by converting electrical signals into light signals. These light signals travel through the fiber's core, bouncing off the walls of the cable in a process called total internal reflection, and can transmit data at very high speeds with minimal loss of signal strength [1].

I.2.1 Description of an Optical Communication System

When the input data, in the form of electrical signals, is given to the transmitter circuitry, it converts them into a light signal with the help of a light source. This source is of LED whose amplitude, frequency, and phases must remain stable and free from fluctuation for efficient transmission.

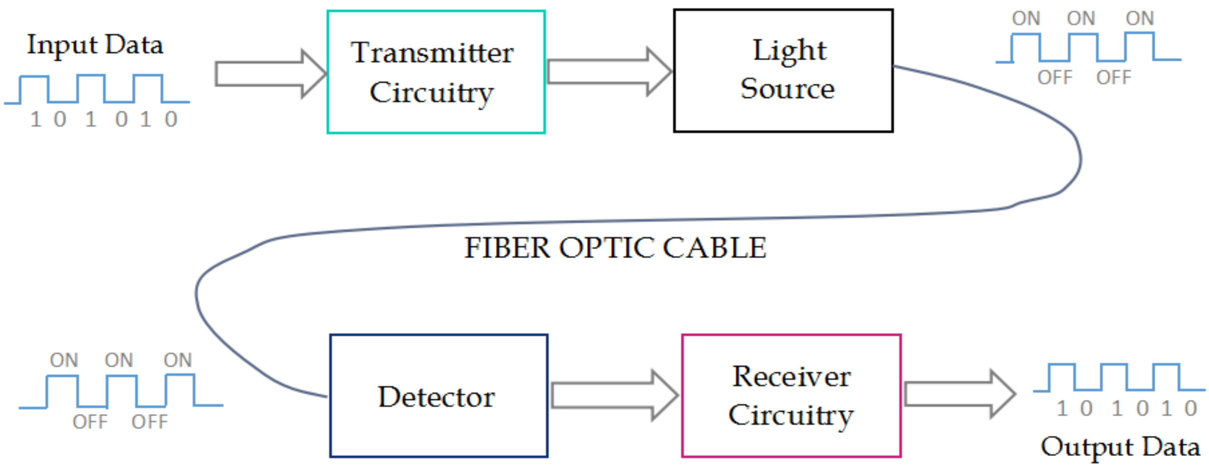


Figure I.1: Illustration of basic optical communication system

A fiber optic cable carries the light beam from the source to the destination circuitry, wherein a receiver circuit transmits the information back to the electrical signal. The receiver circuit consists of photodetector and appropriate electronics capable of measuring the light field's magnitude, frequency, and phase. The optical signal is emitted, transported, regenerated (if necessary), and detected using optical or optoelectronic components [2, 3].

I.3 Optical Fiber

An optical fiber is a dielectric waveguide made of transparent glass or plastic that can guide light along its length with minimal loss. Optical fibers are used for transmitting information in the form of light from one point to another. The information may be in voice, data, or video signals [1].

I.3.1 Principles

Optical materials are characterized by their refractive index, denoted (n). The refractive index of a material is the ratio of the speed of light in a vacuum to the speed of light in the material. When light travels from one material to another with a different index of refraction, the light bends at the interface.

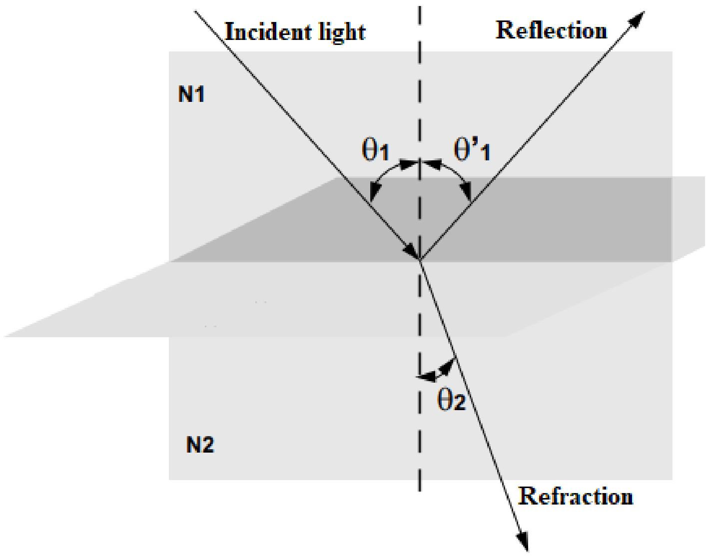


Figure I.2: Descartes Law

The refraction is described by Snell's law:

$$N_1 sin\theta_1 = N_2 sin\theta_2 \qquad \text{(I.1)}$$

Where (N_1) and ((N_2) are the refractive indices of the material through which the ray is refracted, and (θ_1) and (θ_2) are the angles of incidence and refraction of the ray. If the angle of incidence is greater than the critical angle of the interface, the light is reflected losslessly back into the incident medium by a process called total internal reflection [1].

An optical fiber transmission system implements (Figure I.3):

– A light emitter (transmitter), consisting of a LED (Light Emitting Diode) or a LASER diode (Light Amplification by Stimulated Emission of Radiation), which transforms electrical impulses into light impulses;

– A light receiver, consisting of a photodiode PIN (Positive Intrinsic Negative) which translates the light pulses into electrical signals;

– An optical fiber.

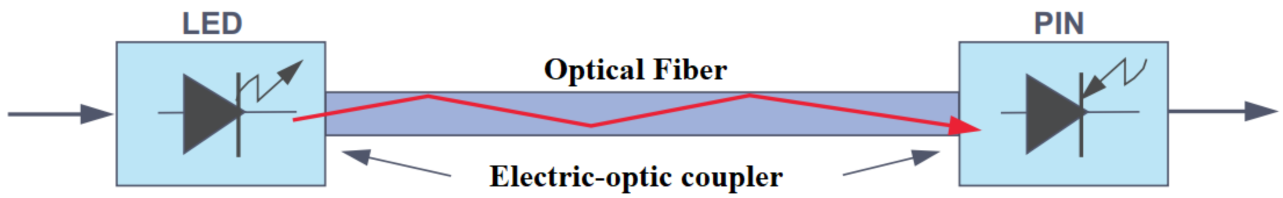


Figure I.3: Principal of an optical fiber transmission system

The power emitted by a LED is low (≈1 mW) and only a small percentage of this power is recovered in the fiber. For high-speed links, LASER diodes are preferred. The latter allow a transmission power close to 5 mW with a coupling efficiency of around 50%. A LED has a bandwidth of 100 MHz, and LASER diode allows a bandwidth of 800 MHz. For the optical fiber link, the transmission system is unidirectional. Therefore, an optical link requires the use of 2 fibers (one for the emission and the one for the reception).

I.3.2 Optical Fiber Types

We can classify the optical fibers on two categories: Single-mode fiber (SMF) and Multimode fiber (MMF).

I.3.2.1 Single-mode Fiber

Single-mode fiber has a smaller core than multimode fiber, allowing only one mode of light to pass through. This type has the lowest signal attenuation due to less reflection of light and the light can travel farther. It connects to single-mode optics that use laser light as a light source, and sends a single wavelength in a straight line along an optical fiber. It still has the same 125 µm cladding as multimode fiber, but the core is typically 8 to 10 µm thick instead of 50 µm or thicker. Single-mode fiber has higher bandwidth and is the most suitable type of fiber for long-distance networks. It also comes in several types, optimized for different areas in the fiber [2,1].

I.3.2.2 Multimode Fiber

Multimode fiber has a relatively large core diameter, typically between 50 and 100 microns. They allow multiple modes of light to propagate through the fiber simultaneously, with each mode taking a slightly different path due to the different refractive indices of the core and cladding. This causes scattering, which limits how far a signal can travel without significant attenuation. Multimode fiber is commonly used in short-distance communication systems such as local area networks (LANs) and data centers, also there are two types of multimode fiber.

I.4 Comparison between different optical fibers

Fiber optic cables are used in a variety of applications to transmit data and signals over long distances. Although there are different types of fiber, the most commonly used are single-mode fiber (SMF) and multimode fiber (MMF). Here's a comparison of the two types:

Fiber Type	Bandwidth	Advantages	Disadvantages
Single Mode	100 GHz-Km	-Faster than multimode over long distance. - Single-mode cable and connectors are generally less expensive than multimode.	- Single-mode solutions are often more expensive to deploy and operate since laser-based equipment generate more heat.
Graded Index	500 MHz-km at 1300 nm 160 MHz-km at 850 nm	-Lower operating, installation and maintenance costs for multimode cables -High speed and high bandwidth over a short distance -Simultaneous transmission of multiple optical signals in allowed mode	- Multimode cables are more limited in both speed and distance
Step Index	20 MHz-km	-Easy to manufacture -Cheaper compared to the graded index -Less Attenuation	-Interfacing module is more expensive -High directive light source is required

Table I.1: Comparison between different optical fibers

The attenuation (or loss) of optical fibers is determined by a combination of intrinsic and extrinsic factors, including absorption, scattering, and bending losses, total attenuation is the sum of all losses, Optical losses of fiber are expressed in (db/Km), and the expression is called the Fiber's attenuation coefficient α

$$\alpha = -\frac{10}{z[\mathrm{km}]}\log\left(\frac{P(z)}{P(0)}\right) \qquad \text{(I.2)}$$

The exact value of the attenuation coefficient depends on several factors such as the wavelength of the light used, the type of fiber, and the length of the fiber. For example, for a single-mode fiber operating at a wavelength of 1550 nm, the overall attenuation coefficient is typically about 0.2 dB/km. For multimode fiber, the attenuation factor can be higher, typically in the range of 2 to 4 dB/km [1].

I.5 Interactions Between light and matter

The five most important different interactions between light and matter are:

I.5.1 Absorption

This is the process by which a material absorbs light energy and converts it into another form of energy, such as heat. The absorbed energy moves the electrons in the material to a higher energy level, and the energy difference between the levels corresponds to the energy of the absorbed light.

I.5.2 Reflection

This is the process of redirecting light when it hits an impenetrable surface. The angle of incidence of the incoming light wave is equal to the angle of reflection of the outgoing light wave.

I.5.3 Refraction

This is the bending of light as it travels from one medium to another with a different index of refraction. The amount of bending depends on the angle of incidence and the refractive indices of the two media.

I.5.4 Scattering

This is the process by which light is redirected in many different directions when it interacts with small particles or irregularities in a material. Scattering causes light to become diffuse or lose intensity.

I.5.5 Emission (diffraction)

This is the process by which a material emits light energy in response to an external stimulus.

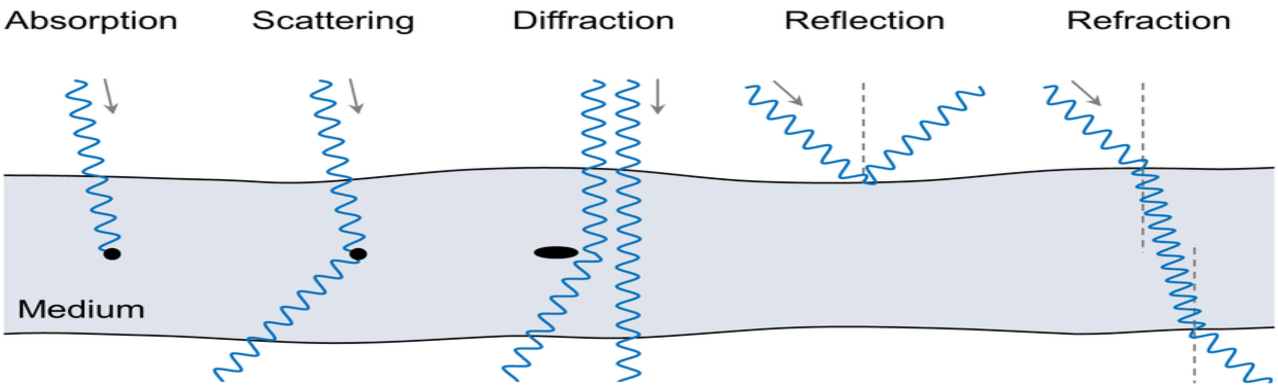


Figure I.4: Basic interactions between light and matte

I.6 Advantages of optical fiber

- Higher bandwidth than copper
- Less power loss, allowing data transmission over longer distances
- Optical cable anti-electromagnetic interference
- The size of the optical cable is 4.5 times that of the copper wire,
- These cables are lighter, thinner and take up less space than metal wires.
- Installation is very easy due to its light weight.
- Fiber optic cable is difficult to tap because it produces no electromagnetic energy. These cables are very secure when carrying or transferring data.
- Fiber optic cables are very flexible, bend easily, and withstand most acidic elements that come into contact with copper wires.

I.7 Disadvantages of optical fiber

- Fiber optic cables are very difficult to connect and there is beam loss within the cable during scattering.
- Installing these cables is not expensive. They are not as strong as wires. Fiber optics often require special test equipment.
- Optical cables are compact and very fragile during assembly
- These cables are more fragile than copper wire.
- Testing the transmission of fiber optic cables requires special equipment.

I.8 Application of Optical Networks (OF)

- Internet

- Computer Networking
- Medical Applications
- Automotive Industry
- Telephone

I.9 Conclusion

An optical network is a communication network that uses optical fibers to transmit data over long distances at high speeds. They have become integral to modern communications, enabling high-bandwidth services. They also have lower power consumption, less electromagnetic interference, and are immune to hacking. An optical network consists of several key components, including optical fibers, optical amplifiers, and optical transceivers. In this chapter, we have presented the theoretical background of optical network. In the next chapter, the DWDM multiplexing technology will be presented.

Chapter II: DWDM Multiplexing Technology

II.1 Introduction

Telecommunication has come a long way over the past century, transforming the way we communicate with each other and enabling us to connect with people and information from all corners of the world. However, the development of DWDM technology helped to overcome many of challenges, enabling faster, more efficient, and more cost-effective communication over long distances. In this chapter, we will present the DWDM multiplexing technology.

II.2 Principle of WDM

The WDM (Wavelength Division Multiplexing) technology implements wavelength division multiplexing. The idea is to simultaneously inject multiple trains of digital signals on distinct wavelengths into an optical fiber, WDM consists of dividing the optical spectrum into several sub-channels, each sub-channel being associated with a wavelength. The optical fiber is well suited for this type of use because its bandwidth is very high: of the order of 25,000 GHz. Therefore, it has a high potential for multiplexing many channels over long distances [6].

II.3 Operational Principle of WDM

The WDM technology is represented by two terminals and a single mode optical link connecting them. The first is a multiplexer and the second is a demultiplexer. The role of the multiplexer is to change the wavelengths of the incoming signals and multiplex them onto a single channel. To change the incoming wavelengths, it is necessary to use a transponder.

When the signals arrive at the multiplexer, they may have the same wavelength, even if the emitter is different. Since it is not possible to send the same wavelength twice on the same link, risking to corrupt the information of both signals, the transponder will take charge of the wavelength of one of the two signals. Thus, each incoming stream will be coded onto a carrier by amplitude or phase modulation. This makes it possible to broadcast signals from different sources and having identical wavelengths on the same channel. Upon reaching the demultiplexer, it will act as a set of filters in certain wavelength zones, knowing the wavelengths circulating in the optical link. It can recover the entirety of a signal that had been multiplexed [7].

II.4 Components used in WDM system

A WDM system comprises several key components that work together to enable the transmission and reception of these multiple channels of data. Each of these components plays a critical role in the overall functioning of the WDM system, enabling it to transmit large amounts of data over long distances with high efficiency and minimal signal loss. These components include optical transceiver, amplifiers, multiplexers/demultiplexers, optical filters, optical fiber, optical receivers.

II.4.1 Optical transceiver

Optical transmitters play a crucial role in DWDM systems as they generate the source signals that are then combined. The quality and characteristics of these transmitters have a significant impact on system design, and multiple transmitters are used as light sources in a DWDM system. These transmitters are modulated by incoming electrical data bits (0 or 1), where a flash of light represents 1, and the absence of light represents 0. Lasers generate light pulses with a specific wavelength, measured in nanometers (nm), and these pulses are sent to a physical layer device that converts the digital information into a light source that can be transmitted over a fiber optic cable. The E-O conversion process converts the digital signal from electrical to optical form, without affecting the format of the underlying digital signal. The light pulses travel through the optical fiber using total internal reflection, and at the receiving end, an optical sensor (photodiode) detects the pulses and converts them back to electrical form. Each device is connected by a pair of fibers (one transmits fiber and one receive fiber) in most cases.

II.4.2 Optical amplifier

Optical amplifiers (OAs) are devices that increase the amplitude or gain of optical signals as they travel through a fiber. OAs directly stimulate the photons of the signal with additional energy, and they are located within the fiber itself. They can amplify optical signals across a wide range of wavelengths, which is crucial for the effective functioning of DWDM systems. Erbium-doped fiber amplifiers (EDFAs) are the most commonly used type of in-fiber optical amplifier.

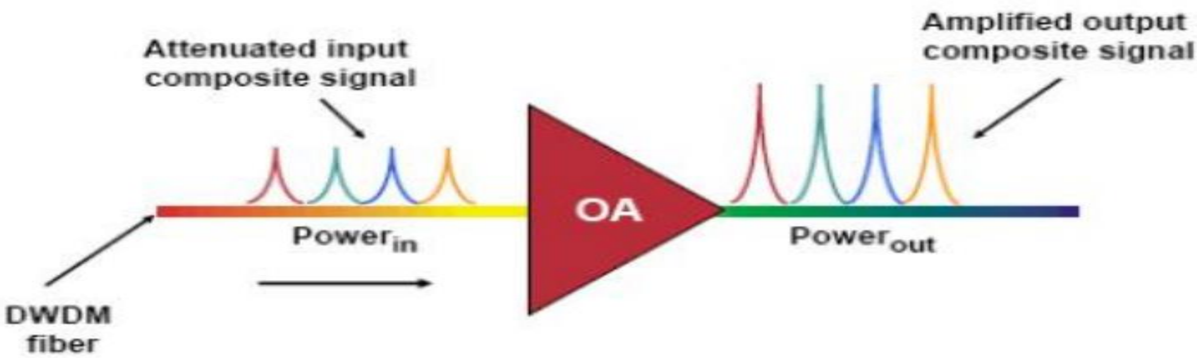


Figure II.1: Optical Transceiver

II.4.3 Multiplexer/Demultiplexer

In DWDM systems, multiple transmitters create signals of different wavelengths within the 1550 nm band, and these signals are carried by separate fibers. An optical filter, known as a multiplexer filter, combines these signals onto a single fiber to create a composite signal. At the receiving end, an optical drop filter, or demultiplexer, separates the individual wavelengths of the composite signal onto separate fibers. These fibers then transmit the demultiplexed wavelengths to optical receivers.

Typically, the multiplexer and demultiplexer components are contained within the same enclosure, and they can be passive, meaning no external power source is required since the signals are multiplexed and demultiplexed optically rather than electronically. The block diagram in figure 2 illustrates bidirectional DWDM operation, where N light pulses of N different wavelengths carried by N different fibers are combined by a DWDM multiplexer and then transmitted onto a pair of optical fibers. A DWDM demultiplexer receives the composite signal and separates each of the N component signals, passing each to a fiber. The transmitted and received signal arrows in the diagram represent the client-side equipment, which requires the use of a pair of optical fibers for transmission and reception.

II.4.4 Optical fiber

The optical fiber is made of 3 concentric layers [1]:

- Core: The central part of silica or doped silica is the light-transmitting region fiber.

- The cladding: It is the layer surrounding the core and is composed of silica, but with a different composition than the core. It forms an optical waveguide that confines the light to the core through total internal reflection at the core-cladding boundary.

- The coating: which is the outermost layer surrounding the cladding, consists of one or more polymer layers that safeguard the silica structure from physical or environmental damage. When the fiber is connectorized or fusion spliced, the coating is removed.

II.4.5 Optical filters

An optical filter is a device that selectively allows transmission or blocks a range of wavelengths. Optical filters are usually bandpass or bandstop filters (see figure below). Bandpass filters pass a specific range of light wavelengths and attenuate the rest (left), while bandstop filters attenuate a band of light wavelengths and pass others (right) [9].

II.4.6 Optical receiver

An optical receiver is a device used in fiber-optic communications to convert optical signals to electrical signals. The receiver consists of photodetector and associated electronics that amplify and convert the electrical signal to a usable form. The receiver's performance is characterized by its sensitivity, which is the minimum optical power required for the receiver to detect and correctly interpret an optical signal [1].

II.5 Topologies and Protection Schemas for DWDM

Network architecture is based on many factors, including types of applications and protocols, distance, usage and access patterns, and traditional network topology. For example, in the metro market, point-to-point topologies can be used to connect corporate sites, ring topologies can be used to connect inter-office facilities (IOF) and home access, and mesh topologies can be used for inter-POP connections and as connections to long-haul backbones. In fact, the optical layer must be able to support multiple topologies, and due to unpredictable developments in the field, these topologies must be flexible [10].

II.5.1 Point-to-Point Topologies

In a point-to-point topology, the optical signal travels in only one direction from the source node to the destination node, and no intermediate wavelength routing or switching is required. Communication links are typically established using a pair of optical transceivers, which convert electrical signals into optical signals for transmission over the fiber optic link, Overall, point-to-point topologies in DWDM offer a simple and efficient way to establish high-bandwidth communication links between two locations with minimal latency and signal loss [10].

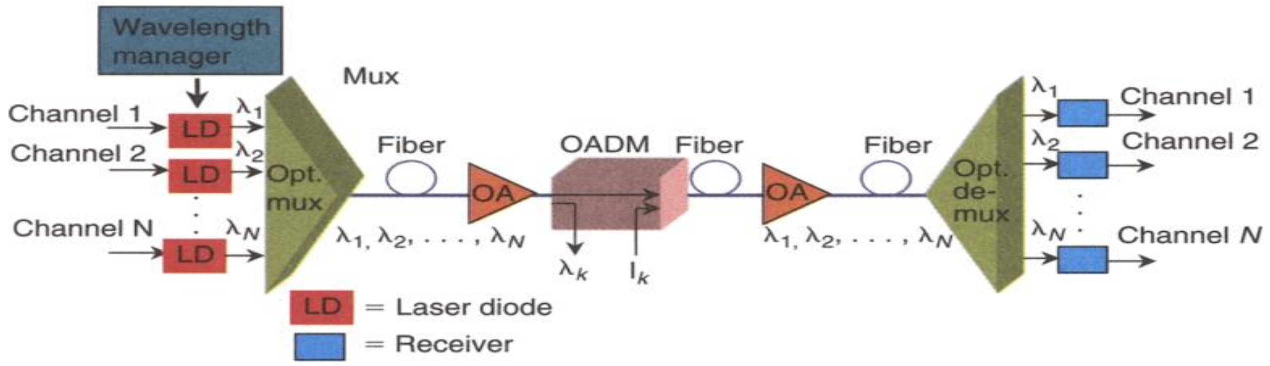


Figure II.2: Point-to-Point Architecture

II.5.2 Ring Topologies

Ring topology in DWDM offers several advantages such as: Fault tolerance and the ability to easily add or remove nodes from the network. In a ring topology, if a node or link fails, signals can be automatically rerouted around the ring in the opposite direction to reach the destination node, ensuring continuous communication between nodes. Additionally, the ring topology enables efficient wavelength sharing among multiple nodes, as each node can use the same wavelength to transmit and receive data. However, a potential disadvantage of ring topologies is that they may introduce additional latency and signal loss compared to point-to-point topologies, since the optical signal must traverse the entire ring before reaching its destination [10].

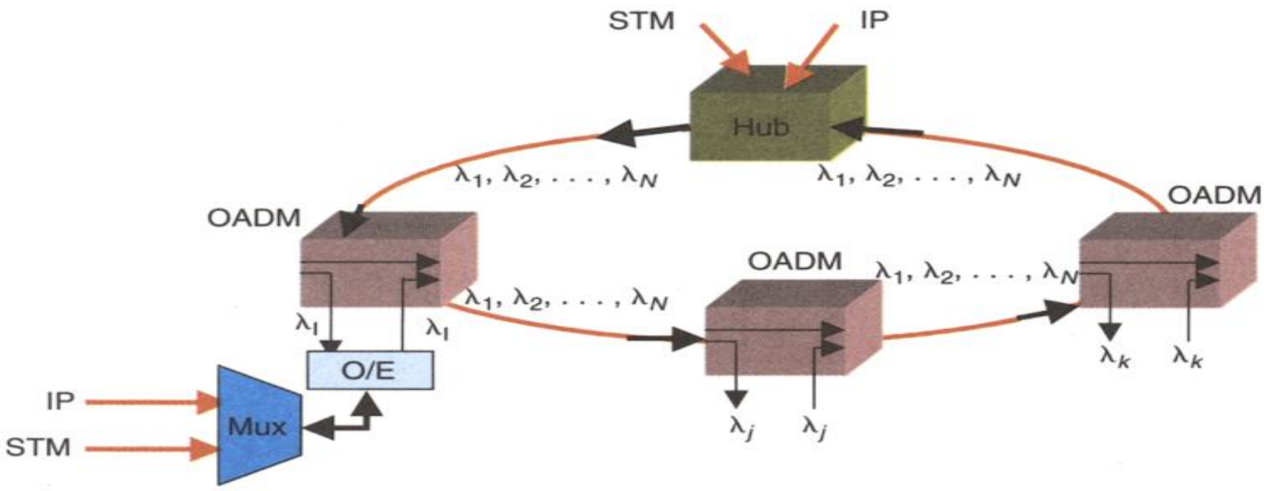


Figure II.3: Ring Topologie

II.5.3 Mesh Topologies

In a mesh topology, each node is connected to multiple other nodes, and a signal can have multiple paths to travel from a source node to a destination node. This enables efficient load balancing and fault tolerance, as well as the ability to dynamically reconfigure the network to optimize performance or respond to changing traffic patterns, However, mesh topologies can be more complex to set up and maintain than ring or point-to-point topologies, requiring more sophisticated routing algorithms and controls to manage network traffic and ensure optimal performance. Additionally, using multiple paths for signal transmission results in additional latency and signal loss compared to simpler topologies [10].

II.6 Different technology WDM

There are several types of WDM, including coarse wavelength division multiplexing (CWDM), dense wavelength division multiplexing (DWDM), and wideband wavelength division multiplexing

(WWDM), which differ in the spacing between wavelengths and the number of channels that can be transmitted simultaneously. WDM systems require complex components and techniques to transmit, receive and process optical signals, including lasers, modulators, detectors, amplifiers and multiplexers/demultiplexers.

WDM technology continues to evolve, with ongoing research focused on developing new technologies to increase capacity and reduce costs. Recent innovations include the use of advanced modulation formats, such as quadrature amplitude modulation (QAM), and the development of new materials and structures for optical components [5].

II.6.1 CWDM (Coarse Wave Division Multiplexing)

CWDM is a WDM technology that uses relatively large spacing between wavelengths to allow the use of simpler and less expensive components such as cheaper lasers and detectors. Typically, CWDM operates in the wavelength range of 1270 to 1610 nm, with approximately 20 nm between wavelengths.

The basic principle of CWDM is to combine multiple optical signals on a single optical fiber by transmitting each signal at a different wavelength. This is done with multiplexers, which combine different signals on a single fiber by transmitting each signal at a different wavelength. On the receiving end, a demultiplexer separates the different wavelengths and forwards each signal to the appropriate receiver [1].

II.6.1.1 Benefits of CWDM

- Passive equipment that uses no electrical power
- Extended Temperature Range
- Protocol transparent
- Simple to install and use

II.6.2 DWDM (Dense Wavelength Division Multiplexing)

Dense Wavelength Division Multiplexing (DWDM) is a technology used in fiber optic networks to increase the amount of data that can be transmitted over a single fiber by using different wavelengths of light to transmit multiple signals simultaneously. With DWDM, individual signals are combined into a single optical signal and transmitted over optical fiber. At the receiving end, the optical signal is demultiplexed into its individual components by a demultiplexer. DWDM is the key technology to realize long-distance high-speed data transmission through optical fiber network [11].

II.6.2.1 Benefits of DWDM

- Increased bandwidth utilization
- Network flexibility
- Cost-effective long-distance

II.6.3 OADM (Optical Add-Drop Multiplexer)

OADM is a passive optical device with one or more wavelengths (or channels), from the optical network WDM. OADM is usually used to drop local channels from high -speed and fast channels, or insert new channels into existing networks [1].

II.6.4 ROADM (Reconfigurable Optical Add-Drop Multiplexer)

ROADM is an extended version of OADM, which can achieve dynamic and software -based loading process control. ROADM can add or delete wavelengths or channels in the network without having to destroy other channels. This makes it possible to create a complicated, outdated network, and can easily re -consider to meet the changing traffic requirements [1].

II.7 Comparison between CWDM & DWDM

There is three point of difference we can compare the two of them:

II.7.1 Wavelength Spacing

One of the main differences between CWDM and DWDM is the spacing between the wavelengths used to carry the different signals. In CWDM, the wavelength spacing is 20 nm, while in DWDM, the wavelength spacing is 0.8 nm or less. This means that DWDM can support many more channels than CWDM.

II.7.2 Number of channels

Another difference between CWDM and DWDM is the number of channels that can be supported. CWDM typically supports up to 18 channels, while DWDM can support hundreds or more.

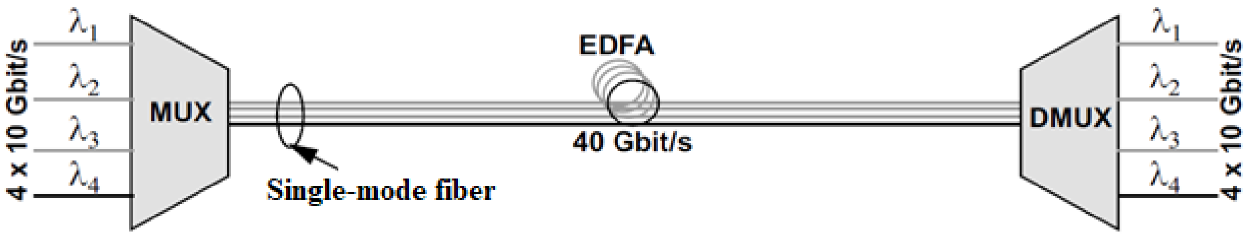
II.7.3 Transmission distance

The transmission distance supported by CWDM is usually shorter than that supported by DWDM because CWDM uses a longer wavelength separation. However, CWDM is generally less expensive for shorter distance applications, while DWDM is better for long distance transmission. The main difference between CWDM and DWDM is the spacing between the wavelengths used to transmit the various signals, with DWDM providing closer spacing and thus a higher number of channels and longer transmission distances. However, CWDM may be a more cost-effective solution for short-range applications [1].

II.8 DWDM Network

II.8.1 Principle and architecture

Dense Wavelength Division Multiplexing (DWDM) is a technology that allows multiple optical signals to be transmitted simultaneously over a single optical fiber. This is achieved by using different wavelengths of light to transmit different data streams. Each data stream is modulated onto a different wavelength, then combined with other wavelengths and transmitted over the same fiber. The appearance of DWDM systems illustrated in Figure (II.4) allows up to 128 communication channels to be arranged on a single fiber. Erbium-doped optical amplifiers (EDFA, Erbium Doped Fiber Amplifier) compensate for insertion losses due to multiplexing and demultiplexing



operations.

Figure II.4: Principal of DWDM link.

The principle behind DWDM is based on the fact that light of different wavelengths can travel through optical fibers with different degrees of attenuation. Attenuation is the loss of signal strength that occurs as light travels through an optical fiber. Light of different wavelengths undergoes different degrees of attenuation, depending on the properties of the fiber. DWDM takes advantage of this property by selecting wavelengths with little attenuation and using them to transmit data. By using a large number of closely spaced wavelengths, DWDM can transmit large amounts of data over a single fiber. In fact, DWDM can support up to 80 lanes (or more) on a single fiber, each lane running at 10 Gbit/s or higher. Key components of a DWDM system include transmitters, multiplexers, optical amplifiers and receivers. The transmitter is responsible for converting electrical signals to optical signals and modulating them to the appropriate wavelength. A multiplexer combines the different wavelengths into one optical signal, which is then transmitted along the fiber. An optical amplifier increases the strength of the optical signal to overcome attenuation losses, and a receiver converts the optical signal back into an electrical signal [11].

II.8.2 DWDM Transmission Technique

DWDM transmission technology is related to the method of encoding and modulating data transmitted by DWDM network transmission. These technologies are important to achieve high data rates and effectively use bandwidth on fiber. The most important transmission technology used in DWDM networks includes:

II.8.2.1 Coherent detection

This technology uses a local oscillator to create a reference signal. The reference signal is mixed with the transmitted optical signal to extract phase and amplitude information. Coherent detection is usually used in high -capacity long -distance networks, where the signal scanning is improved and the transmission distance is increased.

II.8.2.2 Optical modulation format

These are related to how to encode data to a specific option of optical signals. Frequent modulation formats include an amplitude offset (ASK), frequency shift (FSK) and phase shift (PSK). The selection of the modulation format depends on the required data rate, transmission distance and available optical properties.

II.8.2.3 Dispersion compensation

This involves the use of fiber with specific color dispersion characteristics to compensate the decentralized body caused by the fiber itself and other components in the network. Color compensation can improve the quality of optical signals and increase transmission distance.

In general, the selection and implementation of appropriate transmission technology depends on the specific requirements of the network, such as Data rate, transmission distance and available optical properties [1].

II.8.3 Advantages and Disadvantages of DWDM technology

The advantage of DWDM:

- **High capacity**: DWDM can spread several wavelengths (or colors) of light (or color) on a single fiber, which significantly increases the capacity of the network.
- **Effective use of fiber**: DWDM can effectively use existing fiber iron by increasing the ability of each fiber chain.
- **Flexibility**: The configuration method of the DWDM system can support extensive data rates and protocols.
- **Long -distance transmission**: DWDM can transmit data at a large distance at a minimum signal, which is particularly useful for long -distance telecommunications.

II.8.4 Disadvantages of DWDM

- **Cost**: Because special equipment and components are required, the implementation of the DWDM system may be expensive.
- **Complexity**: DWDM system may be complicated when designing, installation and waiting, especially data rates and longer distances.
- **Strengthen and decentralized management**: DWDM signals may be weakened by signals and scattered, which requires careful management through enhanced and decentralized compensation technology.

II.9 Application of DWDM Technology

DWDM technology has a variety of uses in modern communication networks, because large amounts of data can be transmitted through large -scale routes with high width efficiency. Some of the most important applications of DWDM technology include:

- **High -speed data transmission**: DWDM is used in the communication network to transmit high -speed data in a large distance. It can be used to transmit data between data centers, metropolis and even continents.
- **Internet backbone**: DWDM is often used on the Internet main trunk. This is the core network that connects the Internet service provider (ISP) and realizes the global exchange of Internet traffic.
- **Cable TV**: DWDM technology is used in cable networks, and multiple high -resolution video channels are transmitted through single fiber -fiber cables.
- **Telephone network**: DWDM is used in the telephone network to carry a lot of voice traffic between different positions.
- **Military communication**: DWDM is used in a military communication network to make high -speed data transmission at a large distance.
- **Scientific research**: DWDM is also used in scientific research, especially in the field of astronomy. In the field of astronomy, it is used to transmit high -quality astronomical data at the main distance [1].

II.10 Conclusion

DWDM is a powerful technology that can be transmitted high-speed data at a considerable distance. It provides several advantages over other technologies, such as lower cost, higher ability, and greater flexibility. DWDM can support high-speed data transmission. DWDM is a reliable and effective multiplexing technology essential for modern communication networks. Its ability to provide high-capacity, long-distance transmission makes it a key enabler for the digital future. In this chapter, we have presented the DWDM multiplexing technology. The next chapter is the simulation part. It is reserved for the simulation of the DWDM network.

Chapter III: Simulation with Optisystem

III.1 Introduction

DWDM systems have significant advantages in terms of increased transmission capacity and scalability. OptiSystem offers a comprehensive set of tools and components tailored specifically for DWDM applications. Users can create virtual optical networks by combining transmitters, receivers, multiplexers, demultiplexers, optical amplifiers, and optical fibers. OptiSystem allows users to configure and customize the properties of each element in the DWDM system. Based on the OptiSystem, we will simulate the DWDM channel network in this chapter.

III.2 Presentation of OptiSystem

OptiSystem is a powerful software tool for the design, analysis and simulation of optical communication systems. It provides an easy-to-use graphical interface that allows users to build complex optical networks by connecting and configuring various components such as transmitters, receivers, optical fibers, amplifiers, and signal processing elements. With OptiSystem, users can simulate and evaluate the performance of their optical systems, analyze parameters such as performance, signal quality and bit error rate, and gain insight into network behavior. It is a valuable tool for researchers, engineers and students working in photonics and telecommunications.

III.3 OptiSystem Application

There is a wide range of application in the field of optical communications and photonics like:

- **Optical Network Design:** OptiSystem is used to design and optimize optical network architectures, including long-haul and ultra-long-haul systems, metro and access networks. It allows engineers to study different network topologies, evaluate system performance and optimize parameters such as signal quality, power budget and dispersion.
- **Wavelength Division Multiplexing (WDM) Systems**: OptiSystem is widely used to design and simulate WDM systems, including Dense Wavelength Division Multiplexing (DWDM) and Coarse Wavelength Division Multiplexing (CWDM) systems. It allows users to study channel spacing, spectral efficiency, crosstalk and other performance parameters of WDM systems.
- **Fiber optic communication systems**: OptiSystem is used to analyze and optimize fiber optic communication systems, including fiber optic links, dispersion compensation, and fiber optic amplification. It allows users to evaluate system performance in terms of signal quality, attenuation, dispersion and nonlinear effects [11].

III.4 OptiSystem Interface

The Interface is designed to be intuitive and easy to navigate, allowing users to efficiently build and configure their optical networks, the principal window contain many parts (Figure III.1):

- Library
- Layout
- Description Layout
- Project browser

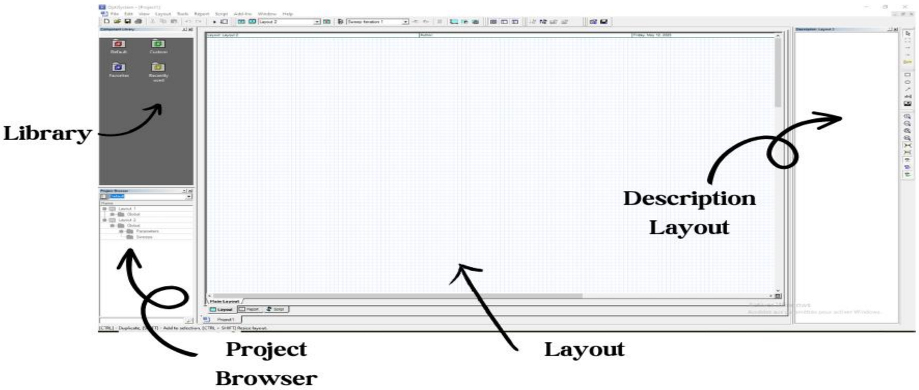


Figure III.1: OptiSystem Interface

III.4.1 Library

The OptiSystem Component Library includes hundreds of components that enable you to enter parameters that can be measured from real devices. It integrates with test and measurement equipment from different vendors. Users can incorporate new components based on subsystems and user-defined libraries, or utilize co-simulation with a third part tool such as MATLAB or SPICE.

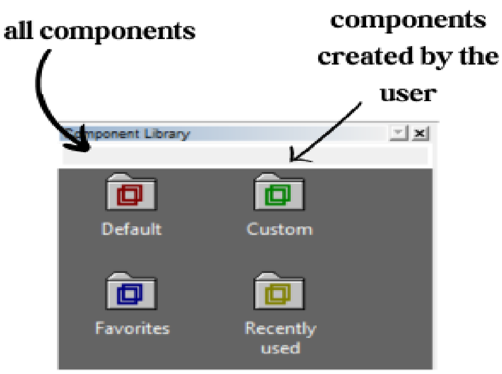


Figure III.2: Component Library

III.4.2 Project Browser

In this window we can see all our component that we use in our project, the window used to display the contents.

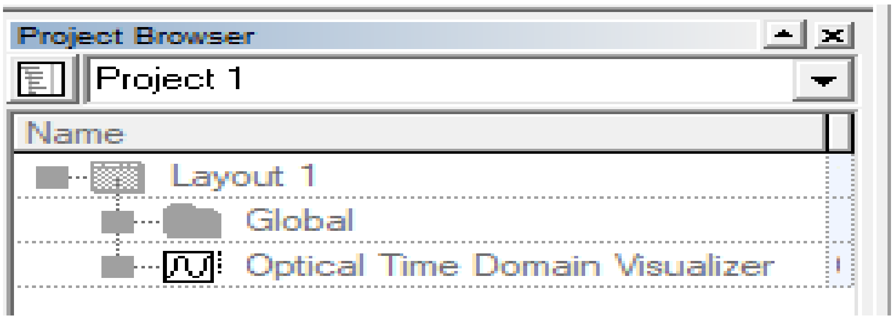


Figure III.3: Project Browser

III.5 Components used for an Optical Transmission

In this part, we want to display all the components that we use in our Optical transmission, and only for our simulation that we want to create.

III.5.1 WDM transmitter

We use WDM transmitter for multiplexing multiple optical signals onto a signal optical fiber for high-capacity data transmission, it combines and modulates different wavelengths of light to carry multiple data streams simultaneously.

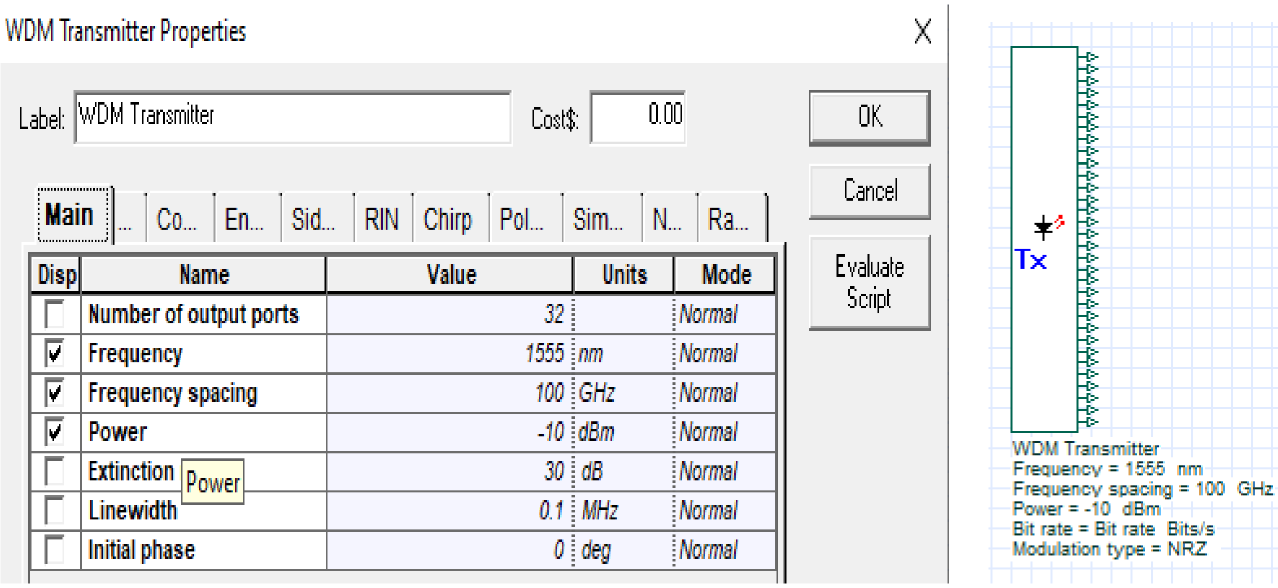


Figure III.4: WDM Parameter

The ideal mux multiplexes a user defined number of inputs WDM signal channels. This model is equivalent to an ideal adder since there is no power splitting and filtering. The Optical Fiber (SMF) is presented in the following figure.

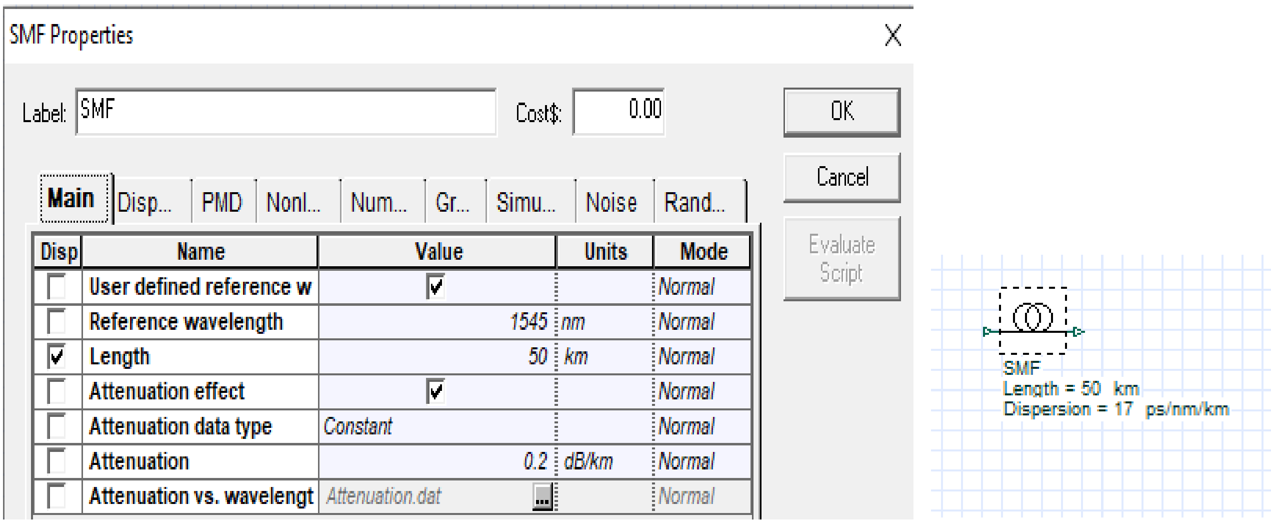


Figure III.5: SMF Parameter

III.5.2 Optical Fiber (DCF)

The role of DCF is to mitigate the effects of dispersion in optical communication systems, ensuring improved signal quality and longer transmission distances.

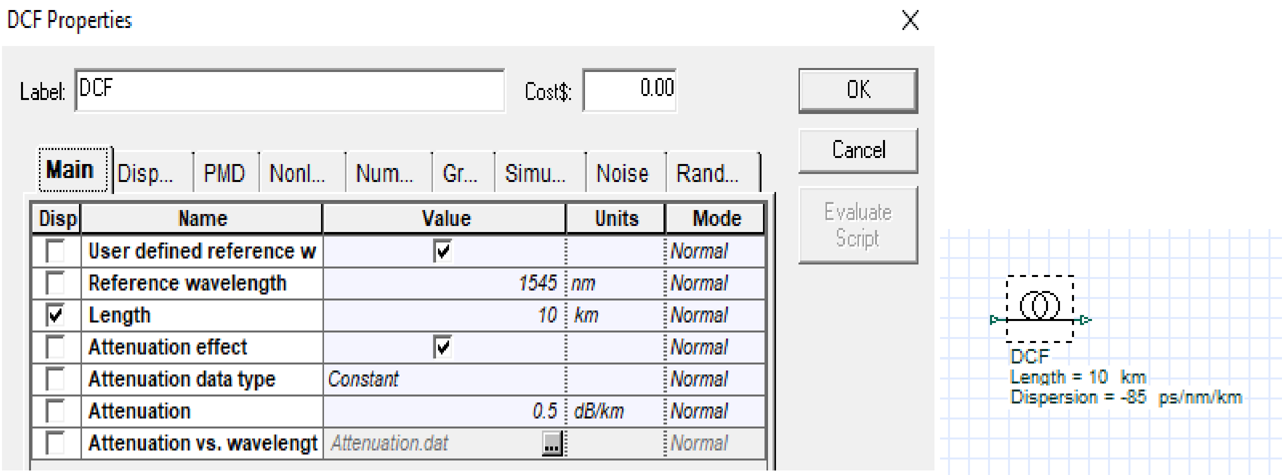


Figure III.6: DCF Parameter

III.5.3 Erbium Doped Fiber Amplifier (EDFA)

The Erbium Doped Fiber Amplifier (EDFA) in OptiSystem is used to amplify optical signals in fiber optic communication systems and provide high power amplification for long distance transmission without electrical/optical conversion.

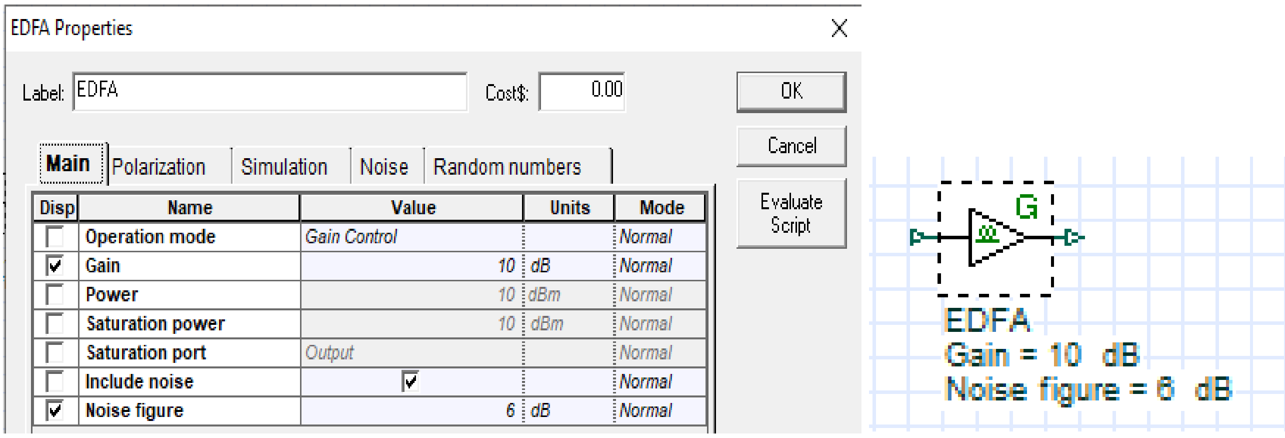


Figure III.7: EDFA Parameter

III.5.4 Loop Control

The role of loop control in OptiSystem is to provide a mechanism to implement feedback control loops in optical communication systems, allowing dynamic adjustment of system parameters to optimize performance, such as: Power level, modulation format or equalization settings.

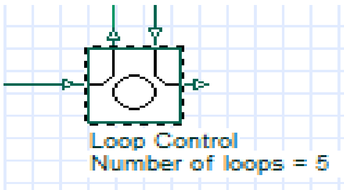


Figure III.8: Loop Control

III.5.5 WDM DE-multiplexer

This Component used for wavelength division multiplexing and demultiplexing, separating optical signals of multiple wavelengths into separate channels. It enables efficient optical communication and signal processing in multi-channel systems.

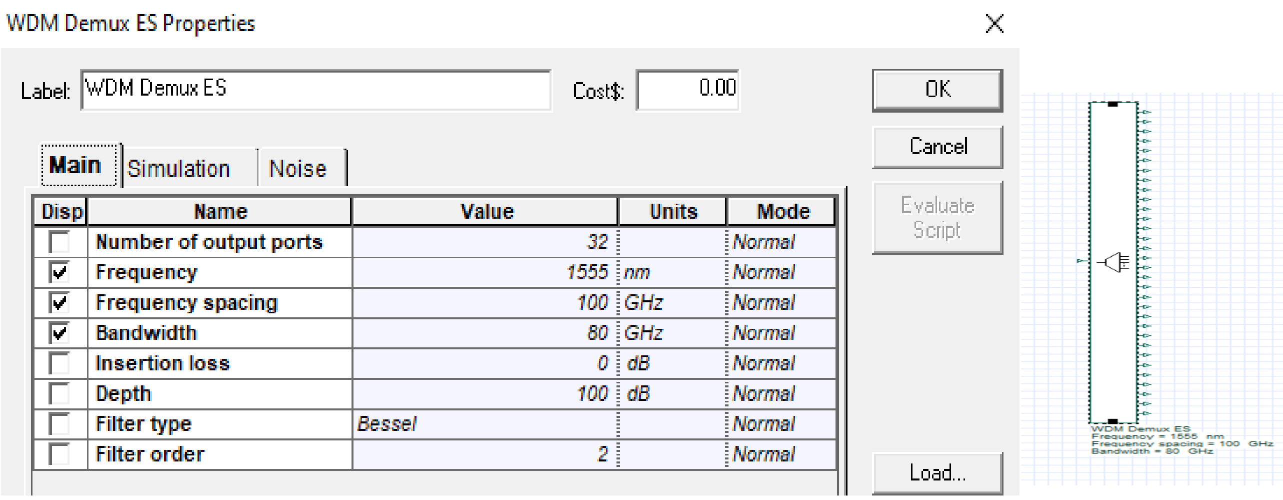


Figure III.9: WDM DEMUX Parameter

III.5.6 Optical Receiver

The role of the optical receiver is to convert the optical signal received at the output end of the optical fiber back into the original electrical signal.

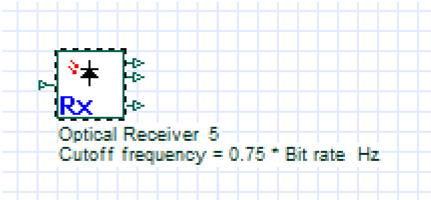


Figure III.10: Optical Receiver

The BER analyzer and Optical Spectrum Analyzer are given in the below figure.

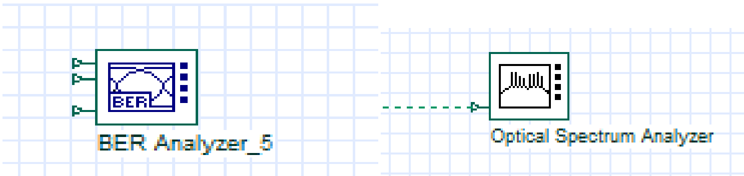


Figure III.11: BER and Optical Spectrum Analyzers.

III.5.7 WDM Analyzer

This Component is used to analyze power spectral density, channel power, channel spacing and optical signal-to-noise ratio (OSNR) in wavelength division multiplexing (WDM) systems, helping to evaluate and optimize system performance.

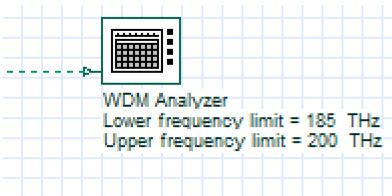


Figure III.12: WDM Analyzer

III.5.8 Optical Time Domain Visualizer

The OTDV is used to visualize and analyze the behavior of optical signals over time, helping to assess signal quality, detect impairments, and evaluate system performance in the time domain.

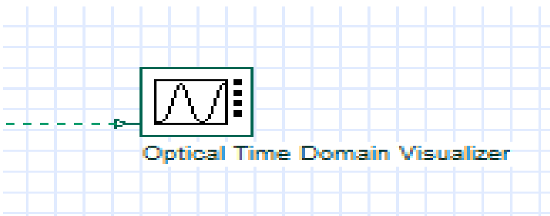


Figure III.13: OTDV

III.6 Transmission quality criteria

In order to determine the proper functioning of a system, the transmitted sequence is compared to the received one, which is obtained by measuring the quality of the transmission. For this purpose, there are five main criteria: the quality factor, the bit error rate, and the eye diagram, threshold, and the decision inst **[12].**

III.6.1 The quality factor

The quality factor, or Q factor, is a quality criterion for an optical signal. It is obtained from the statistics of the noise levels (1) and (0) of the signal to be detected, such as:

$$Q = \frac{I_1 - I_0}{\delta_1 - \delta_2}$$

(III.1)

Where I1 and I2 are the mean values representing the useful signal, δ1 and δ2 are the standard deviations of the probability densities of the symbols 1 and 0.

III.6.2 Bit Error Rate (BER)

The quantitative measure to evaluate the quality of a transmission is to assess the probability of error, which corresponds to the probability of making an incorrect decision on a bit. The bit error rate (BER) is the ratio between the number of erroneous bits and the number of transmitted bits. The receiver makes a decision about the presence of a "1" or "0" symbol based on the received signal level at a specific moment called the decision instant. If there are significant amplitude and temporal fluctuations, the voltage of a "1" symbol may fall below the threshold, and the voltage of a "0" symbol may rise above the threshold, resulting in errors. An acceptable BER at the receiver is generally below 10^{-9} **[12]**.

$$bit\ error\ ratio = \frac{number\ of\ bit\ errors}{number\ of\ bits\ transferred} \quad \text{(III.2)}$$

III.6.3 Eye diagram

The eye diagram method is often used to describe the degradation caused by noise and signal dispersion in digital signals. The eye diagram provides a simple way to assess the quality of received digital signals before they reach the demodulation device. It is a fundamental measure in digital transmission. If successive symbols are overlaid in pairs on an oscilloscope, the eye diagram is obtained. Specialized devices generate random sequences and compare the output signal from the optical link with the input signal. A random sequence of bits is visualized on an oscilloscope in an accumulation mode over time. The sum of all signals results in a signal shape called an "eye”: without noise, the traces exactly overlap, but as the noise increases, the signals vary, and the trace becomes thicker.

The figure below shows a series of observable parameters. The general principle is that the larger the central area, the better the quality of the received signal. The width is related to the ease of synchronizing and differentiating successive samples, while the height of the central lobe reflects the energy ratio between the original signal and the channel noise.

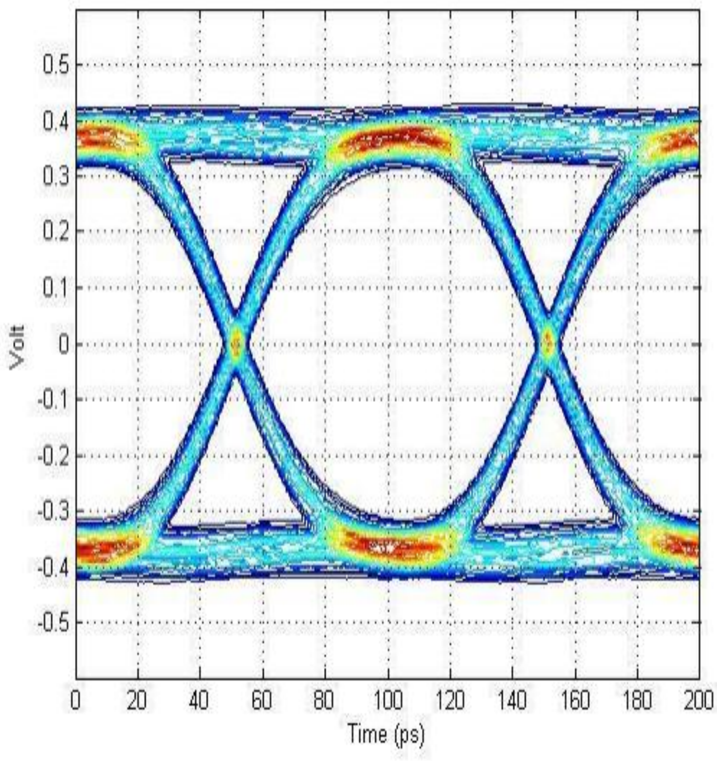


Figure III.14:Example of an eye diagram

III.6.4 Threshold

A threshold is a value that is compared against the predefined threshold configurations. It is evaluated to see whether it violates a specific restriction. The primary objective of thresholding is to determine any violations and to generate alerts. When the value falls outside the acceptable threshold range.

III.6.5 Decision Instant

The decision instant refers to the specific moment in a digital communication system when a decision is made to determine the transmitted symbol or bit based on the received signal. It is a critical point where the signal is compared to thresholds to estimate the transmitted information.

III.7 Simulation Overview

We simulated a 32-channel DWDM network with modulation formats RZ and NRZ at a data rate of 40 Gbit/s. 32-channel WDM transmitter and frequency spacing is a 100GHz transmission loop as an optical link with SMF, 10km DCF and two EDFAs. The receiver is a 32-channel WDM demultiplexer and BER tester. Test the simulation results with a BER analyzer.

III.8 Simulation Description

The whole project is divided into three sub-parts: DWDM transmitter, fiber optic link and DWDM receiver. **Figure III.16** shows the structure of a DWDM network. described as follows:

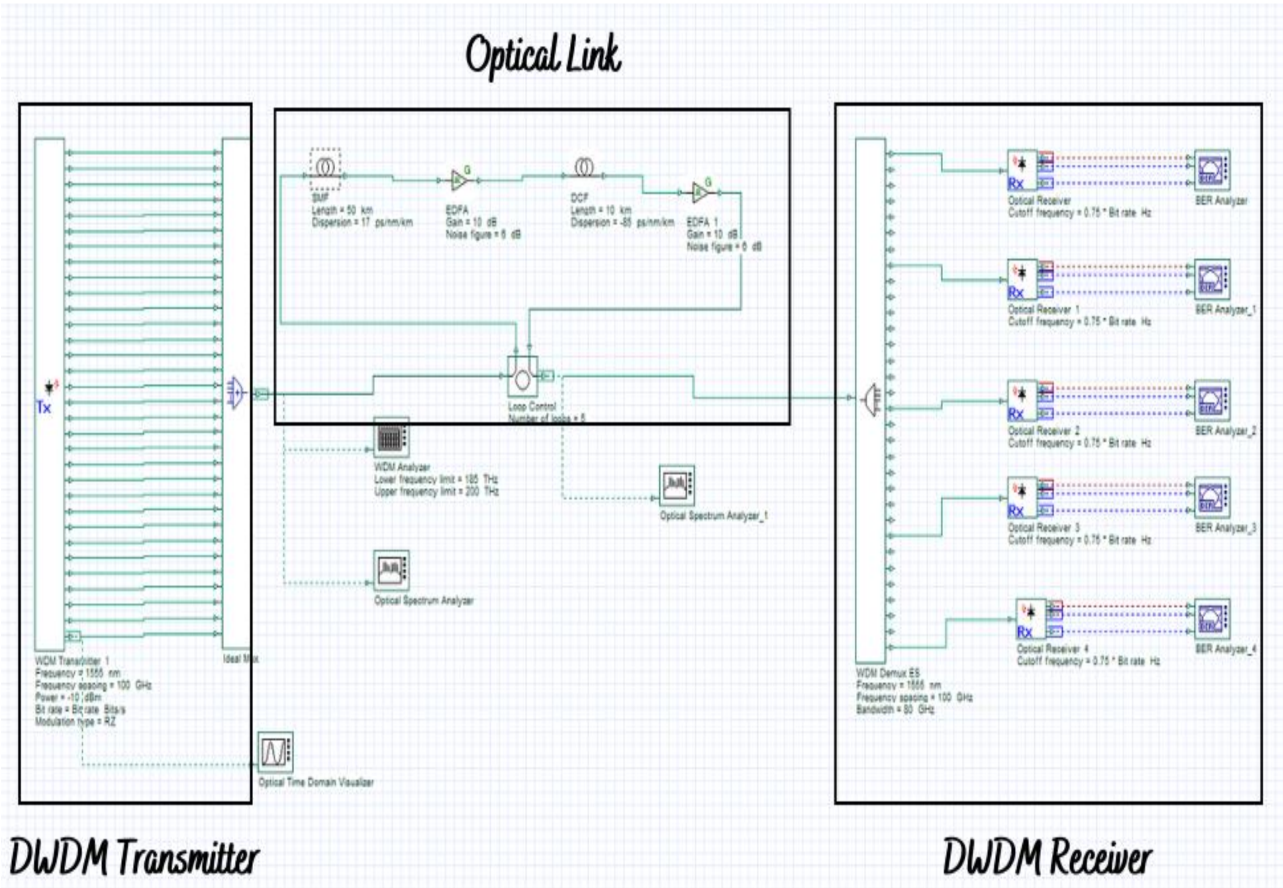


Figure III.15: DWDM Network Layout

III.8.1 Part One

In the DWDM transmitter, a laser source with a wavelength of 1555nm is used, which is used for high-speed connections because of the slower attenuation at 1550nm. 32 channels are exported with a channel spacing of 100 GHz. The data rate used is 10 Gbit/s. RZ and NRZ formats are used as modulation formats. Laser signals from all channels are multiplexed using a multiplexer. Signals from all channels are multiplied and combined in one fiber.

III.8.2 Part Two

The second part consist of fiber optical link, which includes a single mode fiber (SMF)of core diameter 6 µm and a numerical aperture of 0.1 and V number of 2.4 at a wavelength of 1545 nm, but the dispersion is very high in this region (17 ps/nm/km). The length of the single mode fiber used is 50km. The signal from the fiber is given to Erbium doped Fiber Amplifier (EDFA) to boost the signal, with a gain of 10dB and noise figure of 6 dB. The important feature of EDFA is the ability to pump the devices at different wavelength which is very suitable for DWDM, and also it has a very low coupling loss to the compatible sized fiber transmission medium and a very low dependence of gain on light polarization. EDFA's are highly transparent to signal format and bitrate and highly immune to interference effects between different channels so only EDFA has been chosen for long distance transmission.

The signal from EDFA is next given to Dispersion Compensation fiber (DCF), the dispersion that is present in fiber is compensated and it is negligible. The distance of the DCF fiber used is 10 km. Next the signal is given to again another EDFA to boost the signal, with a gain of 10dB and noise figure of 6 dB. The one end of the SMF and another end of EDFA is given to loops of three rounds for control mechanism. The output of the loop control is given to the one end of the WDM demux.

III.8.3 Part Three

In the WDM demux the total bandwidth of 80 GHz with the frequency spacing of 100GHz. Here the 32 channels are separated and given to 32 different receivers. The receiver used here is PIN receivers is the simple semiconductor photo detector. The device structure consists of p and n region separated by a very lightly doped intrinsic material. It works in reverse bias. The detector is designed to operate in the wavelength region of 1100nm -1600 nm. The material used is III and V group elements such as In GaAs. It has the quantum efficiency ranging from 30 to 95%. The output of the receivers is given to the BER analyzers.

III.9 Results and discussions

In the layout above, we simulate a 32-channel DWDM network with RZ and NRZ modulation formats at 40 Gbps. The transmitter section consists of a 32-channel WDM transmitter and multiplexer; the frequency spacing is 100 GHz. We use a transmission ring as an optical link with a length of 50 km SMF, 10 km DCF and two EDFAs. The receiver is a 32-channel WDM demultiplexer with PIN photodetector and BER tester.

Frequency (THz)	Signal Power (dBm)	Noise Power (dBm)	OSNR (dB)
192.79258	-13.290009	-42.057912	28.767903
192.89258	-13.392937	-39.872113	26.479175
192.99258	-13.303659	-39.788058	26.484399
193.09258	-13.318401	-39.87136	26.552959
193.19258	-13.314592	-39.750475	26.435883
193.29258	-13.389698	-39.780099	26.390401
193.39258	-13.381605	-39.89323	26.511625
193.49258	-13.320551	-39.649085	26.328534
193.59258	-13.397299	-39.647571	26.250272
193.69258	-13.38358	-39.738678	26.355098
193.79258	-13.327988	-39.881345	26.553357
193.89258	-13.30816	-39.923812	26.615653
193.99258	-13.380632	-39.916016	26.535384
194.09258	-13.37882	-39.934011	26.555191
194.19258	-13.389575	-39.823995	26.43442
194.29258	-13.31141	-40.165989	26.854579
194.39258	-13.314857	-39.943849	26.628992
194.49258	-13.36714	-39.921355	26.554215
194.59258	-13.379799	-40.046423	26.666624
194.69258	-13.376116	-40.012258	26.636142
194.79258	-13.386166	-39.957553	26.571388
194.89258	-13.315851	-39.874711	26.55886
194.99258	-13.311813	-39.897771	26.585958
195.09258	-13.388127	-39.839628	26.451501
195.19258	-13.388184	-39.943125	26.554941
195.29258	-13.382826	-39.843713	26.460887
195.39258	-13.377872	-39.867664	26.489791
195.49258	-13.385419	-39.885534	26.500116
195.59258	-13.315263	-39.975696	26.660434
195.69258	-13.355734	-39.859146	26.503413
195.79258	-13.387116	-39.961097	26.573981
195.89258	-13.274356	-42.069356	28.795

Frequency (THz)	Signal Power (dBm)	Noise Power (dBm)	OSNR (dB)
192.79258	-18.233702	-43.207333	24.973631
192.89258	-18.363141	-41.397021	23.033881
192.99258	18.286925	41.402462	23.115537
193.09258	-18.329751	-41.414387	23.084635
193.19258	-18.321527	-41.271977	22.950451
193.29258	-18.358598	-41.291635	22.933037
193.39258	-18.375067	-41.319121	22.944055
193.49258	-18.313602	-41.267226	22.953625
193.59258	-18.38102	-41.312021	22.931001
193.69258	-18.380408	-41.354901	22.974493
193.79258	-18.355425	-41.408473	23.053048
193.89258	-18.303109	-41.499303	23.196193
193.99258	-18.395351	-41.502852	23.107501
194.09258	-18.359195	-41.703652	23.344457
194.19258	-18.394127	-41.344156	22.950029
194.29258	-18.312777	-41.359848	23.04707
194.39258	-18.322125	-41.400271	23.078145
194.49258	-18.3586	-41.501752	23.143152
194.59258	-18.367704	-41.566643	23.198938
194.69258	-18.386674	-41.566223	23.179540
194.79258	-18.423378	-41.44321	23.019832
194.89258	-18.321039	-41.37318	23.052141
194.99258	-18.309607	-41.33221	23.022603
195.09258	-18.426644	-41.285538	22.858894
195.19258	18.391539	41.515357	23.123817
195.29258	-18.367783	-41.303447	22.935664
195.39258	-18.361501	-41.600733	23.239232
195.49258	-18.381466	-41.346509	22.965043
195.59258	-18.323289	-41.454774	23.131485
195.69258	-18.321935	-41.442863	23.120928
195.79258	-18.347897	-41.468812	23.120914
195.89258	-18.197568	-43.171145	24.973577

Signal Index: 0
Frequency — Units: THz
Power — Units: dBm
Resolution Bandwidth — Res: 0.10000 nm

Figure III.16: WDM analyzer for NRZ and RZ modulation formats

This figure Shows the comparison table of results for NRZ and RZ modulation formats using a WDM analyzer. The table compares all the 32 no. of channel's frequency, and their signal power, noise power and Optical to signal Noise Ratio (OSNR) obtained for the above WDM network. The OSNR values shows that the signal is received with less distortion and less noise for all the channels, so only it has a constant value.

III.9.1 Optical Spectrum

III.9.1.1 The power at the optical spectrum before the optical link transmission

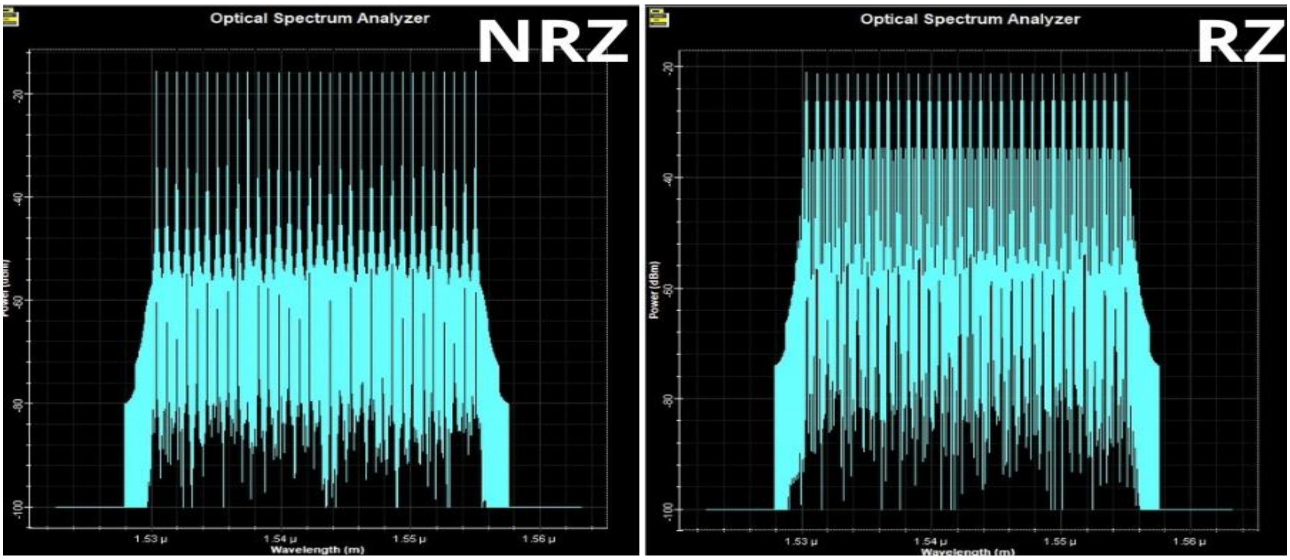


Figure III.17: The Optical spectrum analyzer output for NRZ and RZ modulation formats BEFORE

III.9.1.2 The power at the optical spectrum after the optical link transmission

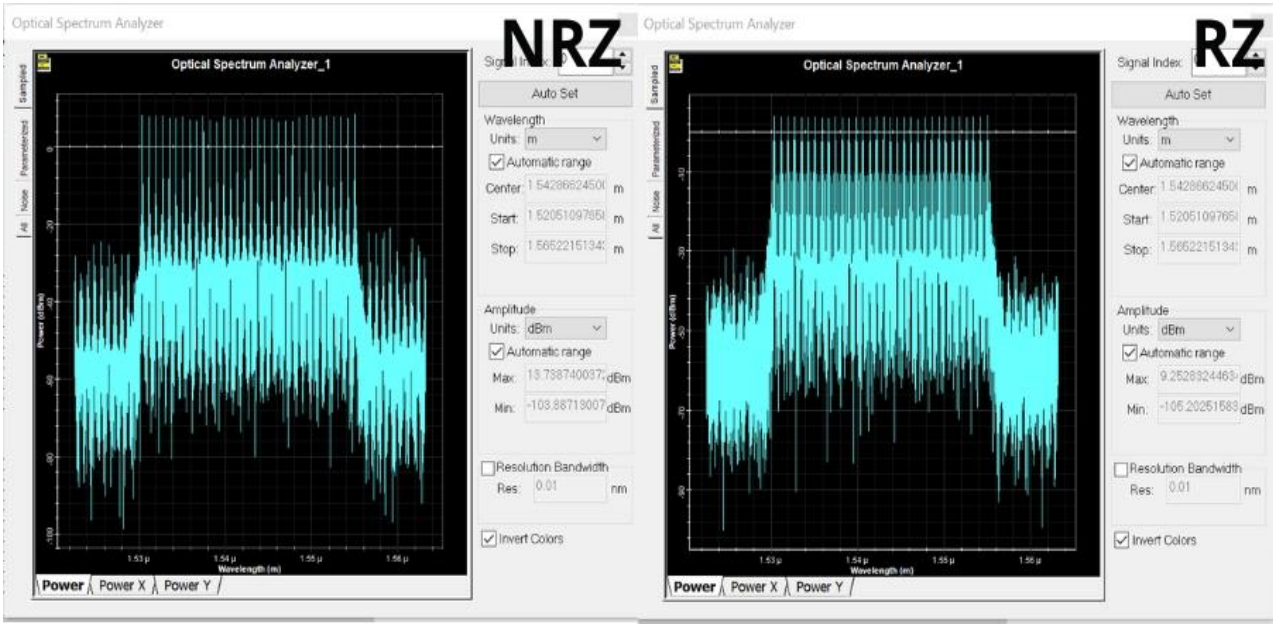


Figure III.18: The Optical spectrum analyzer output for NRZ and RZ modulation formats AFTER

Optical spectrum analyzer output is shown in Figure III.17 & III.18 for NRZ and RZ modulation formats. The spectrum shows the signal power obtained for both NRZ and RZ for all the 32 channels. The individual 32 frequencies are shown in optical spectrum analyzer. We have also checked the transmission of individual 32 channels in transmitter end and the same 32 channels have been received individually with the same power.

III.9.2 Comparative analysis of the modulation scheme

For 32-channel DWDM network with RZ and NRZ modulation formats at 40 Gbps. The comparison between the Q factors of RZ and NRZ modulation schemes is followed:

Channel 1:

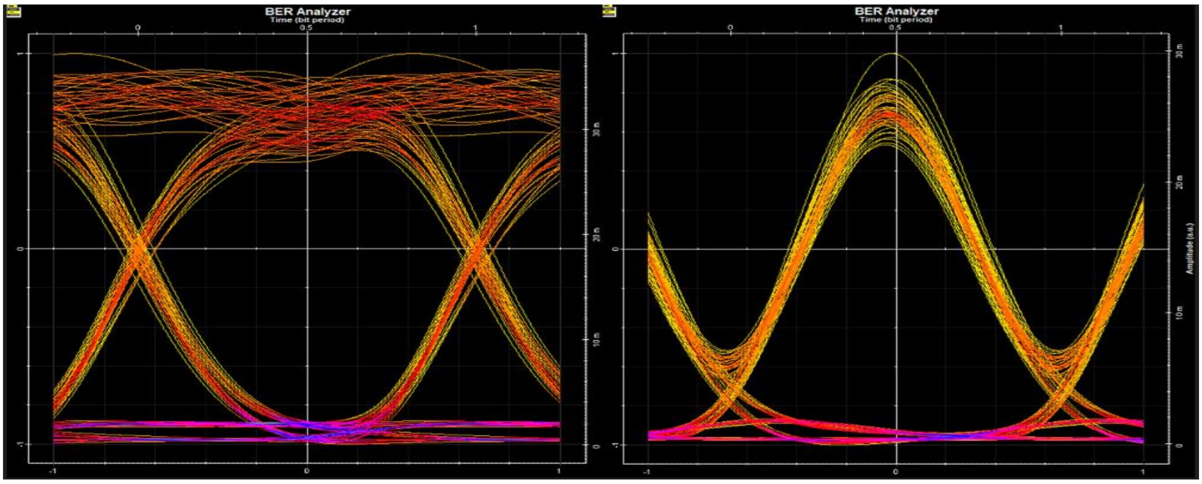


Figure III.19: Q factors of RZ and NRZ modulation channel 1

	NRZ	**RZ**
Q FACTOR	11.8213	16.1018
Min BER	1.3151 e-32	9.79616 e-59
EYE HEIGHT	0.0224815	0.0201287
THRESHOLD	0.00850251	0.0046676
DECISION INST	0.621094	0.535156

Table III.1: Comparison between RZ & NRZ for Channel 1

Channel 8:

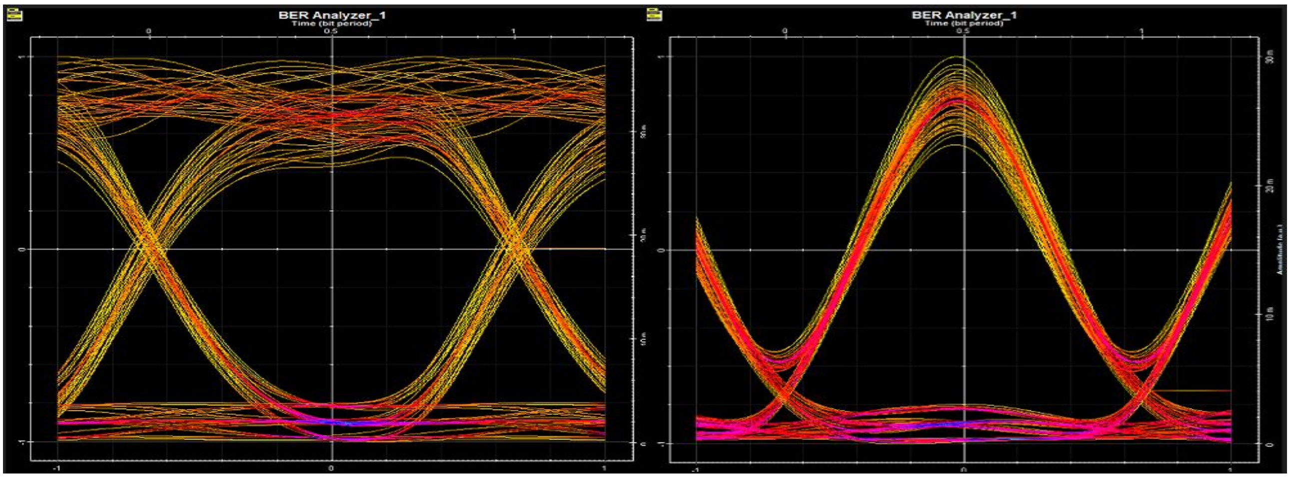


Figure III.20: Q factors of RZ and NRZ modulation channel 8

	NRZ	RZ
Q FACTOR	9.11893	11.2369
Min BER	3.62532 e-20	1.31772 e-29
EYE HEIGHT	0.0200741	0.0184385
THRESHOLD	0.0123329	0.0113849
DECISION INST	0.623047	0.441406

Table III.2: Comparison between RZ & NRZ for Channel 8

Channel 16:

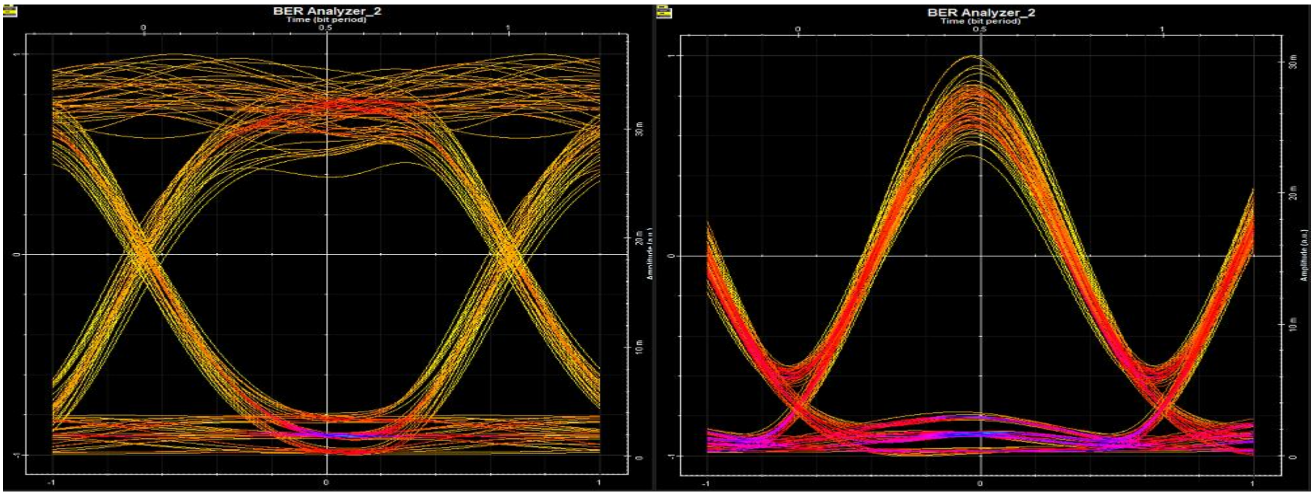


Figure III.21: Q factors of RZ and NRZ modulation channel 16

	NRZ	RZ
Q FACTOR	10.0036	9.90926
Min BER	7.1469 e-24	1.84152 e-23
EYE HEIGHT	0.0206798	0.0173352
THRESHOLD	0.0132303	0.0108788
DECISION INST	0.615234	0.439453

Table III.3: Comparison between RZ & NRZ for Channel 16

Channel 24:

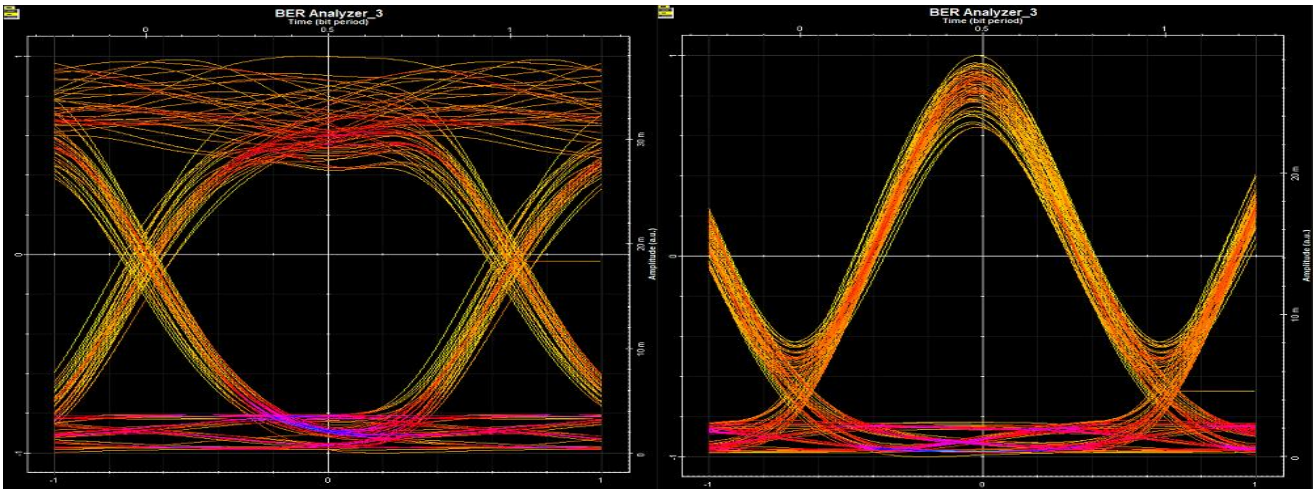


Figure III.22: Q factors of RZ and NRZ modulation channel 24

	NRZ	**RZ**
Q FACTOR	8.75728	13.7635
Min BER	9.10629 e-19	1.99993 e-43
EYE HEIGHT	0.0193231	0.0193728
THRESHOLD	0.0109277	0.00968814
DECISION INST	0.613281	0.447266

Table III.4: Comparison between RZ & NRZ for Channel 24

Channel 32:

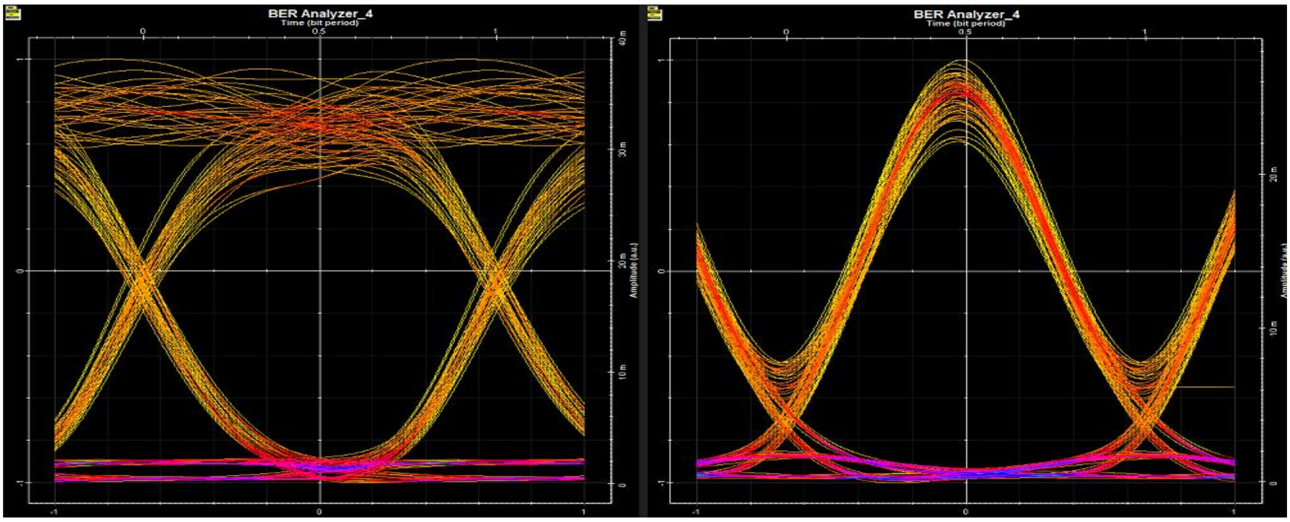


Figure III.23: Q factors of RZ and NRZ modulation channel 32

	NRZ	**RZ**
Q FACTOR	11.6855	19.0434
Min BER	6.31343 e-32	2.73749 e-81
EYE HEIGHT	0.0227256	0.0206004
THRESHOLD	0.00787722	0.00367033
DECISION INST	0.501953	0.546875

Table III.5: Comparison between RZ & NRZ for Channel 32

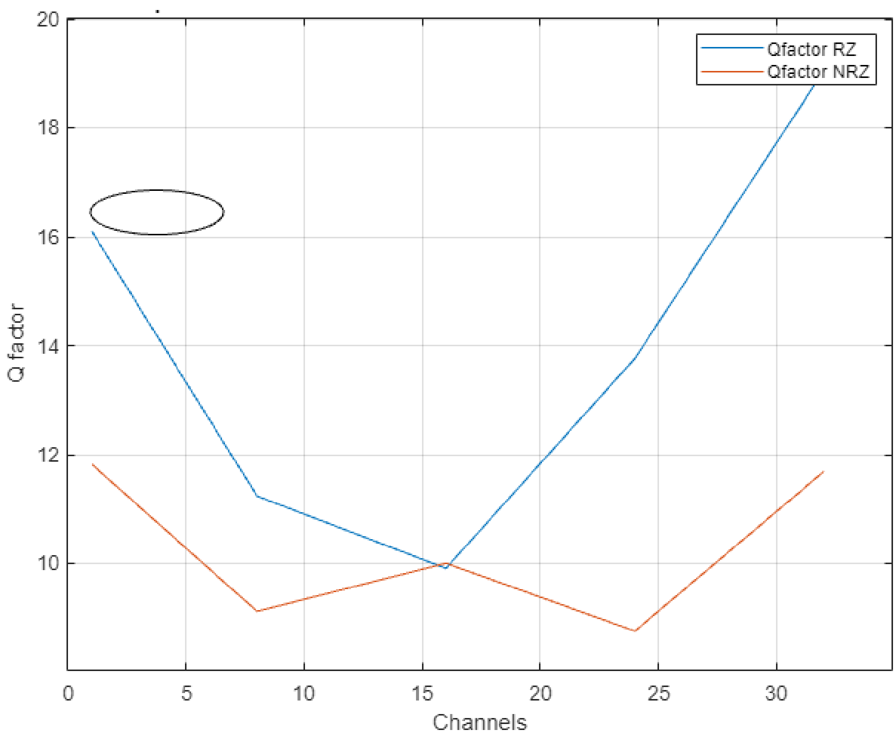


Figure III.24: Comparison between Q Factors in 5 different channels with RZ and NRZ

We plotted the Q factor versus channel and found that the Q factor drops much faster for RZ modulation than for NRZ modulation. This again shows that RZ modulation performs worse than NRZ modulation when the number of channels in the system becomes large.

Remarque

In channel 16 the equal Q-factor values indicate that both RZ and NRZ modulation formats are providing similar levels of signal quality. This means that the received signals in both formats have similar separation between the signal levels and noise levels, resulting in similar error rates.

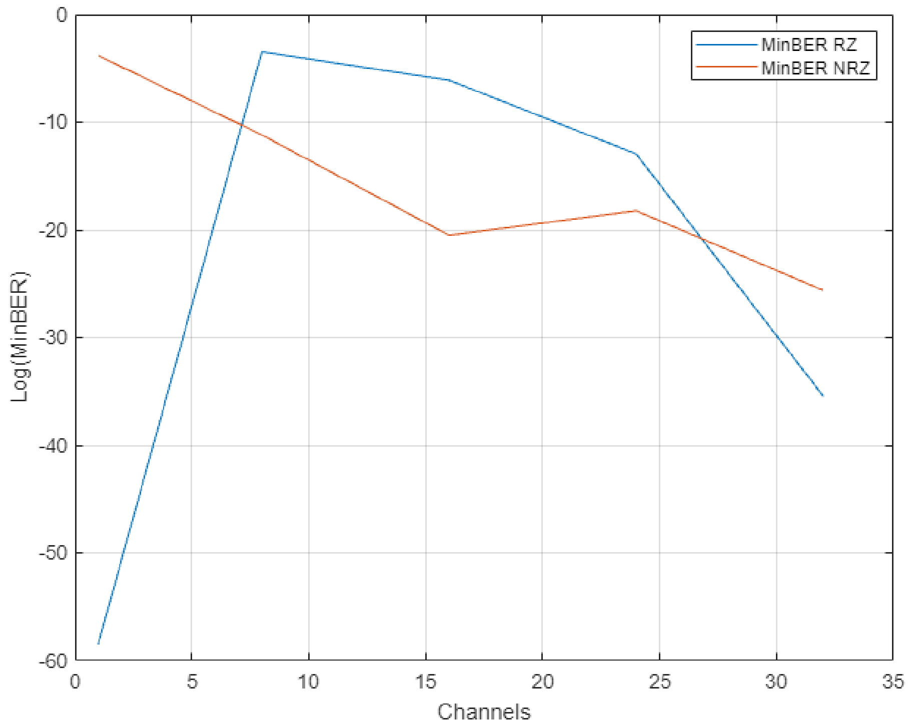


Figure III.25:Comparison between Min BER in 5 different channels with RZ and NRZ

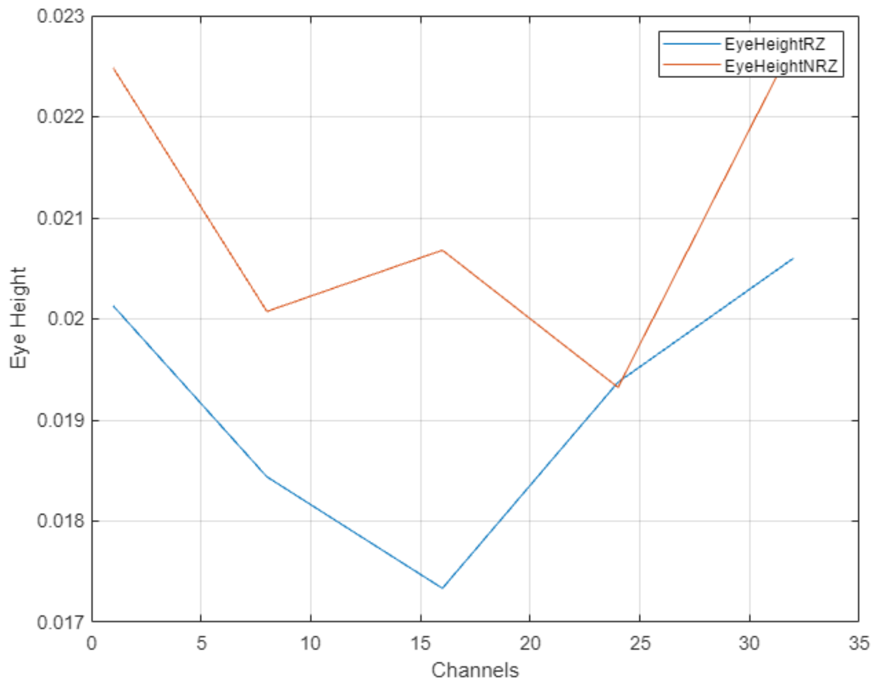


Figure III.26: Comparison between eye height in 5 different channels with RZ and NRZ

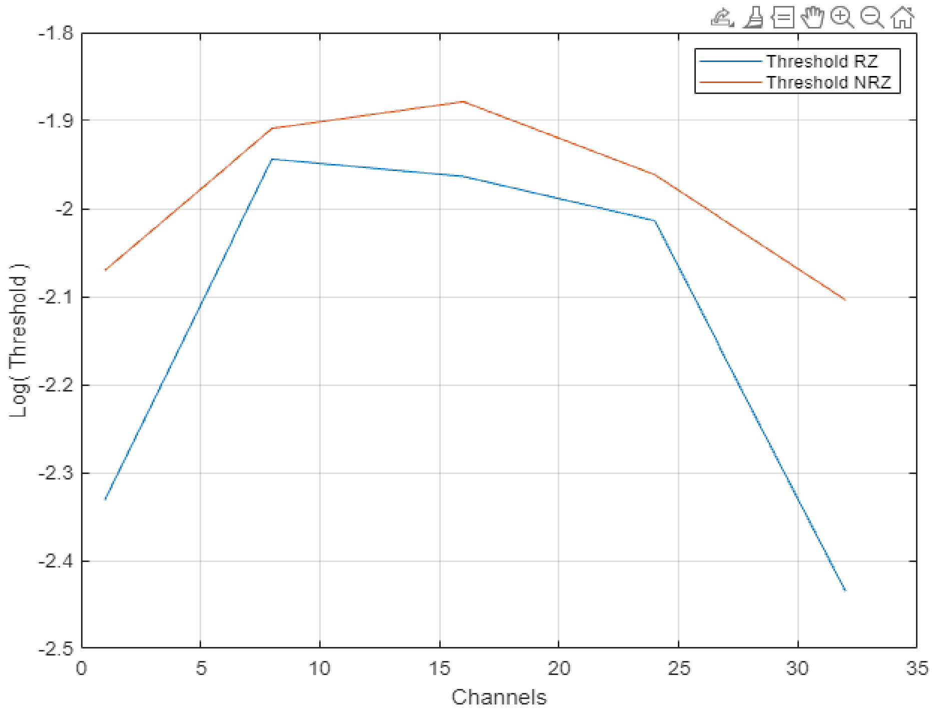


Figure III.27: Comparison between threshold in 5 different channels with RZ and NRZ

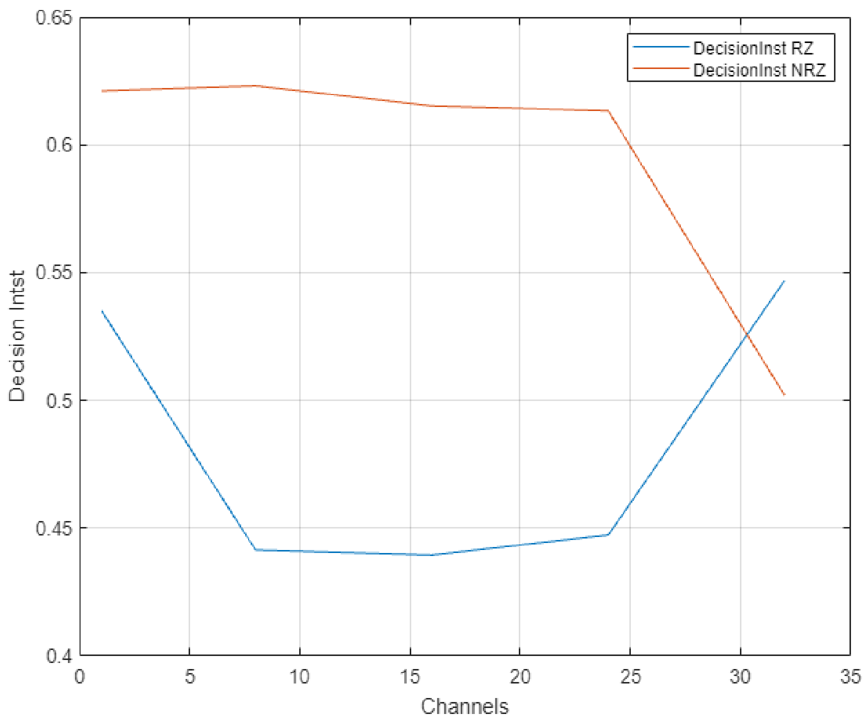


Figure III.28:Comparison between Decision Inst in 5 different channels with RZ and NRZ

III.10 Interpretation of the results

The DWDM system is successfully designed. By varying the modulation scheme, it is observed that the Q factor, BER, eye height, and threshold performance yield the best result in both the RZ and NRZ modulation schemes. A 32-channel, 40 Gb/s system was analyzed using both RZ and NRZ modulation techniques. The results obtained are in line with the findings in the scientific literature and demonstrate that NRZ modulation is a superior technique when dealing with high-capacity WDM systems. The input power versus eye diagrams showed that the NRZ modulation worked better for both low and high input powers, regardless of whether it was more affected by its nonlinearity in the high power regime. As a further study of the system performance, we plotted the Q factor versus channel and found that the Q factor drops much faster for RZ modulation than for NRZ modulation. That’s mean NRZ modulation perform better than RZ in this simulation.

III.11 Conclusion

This chapter presents and discusses the simulation study results of a DWDM optical fiber transmission system using the OptiSystem software. We have studied the system performance parameters such as BER and Q factor. The obtained results are significant, with a clear opening of the Eye Diagram, an excellent quality factor, and a bit error rate (BER) of more than 1.3151 e-32, lower than the accepted value in optical telecommunications (BER = 10 e-12).

General Conclusion

The increasing demand for communication in a limited bandwidth has led to the application of DWDM. In this work, we have discovered the field of optical networks, especially the DWDM technology. We have introduced the general concept of optical networks, the principle behind DWDM, and the techniques used to achieve efficient multiplexing of multiple channels over an optical signal. We have presented and discussed the results of a simulation study of a DWDM optical fiber transmission system using the OptiSystem software. We have studied the system performance parameters such as BER and Q factor. The obtained results are significant, with a clear opening of the Eye Diagram, an excellent quality factor, and a bit error rate (BER) of more than 1.3151 e-32, lower than the accepted value in optical telecommunications (BER = 10 e-12). Finally, we conclude that the DWDM technology has significant advantages in optical networks. DWDM can transmit large amounts of data simultaneously, resulting in a powerful and efficient communication network, so our project contributes to the body of knowledge in optical networks.

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ملخص

أدى الطلب المتزايد على الاتصال في نطاق ترددي محدود إلى تطبيق DWDM (مضاعفة تقسيم الطول الموجي الكثيف) في طبولوجيا مختلفة أو شبكات من نقطة إلى نقطة. إنها تقنية تتيح النقل المتزامن لعدة تدفقات من المعلومات عبر مسافات طويلة عبر ألياف بصرية واحدة. يوفر هذا طريقة فعالة من حيث التكلفة لزيادة سعة القناة، مما يؤدي بدوره إلى زيادة معدل البت للشبكات الحالية دون إضافة ألياف إضافية، مع تقليل تكلفة الألياف أيضًا. في هذا المشروع الرئيسي، قمنا بتصميم ومحاكاة شبكة DWDM ذات 32 قناة لمحاكاة خصائص شبكة DWDM. استخدمنا معدل خطأ البت (BER) كأداة اختبار لتنسيقات التعديل المختلفة باستخدام أدوات محاكاة Optisystems.

الكلمات المفتاحية: DWDM، معدل خطأ البت، Optisystems

Résumé

La demande croissante de communication dans une bande passante limitée a conduit à l'application de la DWDM (Dense Wavelength Division Multiplexing) dans différentes topologies ou réseaux point à point. C’est est une technologie qui permet la transmission simultanée de plusieurs flux d'informations sur de longues distances via une seule fibre optique. Cela offre une méthode rentable pour augmenter la capacité des canaux, ce qui à son tour augmente le débit binaire des réseaux existants sans ajouter de fibres supplémentaires, tout en réduisant également le coût de la fibre. Dans ce projet de Master, nous avons conçu et simulé un réseau DWDM à 32 canaux pour simuler les caractéristiques du réseau DWDM. Nous avons utilisé le taux d'erreur binaire (BER) comme outil de test pour différents formats de modulation en utilisant des outils de simulation Optisystems.

Mots Clés : DWDM, taux d’erreur binaire, Optisystems

Abstract

The increasing demand for communication in a limited bandwidth has led to the application of DWDM (Dense Wavelength Division Multiplexing) in different topologies or point-to-point networks. It is a technology that simultaneously transmits several information streams over long distances via a single optical fiber. It provides a cost-effective method to increase channel capacity, which in turn increases the bit rate of existing networks without adding additional fiber and reduces the cost of fiber. In this Master project, we designed and simulated a 32-channel DWDM network to simulate the characteristics of the DWDM network. We used bit error rate (BER) as a test tool for different modulation formats using Optisystems simulation tools.

Keywords: Dense Wavelength Division Multiplexing (DWDM), WDM, BER, Optisystem.