PERFORMANCE ENHANCEMENT OF WDM-XGPON SYSTEM FOR BI-DIRECTIONAL TRANSMISSION

THESIS REPORT

Submitted in partial fulfillment of the requirements for the award of the
Degree of Master of Technology in Electronics and Communication
Engineering with specialization in Communication Systems by the
A P J Abdul Kalam Technological University

by

FATHIMA HAKKIM
Reg.No TKM21ECCS05

DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

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KOLLAM 691 005

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CERTIFICATE

Certified that this Project report titled **”PERFORMANCE ENHANCEMENT OF WDM-XGPON SYSTEM FOR BI-DIRECTIONAL TRANSMISSION”** is a bonafide record of the work done by **FATHIMA HAKKIM** (Reg.No.TKM21ECCS05) under my supervision, in partial fulfillment of the requirements for the award of the Degree of Master of Technology in Electronics and Communication Engineering with specialization in Communication Systems by the A P J Abdul Kalam Technological University.

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ABSTRACT

Optic fibre is crucial to the network's access section. One of the most important technologies for the next generation of optical fibre communication systems that can increase reliability and data throughput is the 10-Gigabit Passive Optical Network (GPON), also referred to as (XGPON). A model based on Wavelength Division Multiplexing 10-Gigabit Passive Optical Network system (WDM-XGPON) is proposed in this paper. It has an 80 km access network connection to a central office optical line terminal (OLT) for multi-channel optical fibre transfers at a 10 Gbps data rate. In a 32 channel Wavelength Division Multiplexing passive optical network, various modulation formats will be compared in this paper along with their performance. The system includes a channel with a 10 Gbps transmission rate. The performance of several modulation formats, including Non return to zero (NRZ), Return to Zero (RZ), Carrier Suppressed RZ (CSRZ), Duobinary (DB), is compared.The suggested system is assessed using the Bit Error Rate (BER), Quality factor (Q-factor),and Eye Diagram using the simulation software Optisystem. As can be observed, DB Modulation format has a longer reach of 120 kilometres, while CSRZ forms is the second-best option, offering a maximum transmission length with high Q-factor.

*K*eywords: Bit Error Ratio, Eye diagram, Q-factor, XGPON, Modulation Formats, RZ, NRZ, CSRZ, DB.

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Chapter 1

Introduction

In the 1980s [5], passive optical networks (PONs) were created as a practical way to share fibre infrastructure for narrowband telephony (TPON) to commercial buildings. Since those early days, PON applications have progressed to interactive broadband networks built as GPON (Gigabit PON) or BPON (Broadband PON) or Ethernet PON (EPON) [12]. One of the most significant issues limiting the transmission distance in optical communication systems is the Q-factor and BER. Low BER and a high Q-factor within the fibre are required for long-distance signal transmission. The signal-to-noise ratio (SNR) of an analogue transmission signal is measured by the Q factor. As a result, it considers the signal's physical flaws, such as noise, chromatic dispersion, and any polarisation or non-linear effects, which might deteriorate the signal and ultimately lead to bit mistakes. In other words, the SNR is better and the likelihood of bit errors is lower the higher the Q factor is. The bit error rate (BER) in telecommunication transmission is the proportion of incorrect bits to all bits received during a transfer. A transmission might, for instance, have a BER of 10^{-9}, which indicates that, out of 1,000,000 bits transmitted, one bit was incorrect. A WDM transmission link multiplexes a number of lower capacity wavelength channels onto a single fibre to carry a huge volume of data traffic. A basic WDM system is typically broken down into three sections: the transmitter, the transmission link, and the receiver.

In the last few years, there has been a noticeable increase in the need for applications with high data rates, increased bandwidth [1, 2], and network reliability. In order to satisfy these needs and overcome any potential obstacles, new strategies are therefore necessary [1], [3], and [4]. The Passive Optical Network (PON) is now receiving more research interest as a result of the quick-growing needs for bandwidth and multimedia services [5], [6]. PON is a network built on a fiber-optic topology that offers significantly more access network bandwidth than conventional networks.[7, 8]. The major objective is to transfer large amounts of data quickly while maintaining network coverage and dependability. One technique for boosting transmission capacity is WDM-based PON. By incorporating WDM into PON, which operates in ”single-wavelength mode,” a person is allowed to support a much higher bandwidth than regular PON. Upstream transmission uses one wavelength, and downstream transmission uses a different wavelength.WDM-PON will therefore be a ground-breaking and scalable technology for broadband connectivity, giving end consumers more bandwidth.Upstream transmission involves sending data from network units on the receiving side to the optical terminal of the transmitter. A simultaneous downstream process reverse is carried out [9][11]. PONs come in two prominent varieties: Gigabit-PON (GPON), which is widely utilised in the United States, and Ethernet-PON (EPON) (deployed in Asia). A high-speed network connection is offered via the GPON, a transmission network that is entirely optical.

1.0.1 Bi-Directional Transmission

Transceivers that use optical fibre are frequently used in optical networks to send and receive data to and from networking devices. This kind of data transmission typically increases the cost of network building. However, we can build a considerably more affordable optical network thanks to the bidirectional optical transceiver's capacity to send and receive data over a single optical fibre. The WDM technology is utilised by the bidirectional optical transceiver. Since WDM technology enables bidirectional communication over a single fibre, creating a connection is easier to deploy, troubleshoot, and configure. This is crucial. The bidirectional optical transceiver typically uses an optical wavelength of 1270/1577 nm and is most frequently used in high-speed duplex data connections over a single optical fibre.

When compared to two-fibre transceivers, bi-directional optical transceivers can use WDM technology. Based on the wavelength of the light, this method divides the data delivered and received over the same cable. The bidirectional optical transceiver must be deployed in matched pairs and tuned to match the predicted wavelength of the transmitter and receiver for it to function at its best. If one transceiver has a transmission wavelength of 1577 nm, the other side must have a receiving wavelength of 1270 nm, and vice versa, to improve the suggested system's performance for the bidirectional fibre link.

1.0.2 Data Modulation Format

In the RZ modulation format as shown in Figure 1.1, the signal returns to zero between each pulse even if a number of consecutive 0s or 1s occur in the signal. Although a separate clock is not need to be delivered with the signal, the return-to-zero format requires twice as much bandwidth to accomplish the same data rate. The RZ pulses are more resilient to the effect of nonlinearity because dispersion broadens them more quickly. The nonlinearity effect is proportional to the signal strength. The transmitted power can also be reduced by using the RZ signal format rather than the NRZ to achieve the needed receiver sensitivity. This suggests that for a given transmitted power, the transmission distance can be enhanced when compared to the NRZ signal.

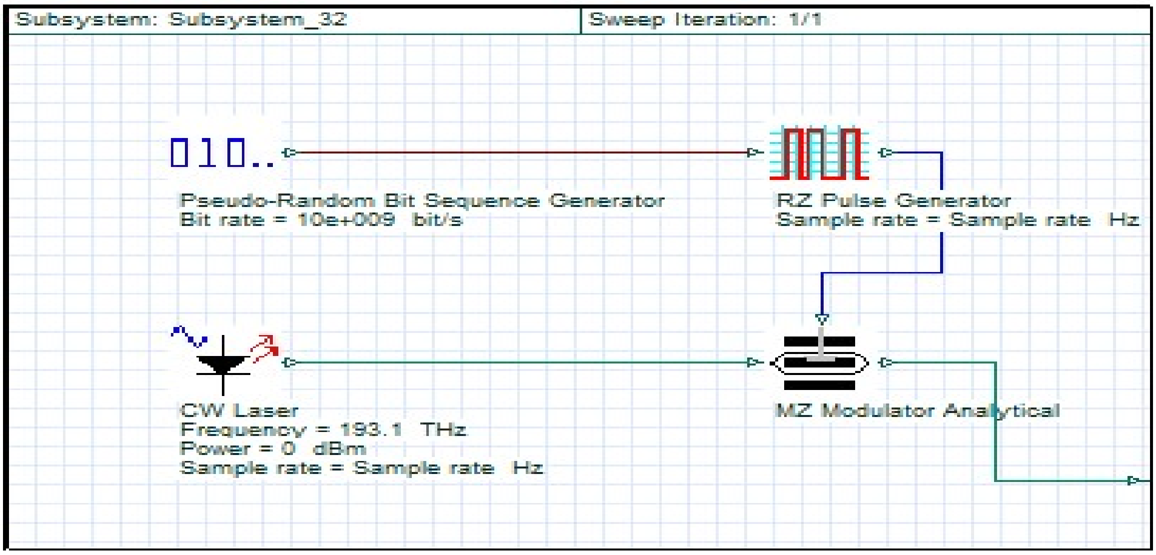


Figure 1.1: Optical transmitter to implement RZ modulation format

In NRZ modulation format, as shown in Figure 1.2, ones are represented usually by positive voltage and zeros are represented usually by a negative voltage, with no neutral or rest condition. Due to its two times smaller signal bandwidth than the RZ modulation format, it is the most popular modulation format. It is also simple to configure. Inter-symbol interference, dispersion, and non-linearity have an impact on it, though.

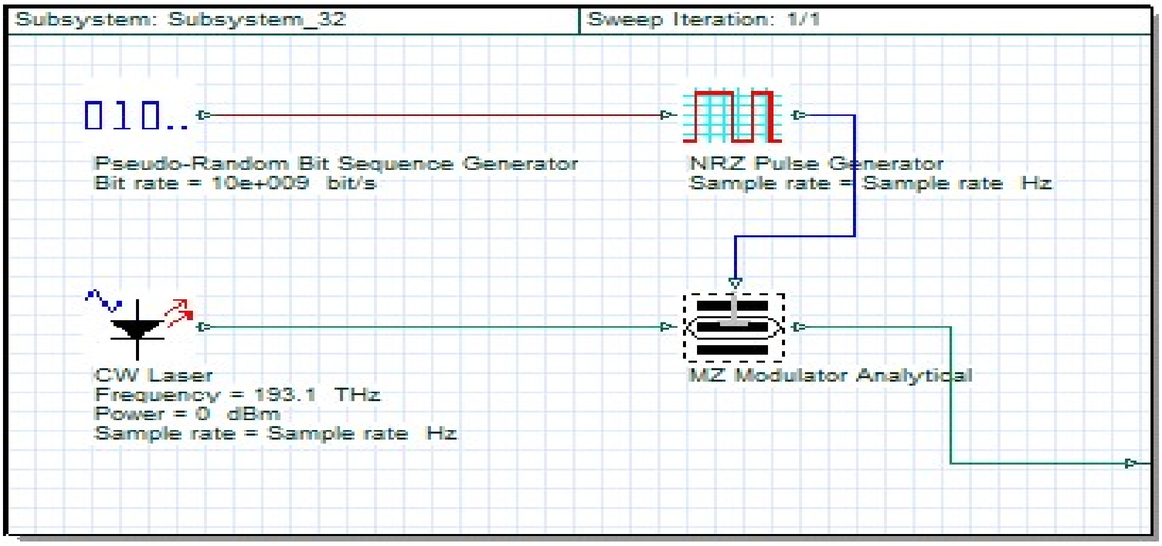


Figure 1.2: Optical transmitter to implement NRZ modulation format

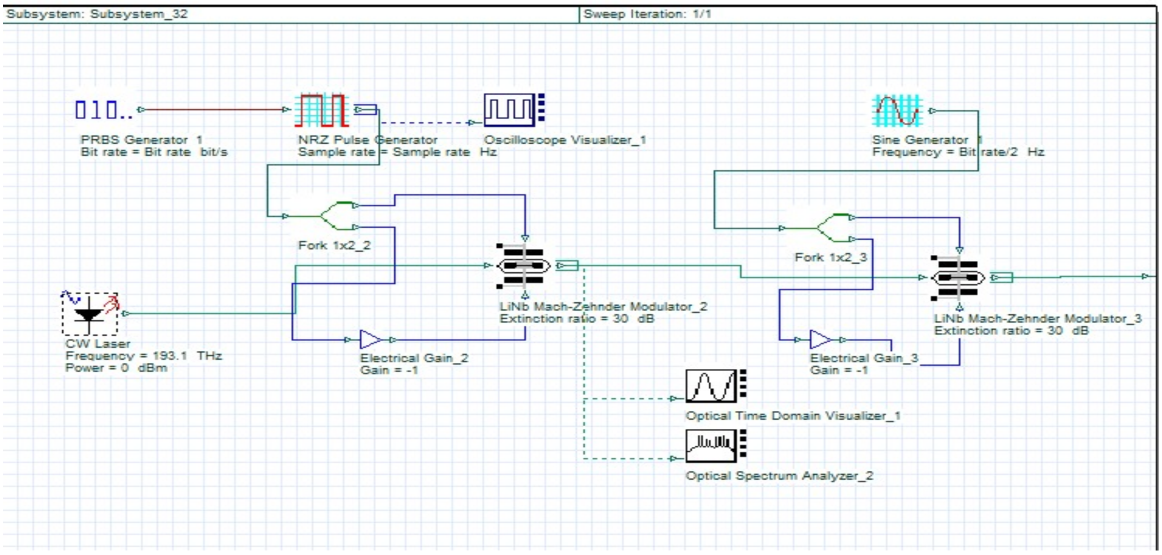


Figure 1.3: Optical transmitter to implement CSRZ modulation format

In CSRZ modulation format, as shown in Figure 1.3 which is a pseudomultilevel modulation format the information is encoded on the intensity levels (representing logical one and zero),but for every bit, the phase is changed by pi .It has no DC component because of this phase alternation.The spectrum has suppressed carrier. Additionally, the bandwidth is smaller than the traditional Return to Zero format.

Additionally, it is thought to be more resilient to nonlinear channel impairments and to offer higher spectral efficiency in high bit rate systems.

In the Duo-binary modulation format as shown in Figure 1.4, phase is only modified for 1-bits separated by an odd number of 0-bits and two intensity levels are employed to encode information. The benefit of DB format is that it has a smaller spectral width and is more tolerant of the effects of chromatic dispersion. Without the need for dispersion compensation, it can be employed for transmission over large fibre distances.

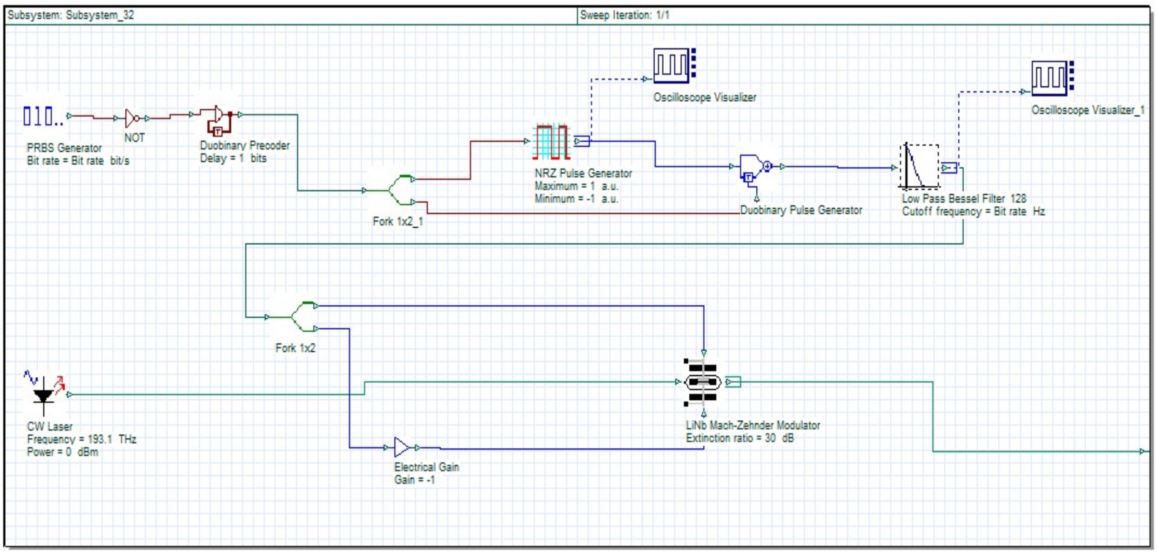


Figure 1.4: Optical transmitter to implement DB modulation format

This paper's primary goal is to compare the various modulation formats to determine which format offers a greater range in an XGPON WDM network, taking into account that each of the abovementioned modulation forms has advantages and disadvantages of its own.

Chapter 2

Literature Review

This section, presents an overview of some works related to the proposed approach.

Bashara J. Hamza *et.al.*[10] proposed SCM/WDM-RoF-XGPON System for Bidirectional Transmission with SRM. WDM technology can be incorporated into bidirectional optical transceivers, as opposed to two-fibre transceivers. Based on the wavelength of the light, this technology separates the data delivered and received over the same fibre. The bidirectional optical transceiver must be deployed in matched pairs and tuned to match the predicted wavelength of the transmitter and receiver for it to function at its best. If one transceiver has a transmission wavelength of 1577 nm, the other side must have a receiving wavelength of 1270 nm, and vice versa, to improve the suggested system's performance for the bidirectional fibre link.Here there is an improvement in the Q-factor when employing the suggested method with SRM as opposed to without. When the fibre is 50 km long without SRM, the Q-factor is 6.4; when SRM is used, it is 9.15. When, from 10 km to 80 km, the Q-factor falls as the distance increases. When the fibre is 80 km long without SRM, the Q-factor is 3.75; when SRM is used, it is equivalent to 6 for the same length of fibre.

Cheikh Kherici *et.al.*[6]. In order to fulfil the high demand for bandwidth, the development of optical technology is currently the subject of intense research. The passive optical network (PON), which expands the optical network to include people and businesses, overcomes the bandwidth problem. In order to demonstrate the best method for the PON network by increasing the Q factor and the OSNR ratio while minimising the bit error rate (BER 10^{-9}), a comparison between the WDM PON system and the CWDM PON system is made in this paper using two different architectures, one for the WDM PON and the other for the CWDM PON. With bidirectional SMF (Single Mode Fiber) fibre lengths and various powers, both systems are simulated at 10 Gbps for four users.The link was developed for fibre lengths of 20, 30, 40, 50, and 60 km as well as for powers ranging from 10 dBm to 10 dBm for four users in order to assess the transmission performance for both systems. This document mandates the usage of the EDFA amplifier in the WDM PON system to reduce attenuation-related deterioration. The CWDM PON system, on the other hand, does not require amplification since the wavelengths employed in this system are not impacted by the water peak, which significantly attenuates wavelengths in the 1370–1410 nm range on optical fibres. Around 1383 nm is when water vapour absorption peaks.

Baljeet Kaura *et.al.*[17] proposed EPON technology. It is the best access way to deliver integrated services to use the proposed EPON technology, which combines a mature Ethernet technology and high-bandwidth PON technology. The "last mile"issue in broadband access networks has been widely viewed as having a possible answer in Ethernet passive optical networks (EPONs). An EPON is a point-to-multipoint optical network that uses only passive optical components (such as fibres and passive star couplers) along the transmission path from source to destination. It typically consists of one optical line terminal (OLT) and numerous optical network units (ONUs). Through the use of Time Division Multiplexing (TDM) and Wavelength Division Multiplexing, bandwidth in a PON can be shared among numerous users (WDM). It is quite difficult to construct the protocol required to use TDM and dynamically assign band width. Utilizing WDM, which can offer a significantly larger bandwidth than the conventional EPON, is one potential method of channel separation. Compared to TDM-PON, WDM-PON offers greater transmission distance and is simpler to implement. Numerous additional benefits of WDM-PONs include their high capacity, simple management, network security, improved privacy, and upgradeability. The use of WDM in ROF networks has various advantages,including the ability to more easily update networks and services, simplify network management, and simplify network design by assigning different wavelengths to individual BSs. Multiple optical mm-wave signals are multiplexed, optically amplified, transmitted via a single fibre, and then demultiplexed to address each BS.

R. Bhattacharjee *et.al.*[12] proposed a 32channel, 256 Gbps, DWDM-based RoF optical system that incorporates DCF and FBG as dispersion compensators, has been successfully simulated and analysed in the Optisystem software. It is capable of transmitting data at 8 Gbps per channel and provides efficient long haul data transmission over a distance of 120 km. The maximum Q factors of our analytical method for reducing the DWDM system's channel spacing are after transmitting through 32 channels, 15.34 and 15.97 for 50 GHz channel spacing for 60 km and 120km, respectively, were obtained. First, when operating in 8 channel mode at 4 Gbps per channel bit rate and lowering FWM side band, the suggested system provided good Q factor of roughly 79 for 50 GHz channel spacing in our comparison analysis with two existing RoF systems.

Fahd Chauoi *et.al.*[20], In order to minimise the nonlinear effects of dense wavelength division multiplexing (WDM) for optical long-haul networks, chirped fibre bragg grating (FBG) has been developed. Architecture of the proposed 16 channel WDM-ROF-PON.Based on various chromatic dispersion levels, the proposed approach has been examined. Regardless of the chromatic dispersion phenomenon, the goal of this approach is to reduce the FWM nonlinear effects in dense WDM optical networks. Since they are inversely proportionate, handling FWM and Chromatic dispersion in optical fibres presents a number of challenges. A module that can address these two key limitations simultaneously is therefore highly desirable.

Yufeng Shao *et.al.*[7], proposed an optical 32QAM-OFDM-PON system with various sub-carrier counts using discrete multitone (DMT) modulation and demodulation. The reception of 32QAM-OFDM downstream signals is accomplished through electron-optic production, immediately photoelectric detection, and electrical self-mixing. Different numbers of subcarriers in 5Gb/s 32QAM-OFDM downlink signals are successfully delivered over 42 km SMF-28. Bit error rate (BER) performance, computational complexity, and peak-to-average power ratio (PAPR) characteristics are all examined. The findings demonstrate the need for careful sub-carrier selection for 32QAM-OFDM downlink signals based on the real needs, taking into account spectral efficiency, PAPR characteristics, computational complexity, and receiver sensitivity.

Due to its high spectral efficiency, tolerance to dispersion, and adaptability to dynamically bandwidth, orthogonal frequency-division multiplexing (OFDM) has recently been widely implemented in several optical access fields, such as OFDM modulated WDM-PONs and OFDM-RoF systems. Few studies currently concentrate on the reception of various downstream QAM OFDM signals employing self-mixing reception in optical access networks. They have designed and experimentally demonstrated two types of full-duplex 60GHz radio over fibre systems with 16QAM-OFDM downlink signals produced by discrete multitone (DMT) modulation and demodulation and received by self-mixing reception in order to simplify the configuration of the optical access system and reduce cost budget.

Doutje T. van Veen *et.al.*[16].The need for bandwidth is continually growing, which motivates researchers to keep looking for low-cost alternatives to boost the line rate in passive optical network (PON) systems. In this study, they outline and explore ideas for upgrading 10G PONs to 25Gbps line rates while using little money and electricity. Our ideas are based on binary nonreturn-to-zero and duobinary-based transmission, which have recently received a lot of attention as ways to upgrade PON to a 25 Gbps line rate in academic papers and from the IEEE, a group that sets standards. They provide the most recent findings from our investigation on duobinary detection, which demonstrate that it is a financially viable technical solution for 25G PON. In the context of 25G PON, issues like forward error correction and power consumption are being investigated.

Since there is always a need for more bandwidth, optical access researchers have constantly looked into efficient ways to increase line rates in optical access networks. Operators demand that an improved passive optical network(PON) be compatible with the current outside fibre plants for all PON generations. As a result, maintaining the same optical power budget as for the lower rate while increasing the bit rate is a hurdle. A worse signal-to-noise ratio at the receivers, a reduced dispersion tolerance, and a need for more expensive premium optical components are all consequences of increasing data rates. Different approaches have been implemented in PON to address this issue, such as the use of single mode distributed feedback lasers (DFB) rather than multi-mode Fabry-Perot (FP) lasers.

Yaoqiang Xiao*et.al.*[15].Since they can reduce the complexity of the optical network unit (ONU) and the external plant, wavelength-division multiplexing(WDM)

PONs perform better than existing optical access networks. The convergence of optical and wireless access systems using radio-over-fiber(ROF) technology has generated a lot of interest because it can increase the capacity and mobility of high-speed wireless data transfer. The vast bandwidth available between the 57 GHz and 64 GHz band has attracted a lot of attention for the license-free ROF system running at 60 GHz . Future access networks would need to offer both wired and wireless connections to end users while being cost-effective . As a result, various WDM-PON architectures that combine ROF technology for wired and wireless connections have been proposed . Both optical mm-wave generation and the bi-directionalarchitecture are essential for the deployment of such fiber-fed wireless access systems. If an additional light source is required for full-duplex operation, the RBS will consume a lot of power, become expensive, and the crosstalk between the many signals will restrict the signal performance.Both optical microwave-wave generation and the bidirectional architecture are essential for the deployment of such fiber-fed wireless access systems. If an additional light source is required for full-duplex operation, the RBS will consume a lot of power, become expensive, and the crosstalk between the many signals will restrict the signal performance.

Vivek Kachhatiya *et.al.*[19] proposed a sixteen channel wavelength division multiplexed passive optical network (WDM-PON) architecture that serves fibre to the house (FTTH) consumers and offers seamless connectivity between mobile switching centres (MSC) and base transceiver stations (BTS). A top solution is thought to be a mobile backhaul network based on WDM-PON because of how easily it can be set up and how inexpensively it is. The number of wavelengths is growing daily as a result of the rising need for connectivity and data transfer. For the discrete reach of 16 channel WDM-PON, the bit error rate (BER) performance is examined for discrete data rates per wavelength (i.e. 2.5 Gbps, 5 Gbps, 10 Gbps, 20 Gbps, and 40 Gbps). For various data rates, the sixteen channel WDMoptical PON's spectrum is observed.For discrete data rates per wavelength, the WDM-fiber PON's reach might vary, and this has an impact on performance metrics like the bit error rate (BER) and quality factor (Q-Factor). It is discovered that the error-free reach of the WDM-PON system diminishes as data rate per wavelength increases. In comparison to the compared work, the proposed WDM-PON architecture outperforms it in similar beginning circumstances. High data rate connectivity is currently in demand from users of wireless and optical access networks. The fundamental benefit of a passive optical network (PON) is that it offers cost-effective high data-rate connectivity. In addition, it also offers end-to-end transparency, simple network upgrades, and energy-efficient network solutions. Next-generation mobile access network systems view wavelength division multiplexed passive optical network(WDM-PON) as one of the advantageous choices for the access network to meet the constantly growing data rate requirement.

Due to its high bit rate capabilities and user-friendly pricing, WDM-PON attracts increased interest as a potential means of accelerating the deployment of PON for both fibre to the home (FTTH) and mobile backhauling. In order to boost the data rate by adding additional channels while maintaining the benefits of WDM-PON,PON networks with a combination of WDM-PON and Dense wavelength division multiplexed passive optical network (DWDM-PON) are studied.

Chapter 3

The Proposed WDM-XGPON System Design

Figure 3.1 presents a block diagram of the proposed architecture.The system transmits a long wavelength at 1577 nm and 1270 nm, respectively, for downstream and upstream directions. For broadcasting, a 10Gbps optical splitter with a 1:32 split-ratio has been used for 32 ONUs. Using the simulation scenario in the Optisystem 20 programme, Figure 3.1 displays the main block diagram of the suggested simulation model that relies on the WDM-XGPON structure.The splitter, receiver, fibre channel, and transmitter are the four main parts of this system.

The data source, CW laser source, pulse generator, and optical amplifier modulator first produce the sent signal. In order to create an encoded signal, a pseudorandom sequence (PRBS) is provided to the block of the pulse generator. The optical amplitude modulator receives the CW laser and the pulse-generated signal after that, and the signal travels through bidirectional optical fibres with an attenuation loss of 0.2 dB km.

The WDM-XGPON system design is presented. Utilising 32 ONUs, we connected four channels with a 0.6 nm separation. Then, using WDM technology and an optical fibre access network with a bit rate of 10Gbps, this links to a central office (OLT). A feeder of about 80 km of single-mode fibre (SMF) has been chosen. On the other hand, 8 km of SMF were selected as the distribution fibres. In numerous locations, optical spectrum analyser are used to track the signal characteristics. In order to

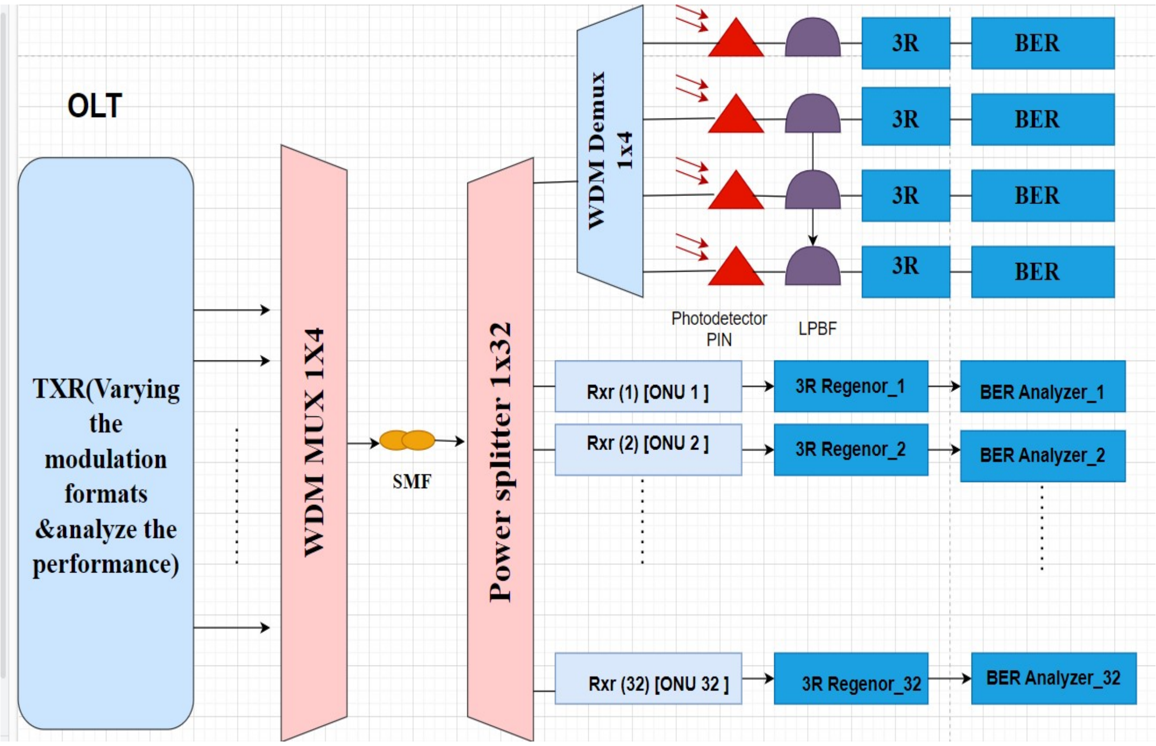


Figure 3.1: Block diagram of the proposed WDM-XGPON system

incorporate signals for future transmission, the WDM MUX is being implemented and the outcomes for different fibre lengths have been compared.

3.1 Simulation Model

As illustrated in Figure 3.2, the input signals can also be modified using the Mach-Zehnder (MZ) modulator at the CW laser array's carrier frequencies, which pumps the optical carrier via four channels starting from 193.1 to 193.4 THz at 0 dBm power.Table 3.1 presents the design parameters used in this work. The bi-directional optical fibre with a channel bandwidth of 25 GHz and a channel spacing of 100 GHz is used to transmit the WDM-Mux output. An optical amplifier that gains 20 dB and has a 4 dB noise figure is used to amplify this. Utilising a splitting ratio of 1:32, where each output feeds the WDM DEMUX, the output is spread equally, as shown in Figure 3.2.

It is divided into four ONUs and is used to identify signals coming from the receiver's side using the same channel frequency. The ONUs are comprised of a photodetector PIN, which converts optical signals into electrical signals, and Bessel

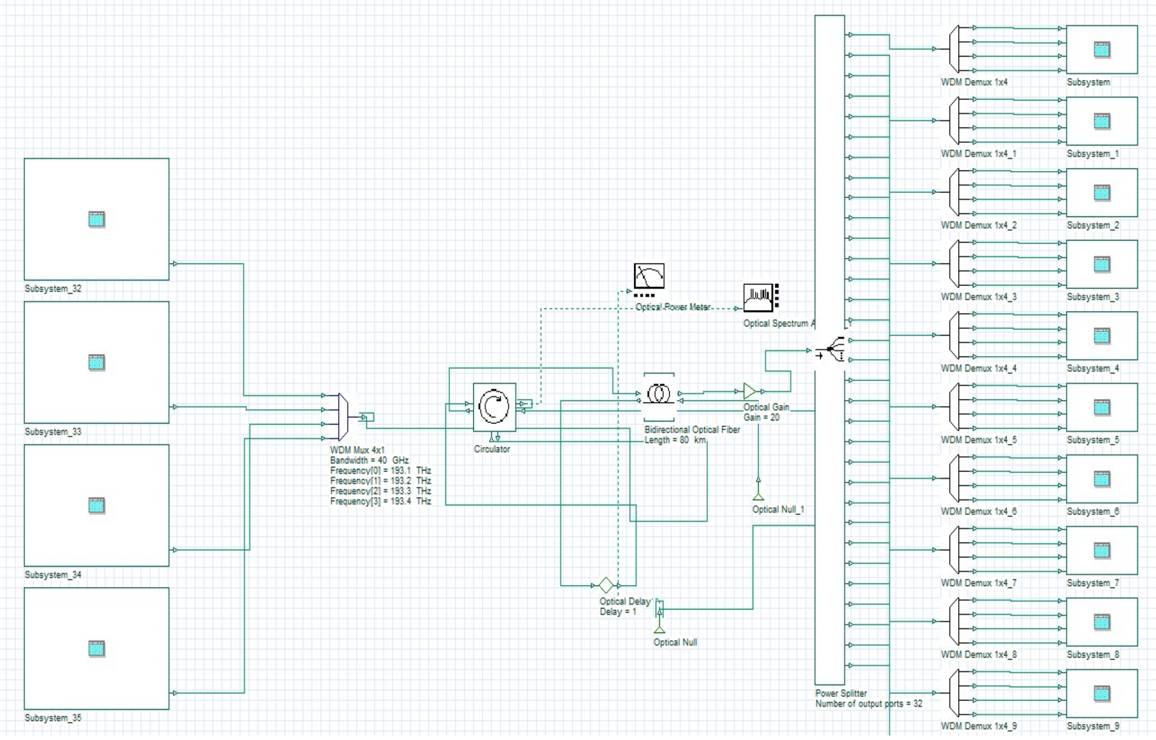


Figure 3.2: The main layout of the proposed simulation model for the WDM-XGPON System

filters with 15 GHz bandpass frequencies (BPF) and 2.5 GHz bandwidth (BW) for electric transmission as shown in Figure 3.2. The photodetector PIN is chosen with (10 A) dark current, 1 A/W response, 800 GHz sample rate, and 0.9375 GHz cut-off frequency. The electrical signal is processed by a Low-pass Bessel filter before being received by a 3R generator. The analyzer determines the system's performance, including the Q-factor, BER, and eye aperture.

A single mode fibre (SMF) connects every component of the ODN to the ONUs. The multiplexer and demultiplexer produce a 3 dB insertion loss. From Figure 1.1 through Figure 1.4, system using various modulation formats are displayed.

RZ transmitter can be seen in Figure 1.1. The main difference between RZ and NRZ transmitter is that an order 5 low pass Bessel filter is used to generate the electrical signal in this.

To generate NRZ pulses, a PRBS (Pseudo Random Bit Sequence) generator is employed. The bit rate of this generator is 10 Gbit/s. The Mach- Zehnder modulator (MZM) is subsequently given the electrical signal.

A continuous wave (CW) laser is a part of the MZM. Figure 3.1 illustrates this.

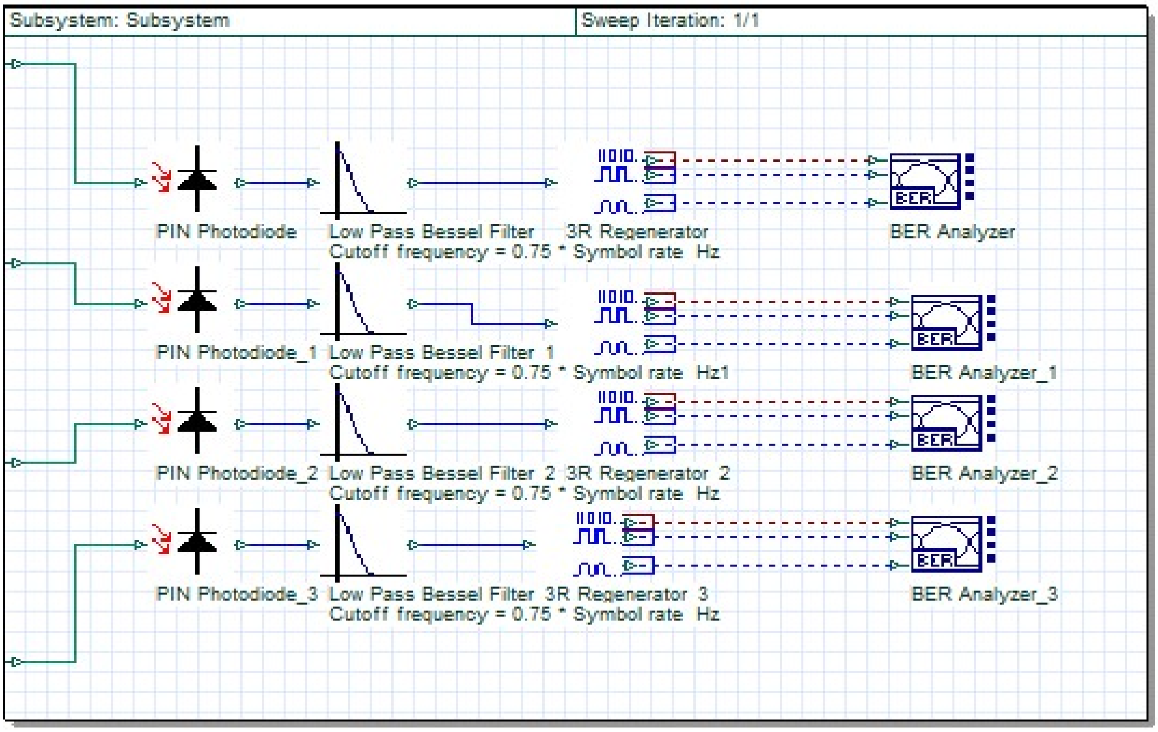


Figure 3.3: Designing inside ONU(Receiver Section)

Table 3.1: Simulation Parameters

PARAMETERS	VALUE
Downstream Max.bit rate-XGPON	10 Gbps
Downstream long wavelength-XGPON	1577 nm
Bi-directional optical fibre length	80 km
Attenuation constant	0.2 dB/km
BW (WDM MUX 4:1)	40 GHz
Dispersion	16.75 ps/nm/km
Dispersion slope	0.075 ps/nm2/km
Splitter ratio-XGPON	32
Modulation formats	RZ, NRZ,CSRZ, DB
OLT and ONU power	0 dB
Carrier frequencies	193.1, 193.2, 193.3, 193.4 THz

The CW laser has a line width of 10MHz and an output power of +2dBm. The MZM's output yields an optical signal.

In CSRZ transmitter, Modulation is carried out in two phases. The first Mach Zender Modulator performs phase or intensity modulation. The second MZM modulator receives a sinusoidal signal with frequency equal to half the bit rate. For the adjacent time slots, this applies a different optical phase between 0 to pi and as shown in Figure 1.3

The Duobinary transmitter is depicted in Figure 1.4. A precoder and a Duobinary pulse generator are initially used to create an NRZ Duobinary signal. A second modulator is then followed by the output of which drives the first MZM modulator.A sinusoidal signal is used to drive the second modulator.

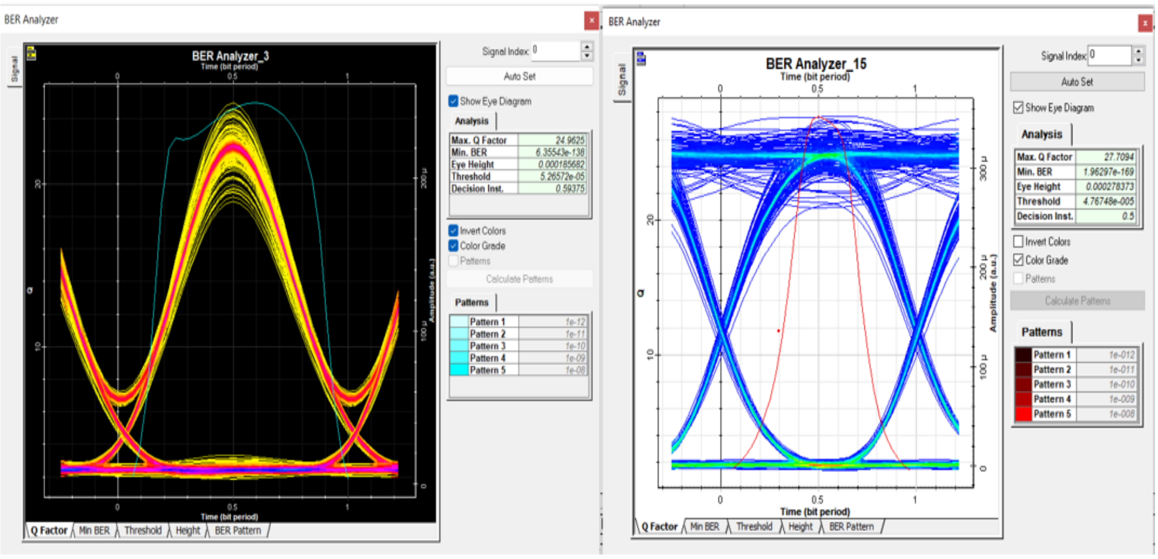
3.2 Software Tool Used

Optisystem20 For the design, testing, and optimisation of nearly any sort of optical link in the physical layer of a wide range of optical networks, from analogue video broadcasting systems to intercontinental backbones, there is an optical communication system simulation package called OptiSystem. OptiSystem is a system level simulator with a strong simulation environment and a genuinely hierarchical definition of components and systems based on the realistic modelling of fiber-optic communication systems. With the addition of user components and fluid interfaces to a variety of widely used tools, its capabilities can be quickly enhanced. The design tools OptiAmplifier and OptiBPM from Optiwave are compatible with OptiSystem.

From map design to transmitter, channel, amplifier, and receiver design to WDM network design and SONET/SDH ring design, OptiSystem supports a wide range of applications.A MATLAB component in OptiSystem enables users to access MATLAB from within the software in order to add additional models or components. The computations are carried out by OptiSystem using the MATLAB.dll files to assess the MATLAB script in the component.

Chapter 4

Simulation Results and Discussions



Signal Index: 0

Auto Set

☑ Show Eye Diagram

Analysis

Max. Q Factor	24.9625
Min. BER	6.35543e-138
Eye Height	0.000185682
Threshold	5.26572e-05
Decision Inst.	0.59375

☑ Invert Colors
☑ Color Grade
☐ Patterns

Calculate Patterns

Patterns

Pattern 1	1e-12
Pattern 2	1e-11
Pattern 3	1e-10
Pattern 4	1e-09
Pattern 5	1e-08

Signal Index: 0

Auto Set

☑ Show Eye Diagram

Analysis

Max. Q Factor	27.7094
Min. BER	1.96297e-169
Eye Height	0.000278373
Threshold	4.76748e-005
Decision Inst.	0.5

☐ Invert Colors
☑ Color Grade
☐ Patterns

Calculate Patterns

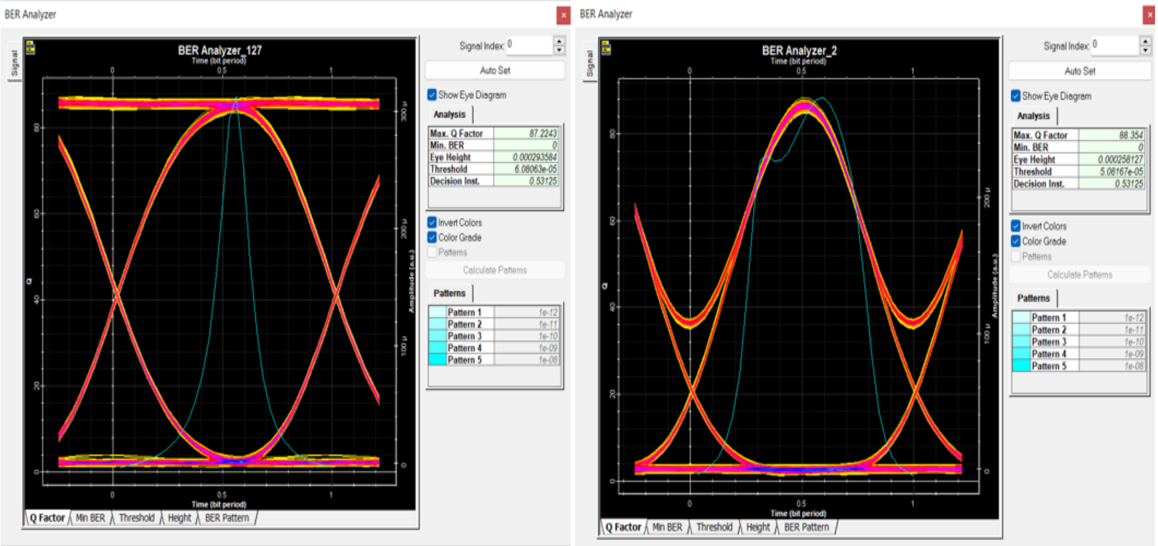
Patterns

Pattern 1	1e-012
Pattern 2	1e-011
Pattern 3	1e-010
Pattern 4	1e-009
Pattern 5	1e-008

Figure 4.1: The eye diagram of the proposed system with a) RZ and b) NRZ modulation format at 80 km fiber length

The eye diagram is used to demonstrate the signal quality received; the more open the eye diagram, the better the signal to noise ratio, and the less open the eye diagram, the worse the signal to noise ratio. The bit error rate (BER) measures the ratio of the transmitted signal to all detected errors in the bits at the receiver; the BER is inversely proportional to the system performance. The following eye diagrams as shown in Figure 4.1 and Figure 4.2 have been generated for each advanced modulation approach studied after running the simulation in OptiSystem 20 and connecting the circuits as shown.

This chapter's objective is to statistically assess various modulation format's per-



Signal Index: 0

☑ Show Eye Diagram

Analysis

Max. Q Factor	87.2243
Min. BER	0
Eye Height	0.000293584
Threshold	6.08063e-05
Decision Inst.	0.53125

☑ Invert Colors
☑ Color Grade
☐ Patterns

Patterns

	Pattern 1	1e-12
	Pattern 2	1e-11
	Pattern 3	1e-10
	Pattern 4	1e-09
	Pattern 5	1e-08

Signal Index: 0

☑ Show Eye Diagram

Analysis

Max. Q Factor	88.354
Min. BER	0
Eye Height	0.000258127
Threshold	5.08167e-05
Decision Inst.	0.53125

☑ Invert Colors
☑ Color Grade
☐ Patterns

Patterns

	Pattern 1	1e-12
	Pattern 2	1e-11
	Pattern 3	1e-10
	Pattern 4	1e-09
	Pattern 5	1e-08

Figure 4.2: The eye diagram of the proposed system with a) CSRZ and b) DB modulation format at 80 km fiber length

formance and determine which is best suitable for WDM-PON optical access systems. Figure 4.3 illustrates the impact of transmission link distance on BER in WDM-PON for various modulation styles. The maximum distance that each modulation format can reach with a BER of less than 10^{-9} is used to gauge the effectiveness of the transmission system. The WDM-PON system channel with the most vulnerable performance's BER values are used.

It was discovered during the simulations that bandwidth tuning of optical and electrical filters has a significant impact on the effectiveness of various modulation schemes. Because of this, it may be assumed that some modulation styles will perform better if a more effective set of filter parameter combinations is found.

The DB modulation format is used to reach the maximum transmission distance upto 120 kilometres with BER smaller than 10^{-9}. CSRZ exhibits the second-best outcome (maximum gearbox distance up to 97 km). This modulation type, in contrast to DB, can reach its maximum transmission length without boosting amplifier gain. NRZ, which can deliver data transmission over an optical fibre span that is 85 km long, displays the third-best result. With a maximum transmission distance of 72 km, the often used RZ only achieved the fourth best performance. With minimum BER its maximum transmission range is 70 km. RZ displays the worst outcomes, with maximum transmission lengths of 60 km. It can be explained by these formats' lower dispersion tolerance, as was already showed.

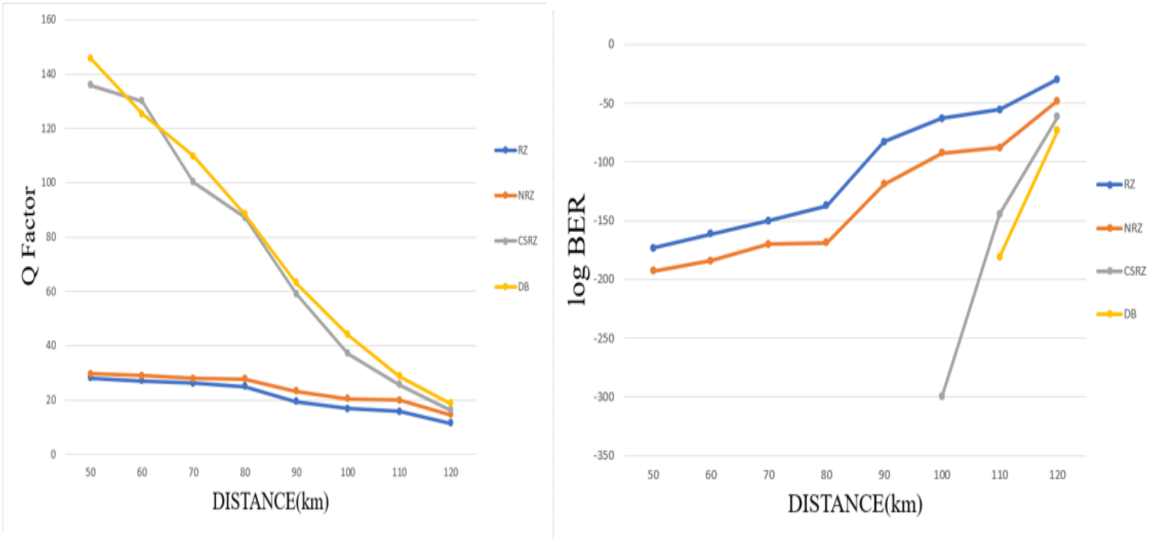


Figure 4.3: a) Q-factors and b) BER performance obtained by the system using different modulation formats for various transmission lengths

Table 4.1: Comparison of Q-factor and BER of the proposed system with RZ, NRZ, CSRZ, and DB modulation format(at 80 km fiber length)

MODULATION FORMATS	Max.Q-factor	Min.BER
RZ	24.96	6.355e-138
NRZ	27.70	1.094e-169
CSRZ	87.22	0
DB	88.35	0

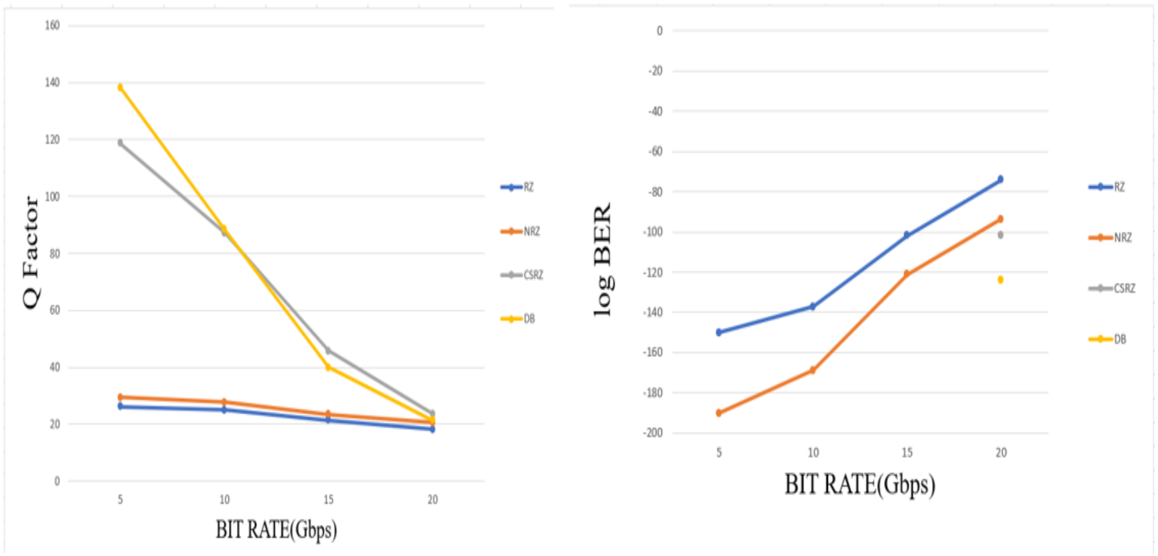


Figure 4.4: a) Bit rate(Gbps) v/s Q-factor and b) Bit rate(Gbps) v/s BER

Chapter 5

Future Scope

Depending on customer demand, the data rate per cell will eventually expand exponentially to a high data rate of one Terabit/second or higher. The transmission rate for each wavelength of WDM in the low dispersion optical window (1300 nm) is 25 Gb/s. Data rate is the key concern of the providers, and it is evident from Fig. 4.4, that OLT bandwidth will increase over time and reach a high of roughly 1Tb/sec using NG-PON in the near future. A rise in data rate demand will be better. Numerous FTTH technologies are widely used. With a vastly increased capacity employing various multiplexing methods (such as TDM, WDM, SDM, etc.). Our top priorities are to enhance capacity or bandwidth per user, reduce costs, and optimise the splitting ratio so that performance can soon be raised in response to end-user demand. Future WDM-PON deployments need to make use of PON infrastructures already in place to reduce installation costs and improve savings.

Furthermore, because OFDM-PON uses multi-carrier modulation techniques, it has attracted the interest of numerous research organisations. Using OFDM, which is compatible with Digital Signal Process (DSP) at the transceiver side, power fading can be reduced. Future studies could be conducted in the areas of MAC Layer (medium access control) and QoS (quality of service), among other things. Different factors, such as Power Budget, Bit-Error-Rate, Colourless ONU, Signal to Noise Ratio, and Rayleigh Scattering, can be taken into account at the physical layer. The various problems and difficulties have been described here, and an effort has been made to identify the research gaps and provide solutions that could be used to meet future demands.

Chapter 6

Conclusion

From the aforementioned experiment, it is reasonable to draw the conclusion with confidence that duobinary is superior to the other three methods for the various types of advanced modulation techniques, including RZ, NRZ, CSRZ, and DB, since it has the highest value of maximum Q factor of 88.35 and lowest value of minimum BER. RZ is the weakest of the three approaches since it has the highest minimum BER of 6.355e-138 and the lowest maximum Q factor of 24.96. The performance of CSRZ modulation is found to be comparable to that of DB based on the results. Therefore, as shown by the results, DB has the best performance for application in WDM-XPON systems.The proposed system with DB yields better results compared to systems with other Modulation Formats(RZ, NRZ, CSRZ). Using DB as Modulation format, we can increase the Transmission distance of the Optical Fibre. Here, obtained the maximum distance that each modulation format can reach with a BER of less than 10^{-9} is used to gauge the effectiveness of the transmission system.

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