*IOSR Journal of Electronics and Communication Engineering (IOSR-JECE)*
*e-ISSN: 2278-2834,p- ISSN: 2278-8735.Volume 13, Issue 6, Ver. I (Nov.-Dec. 2018), PP 11-18*
*www.iosrjournals.org*

# Evaluation of the Effect of Fiber optic Dispersion on a(XGPON)Next Generation passive optical network

Ajibodu,F.A ,Ojo, B.A
*Electrical Electronic Engineering Department Federal Polytechnic ilaro.*
*Corresponding Author: Ajibodu,F.A*

***Abstract:*** *The next generation passive optical network requires a network that can provide high capacity data to meet the increase rate for high speed data. The fiber optic media has low susceptibility to electromagnetic interference hence become a choice for high capacity network. The next generation passive optical network (NGPON) stage 1 defined and standardized by ITU-T, adopted 10G passive optical network (XGPON) has one of the standard capable of meeting the demand. This standard will be used for deployment of high capacity broadband networksand mobile backhaul which will enhance high speed connectivity. This architecture is not immune to loses or signal degradation due to dispersion (chromaticdispersion(CD) and Polarization mode dispersion (PMD)) which causes the signal to degrade as it travels over the fiber length due to pulse broadening. This paper investigates the effect of dispersion on an XGPON in order to provide a guide during practical deployment and suggest maximum bit rate that can be achieved at shorter distances of less than 10Km which is commonly found on metropolitan area. Amodel was setup using Optisystem simulator to observe the effect of dispersion on thearchitecture and also to obtain the maximum bit rate that can be achieved at shorter fiber length. The result obtained suggests that in the presence of dispersion XGPON can reach a maximum distance of 72Km within the acceptable bite error rate (BER) of $10^{-9}$ anda maximum bit rate of 27.5 Gigabit per seconds (Gb/s)at a distance of less than 10Km.*

---

Date of Submission: 09-11-2018 Date of acceptance: 24-11-2018

---

## I. Introduction

The rise in data consumption by subscribers of both fixed and mobile broadband drives the standard to move in order to meet with this challenge. The next generation access network(NGaccess) will provide a very high data rates over long distance to be able to cope with the growing demand for high capacity broadband network. This effort was initiated by The Full Service Access Network (FSAN) and the ITU-T/IEEE[2]. They propose The first, The next generation PON stage 1(NGPON1), which support a capacity of 10Gbit/s Upstream and downstream, which is now standardize by ITU-T has XGPON[1]. The optical access network will accommodate all kinds of information (voice, data, video, (triple play) multimedia 3-D) to be transported uniformly using packet based transport switching media[3]. Present trend[3] shows that future video service, such as high definition television (HDTV) will require higher data rate and guaranteed bandwidth and the next generation access network must be such that it can meet up this requirement or demand. It must be able to handle the convergence of voice, data and video which will suggest higher data rate and capacity[1]. The main objective of an optical access network is to provide access to the user(customer). This type of connection is commonly referred to as Fiber to the Premises (FTTP) or FTTX. A passive optical network is the most suitable to satisfy this demand for high capacity, speed, and lower cost, hence, it is not surprising that Next Generation access standardization is in this direction, Currently Time division multiplexing (TDM-PON) are dominant or majorly deployed such as Gigabyte PON(G-PON) ethernet PON (E-PON) in many part of the world[4]but in this system the bandwidth is shared among users.Today the present demand drives the need for higher data rate. Telecommunication interest groups such IEEE/ITU-T and FSAN has proposed next generation PON (NGPON)[4]. The next generation PON is divided into two as earlier mentioned NGPON1 and NGPON2. In this paper XGPON is investigated to evaluate its performance in the presence of dispersion at a distance of not less than 10km to 80km.

## II. Passive Optical Network System

Passive optical network(PON) allow the sharing of a single fiber link(feeder fiber) between many users, it provide a link without an active or electrically powered component, which in effect reduces installation cost of the fiber link and by extension reduces ongoing operation and maintenance cost[3]. PON operate by using a single or multiple wavelengths to carry downstream and upstream data and voice traffic, as well as video broadcasting traffic on a single strand of fiber[6].

## III. Pon Architectures

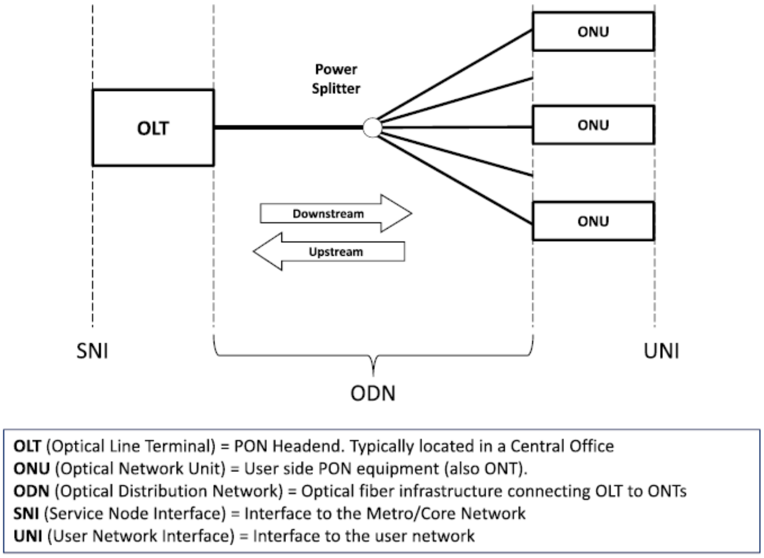



**Figure 1:** PON Architecture [2]

The key elements of the architecture as shown in Figure 1, are the optical line terminal(OLT) sometimes called PON head-end commonly found in the central office, the Optical network unit(ONU) commonly found at the subscriber premises and in between is the Optical distribution network (ODN), this is made up of fiber and optical power splitters[2]. The optical splitter divide the incoming input optical signal from the feeder fiber between a number of output fiber link or customer, this is in the downstream direction, in the upstream direction it combine all the input flow from the customer premises or fiber link into a single one optical signal over the feeder fiber link towards the central office direction[2]. The number of fiber link supported by a OLT port is the maximum splitting ratio and is limited by the power budget considerations[2] the structure of the optical distribution network(ODN) and the class of optics that are deployed determines the value of the maximum splitting ratio[2]. For instance, EPON and GPON specifications include nominal power budgets for each specific class deployed, which indicate the admissible power loss in the ODN. This in turn will limit the maximum power splitting and or the maximum allowable distance from an ONU to the OLT[5]. The Splitter introduce a splitting loss of 3n dB where n is the number of split

## IV. Fiber Link Impairment In Ngpon

This account for distortion experience in a fiber link as the light propagate along line. This impairment can be linear or nonlinear. Attenuation and chromatic dispersion actually account for the major effect of impairment as the light travel through the fiber link.

### CHROMATIC DISPERSION

This is as a result of non-zero spectra width of the optical source. This produce waves propagating at different group velocity which will in effect cause pulse broadening as the signal travel along the fibre link. It is made up of material and waveguide dispersion.

Material dispersion is a property of the fibre that due to the non zero spectra width of the optical source which then causes broaden of the signal pulse, that is effect of multiple lambda from the source.

Waveguide dispersion is due to non zero spectra width of the optical source which when travel along the fiber due to non-uniformity of the fibre changes the refractive index. It can also be caused by stress or bend on the fibre. These can be reduced by using a DFB laser source, due to its near zero spectra width.

### POLARIZATION MODE DISPERSION (PMD)

Polarization mode dispersion occurs when light signal travel in more than one mode that is each mode will arrive at the receiver at different time this occurs because practical fiber is not circular. The different in arrival times, normalized per unit length is known as PMD coefficient (ps/Km)[7]. The effect of PMD is that it limits the amount of transmission bit rate over a fiber link but it is not significant at a bit rate less than or equal 10Gb/s

**FOUR WAVE MIXING (FWM)**

Four wave mixing is a nonlinear effect that occur when signal co-propagate together in a fiber they mix together to form extra channels that can interfere and reduce the transmitted signal output power signal and increase noise in the system, total number of additional wavelength that can be created is given by[11]

$$FWM = \frac{N^2(N-1)}{N} \qquad (1)$$

Where N is the number of original wavelength[11].

## V. System Setup For 10gb/S Tdm-Pon (Xgpon) Investigation

The XGPON uses a wavelength range of 1575nm-1580nm [10]downstream in the L-band and the data bit rate is 10Gb/s downstream and 2.5Gb/s upstream. This design uses time division multiplexing, that is allocated time slot for each transmission ITU-T G987[12].

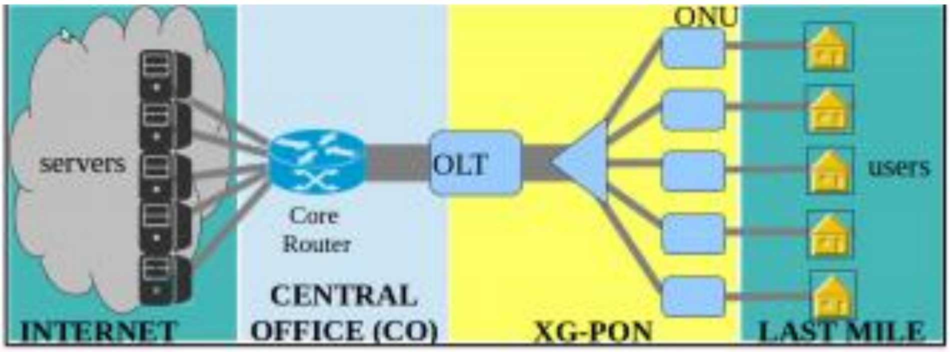



**Figure 2**: XG-PON [9]

The OLT is at the central office which is sometimes called the head end and the splitter with the fiber feeder is located at the optical distribution unit while the ONU is at the user end, each wave arrive at the ONU at a particular time slot[7]. In this model, the performance of XGPON will be investigated under varying length observing a minimum acceptable bit error rate of (BER) of $10^{-9}$, and recording its receiver sensitivity and power budget[9].

## VI. Simulation Setup

In this experiment using Optisystem version 13, the setup is shown in Figure 3,

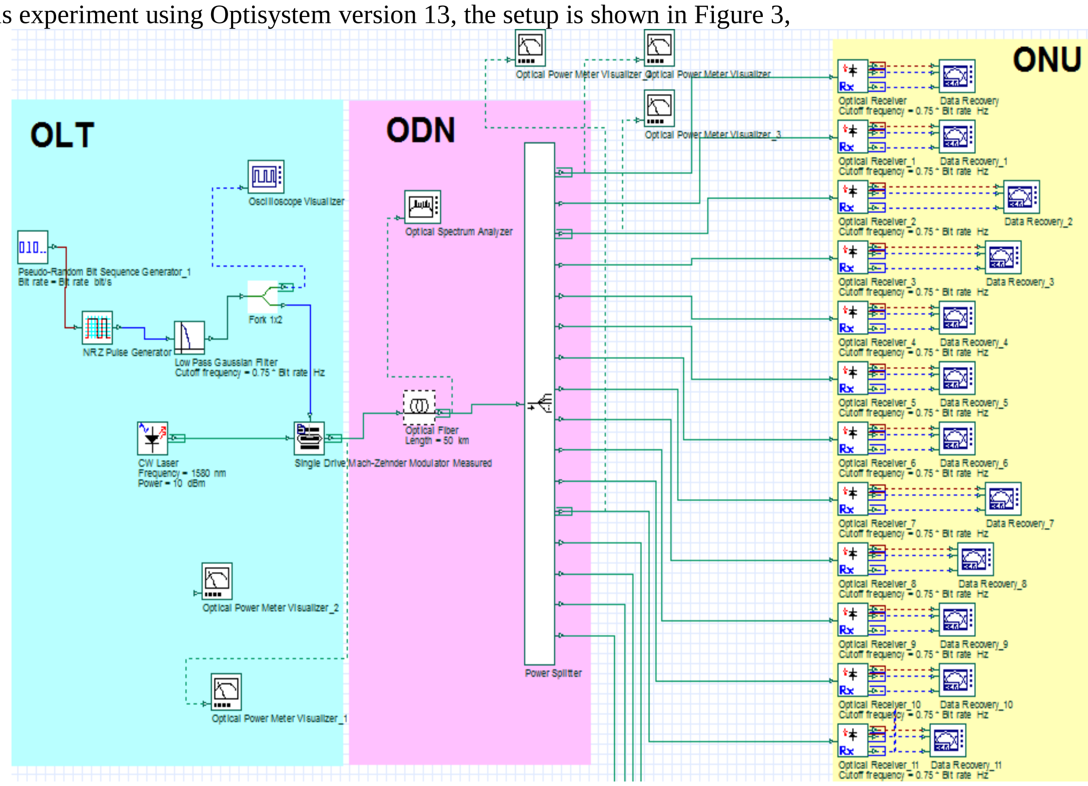



**Figure 3:** 10Gb/s TDM-PON experimental setup

In this setup, a wavelength of 1580nm downstream was used during this experiment has the wavelength of the laser source, at the OLT the PRBS Generator generates pseudo random binary sequence according to different operation modes. The order is 7 (that is $2^7$)making the sequence length 128, the generated data is applied to the laser bias input via NZR pulse generator, the NRZ Pulse Generator generates coded signal in the form of electrical pulses, the output of NRZ Pulse generator is connected to the electrical input of MZ modulator to drive the MZM. The CW Laser emits a continuous laser output, the optical signal output of CW laser is connected to the optical input of MZ modulator. The MZ Modulator provides external modulation [13] which is based on the principle of interferometry, the MZ modulator has extinction ratio of 30dB and k factor equals to -1; which mean an ideal intensity modulator with zero chirp. The optical signal is then modulated by data stream from PRBS and fed into an optical fiber feeder.

To reduce the effect of chirp a Mach-Zender modulator (MZM) was used to provide external modulation. The data is bein generated by a 10Gb/s Pseudo-random bit sequence generator (PRBS) which data is fed into a Non Return to zero generator and through a low pass filter before been fed to the Mach Zender modulator. The generated wavelength from the MZM is then pass through the fiber link leaving the OLT to the ODN and subsequently been splitted by a power splitter to each ONU [13].

**Table 1:** Simulation Parameters

| Parameter | Values |
|---|---|
| Modulator | MZM external modulator |
| Data rate per wavelength | 10Gb/s |
| Fiber attenuation | 0.2 dB/Km |
| Fiber type | SMF fiber |
| Distance | 10 - 80Km |
| Number of wavelength | 1 |
| Splitter loss (1:16 split ratio) | 14dB |
| MZM loss | 5dB |

## VII. Result And Discussion

The performance of the XGPON model above is evaluated by considering Eye diagram, BER and receiver sensitivity signal measurement.

**POWER BUDGET ESTIMATION OF DOWNSTREAM DIRECTION**

Power budget = Output power -Receiver sensitivity[14]
Output power = 10dB
Receiver Sensitivity at $10^{-9}$ =-36.9dB
Power budget = -46.9dB

**Table 2:** Power budget estimation downstream direction

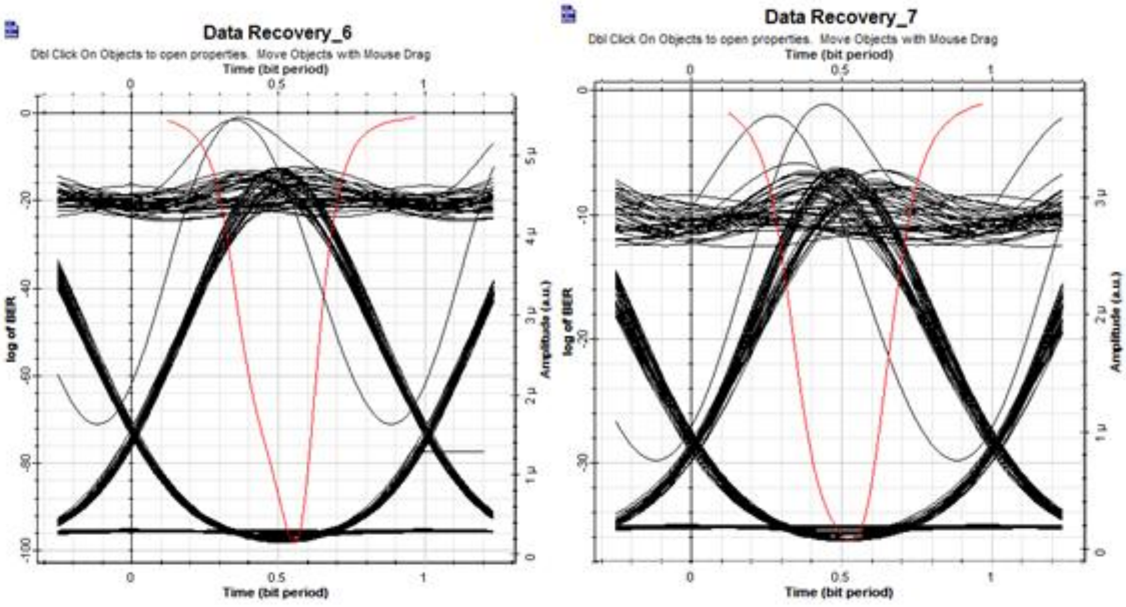
| Downstream | Output Power | Receiver Sensitivity at $10^{-9}$ (at 71.8Km) | Power budget |
|---|---|---|---|
| | 10dB | -36.9Db | -46.9dB |

**TOTAL LOSS BUDGET**

Total loss (dB)= Power splitter Loss + MZM Loss + Fiber loss (at 71.8Km that is $10^{-9}$)
=14dB + 5dB + (0.2 x 71.8)= 12dB + 5dB + 14.36dB
Total loss =33.36dB

**MEASURED BER PERFORMANCE FOR LENGTH 20-120Km FOR THE XGPON MODEL**

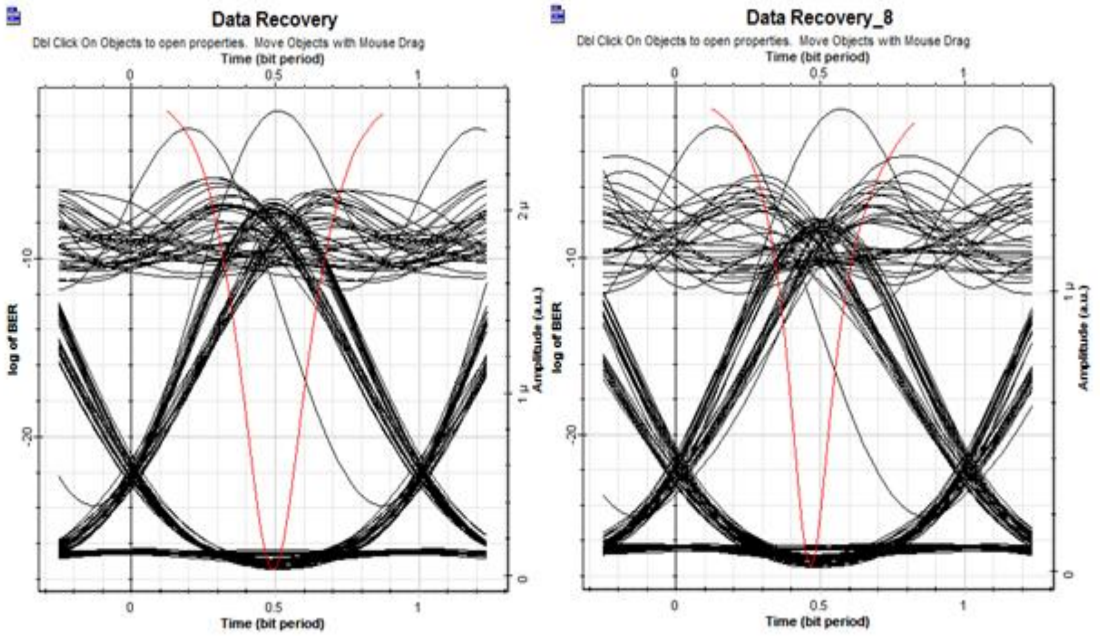
(Withchromatic dispersion and PMD)




(a) (b)

**Figure 4:** Eye diagram at (a) 20Km, (b) 30Km respectively

It can be observed that the eye diagram at 20Km is very open implying low inter symbol interference (ISI) and attenuation as can be seen by the equivalent measured BER value in Table 4, but at 30Km, we can observer a slight increase in inter symbol interference as shown in the upper region of the eye diagram in Figure 4(b)




(c) (d)

**Figure 5:** Shows the Eye diagram for fiber length (c) 40Km and (d) 50Km respectively

In comparison with Figure (a) at 20Km, the height of the eye is reducing and also more ISI is introduced at both 40Km and 50Km, a larger high height reduction is also observed at 50Km has expected. Due to increase in attenuation and broaden of the pulse signal propagating through the system.

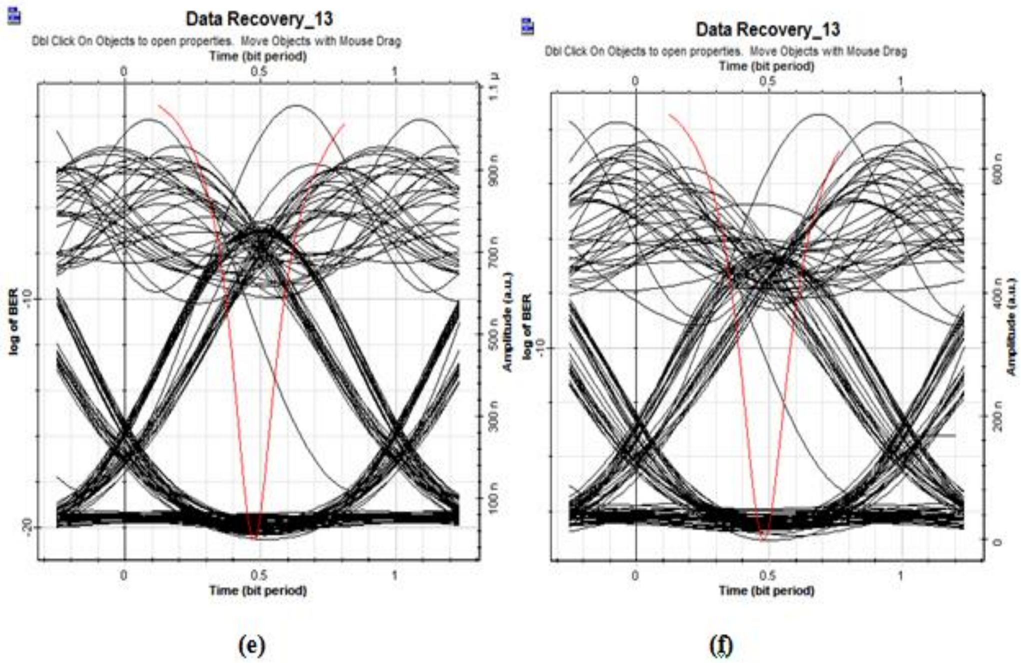



**Figure 6:** Eye diagram at (e) 60Km and (f) 70Km.

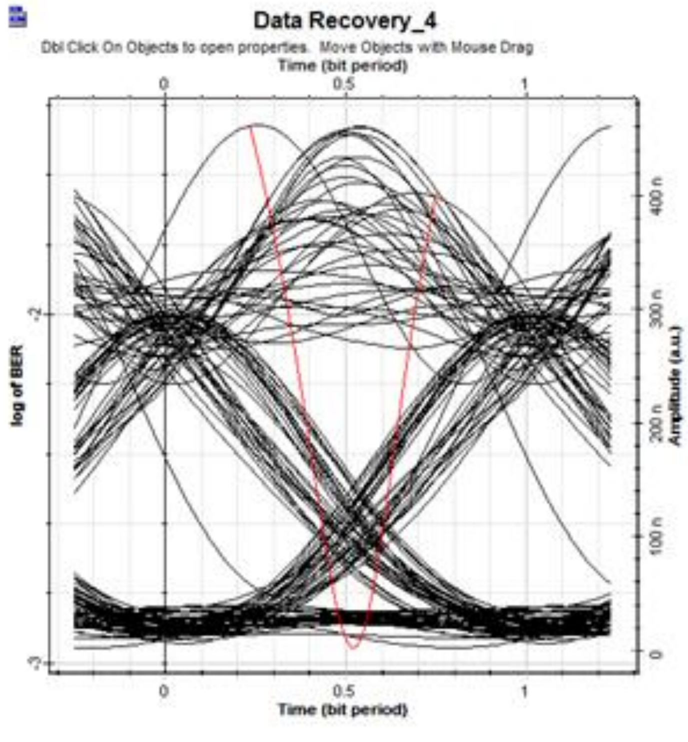



**Figure 7:** Eye diagram at 80km

The effect of attenuation and ISI has become very pronounce as can be seen at 60Km, 70km and 80Km also,a further reduction in the eye opening (eye height)

The eye height reduces and high increase in attenuation and inter symbol interference as depicted by the eye diagram. It was also observed that at this point, the BER value is below $10^{-9}$ acceptable BER Value as can be seen, any other value beyond $10^{-9}$ will result in a degraded system performance.

It can be observed that the same trend is maintained increase in inter symbols interference, and attenuation, the height of the eye become smaller, as can be seen in Figure (e) to (f) and in figure 7

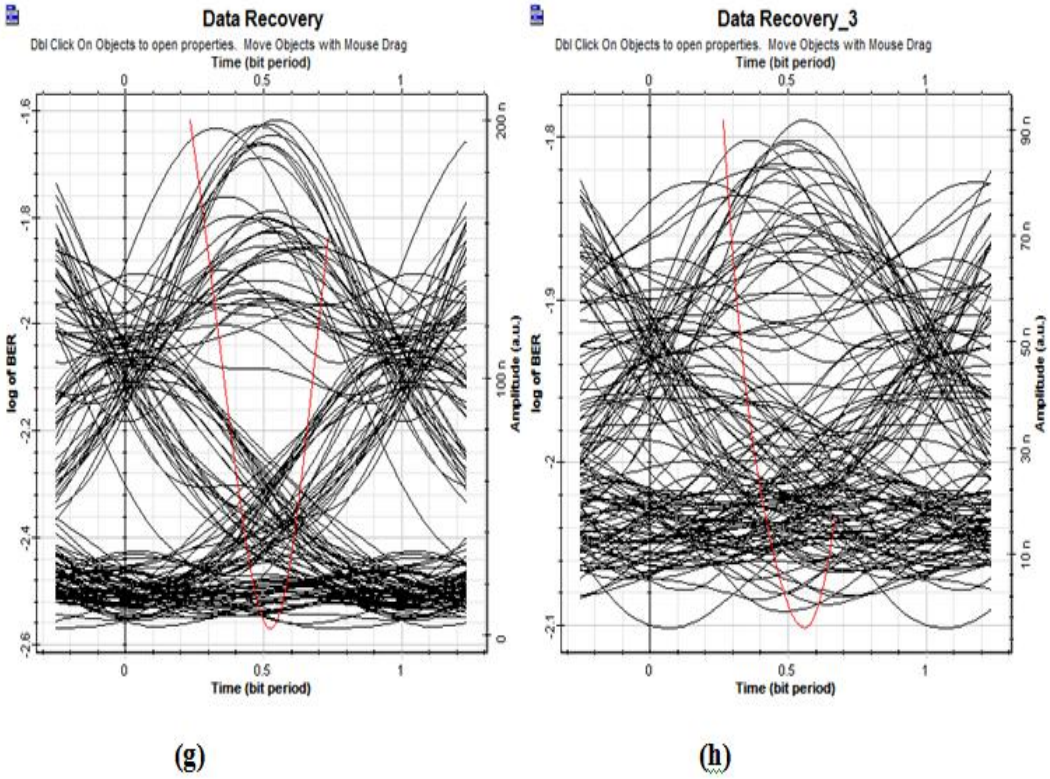



**Figure 8:** The Eye at (g) 100Km and (h) 120Km respectively

It can be observed at this point that the eye is completely close and hence not useable due to inter symbol interference and attenuation which translate to complete distortion or broadening of the signal pulse been transmitted in the system.

**INVESTIGATING THE MAXIMUM BIT RATE THAT CAN BE SUPPORTED BY XGPON**

In this experimental setup, the maximum bit rate that can be supported is determined by increasing the bit rate and reducing the distance to achieve a minimum of $10^{-9}$ BER. At each instance of increase in bit rate, the length is reduced to accommodate the increase until a minimum of 10Km (which is still acceptable) is achieved. Table 4 shows the result obtained.

**Table 4:** Measured maximum bit rate by the XGPON model

| Length | Bit rate Gb/s |
|---|---|
| 10 | 27.5 |
| 12 | 25 |
| 14 | 23 |
| 18 | 20 |
| 20 | 19 |
| 22 | 17 |
| 28 | 16 |
| 30 | 15 |
| 34 | 14 |
| 40 | 13 |
| 42 | 11 |
| 60 | 11 |
| 68 | 10 |
| 70 | 10 |
| 72 | 10 |

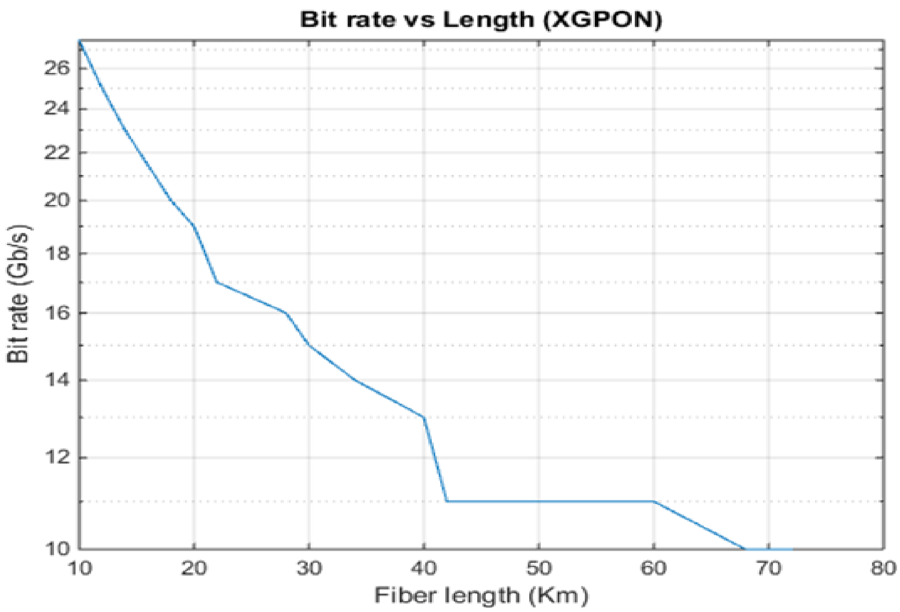



**Figure 9:** Plot of Bit rate versus fiber length.

## VIII. Conclusion

In this study, the performance of XGPON was investigated in the presence of dispersion at a fiber distance of 10km to 120km. The result obtained shows that within 10km to 80 km, an XGPON will perform within the acceptable BER of $10^{-9}$Inferring from Figure 4 to 8 and Table 4at a distance less than 80km the model exhibit a bit error rate ranging from $10^{-99}$ to $10^{-9}$ at a bit rate of 10Gb/s and acceptable minimum BER of $10^{-9}$. From the eye diagrams in Figure 4 to 8, It can be deduced that as the length increases, the height of the eye reduces meaning that more distortion of signal and pulse broadening as the length of the fiber increases.It can also be deduced from Figure 9 and table 4 that the maximum bit rate that can be supported by the XGPON model is 27.5Gb/s at a distance of 10Km.

## References


[1]. S. Bindhaiq,A.Supa'at, N. Zulkifli, A. B. Mohammad, R.Shaddad, M.A.Elmagzoub , A. Faisal "Recent development on time and wavelength-division multiplexed passive optical network (TWDM-PON) for next-generation passive optical network stage 2 (NG-PON2)" Optical SwitchingandNetworking15 (2015)53–6.
[2]. D. Nesset, "NG-PON2 technology and standards" vol 33, #5, IEEE March 1 2015.
[3]. "Gigabit-capable passive optical networks (G-PON)," ITU-T G.984.x specifications.
[4]. "10-Gigabit-capable passive optical network (XG-PON) systems," ITU-T G.987.x specification.
[5]. F.J.Effenberger, J.-I.Kani, Y.Maeda, Standardization trends and prospective views on the next generation of broadband optical access systems, IEEEJ.Sel.AreasCommun.28 (6)(2010) 773–780.
[6]. R. Yadav, "passive optical network base converged access network", Vol. 4, Opt Communication network IEEE, 2012.
[7]. D. van Veen, D. Suvakovic, H. Chow, V. Houtsma, E. Harstead, P.Winzer, and P. Vetter, "Options for TDM PON beyond 10G," presented at the Access Netw. In-house Commun., Colorado Springs, CO, USA, 2012, Paper AW2A.1.
[8]. S. Bindhaiq et al, "80-Gb/s Wavelength Stacked Time and Wavelength Division Multiplexing-Passive Optical Network for the Next Generation-PON Second Stage", Proc. of IEEE 5th International conference on Photonics (ICP), 2014.
[9]. P. Chanclou, A. Cui, F. Geilhardt, H. Nakamura, and D. Nesset, "Network Operator requirements for the next generation of optical access networks," *IEEE Netw. Mag.*, vol. 26, no. 2, pp. 8–14, Mar./Apr. 2012.
[10]. F. J. Effenberger, "10G PON - Explained," in Optical Fiber Communication Conference, OSA Technical Digest (CD)(Optical Society of America, 2010), paper OWX4
[11]. M.A. Elmagzoub∗, A. B. Mohammad, R. Q. Shaddad, S. A. Al-Gailani "Physical layer performance analysis of hybrid and stackedTDM–WDM 40G-PON for next generation PON", Optik 125 (2014) 6194–6197.
[12]. Full Service Access Network (FSAN). [Online]. Available: http://www.fsan.org/
[13]. R. Ramaswami and K.N Sivarajan, Optical Networks: A praticalPerpective, second Ed. 2002
[14]. Lilin Yi, Zhengxuan Li, Meihua Bi, Wei Wei, and Weisheng Hu," Symmetric 40-Gb/s TWDM-PON With 39-dB Power Budget", IEEE PHOTONICS TECHNOLOGY LETTERS, VOL. 25, NO. 7, APRIL 1, 2013.


Ajibodu,F.A. "Evaluation of the Effect of Fiber optic Dispersion on a(XGPON)Next Generationpassive optical network." IOSR Journal of Electronics and Communication Engineering (IOSR-JECE) 13.6 (2018): 11-18.