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Performance Simulation of a FTTH/GPON Optical Communication System for Different Lengths Using OptiSystem software

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Hamza A. Saoud
Libyan Center for Engineering Research and IT / University of Bani -Walid, Libya
hamza.fughi@gmail.com

Abstract

High-speed data transmission over long distances is a big challenge in the telecommunications world. Therefore, a reliable communication network is needed to provide this service to subscribers. Fiber optics is based on Fiber to the Home (FTTH / GPON) network, which is a fiber optic architecture that uses fibers as transmission channels to customers' homes or offices. In this proposed paper, the optical fiber analysis to the houses at different lengths (5-35km) presented and discussed. The transmission power was set to 5 dBm, from the results of the design optisystem tools, when the optical fiber length was 5km length the minimum bit error rate BER obtained = 0, where the length has been changed to 35km, the BER increased and the quality factor decreases gradually as the fiber length increases to reach the lowest value Q= 6.573 and BER=2.4589×10-1. FTTH / GPON technology can be applied for specific distances in cities where cost is reduced and data transmission rates are increased.

Keywords- FTTH; Optical Fiber; minimum bit error rate; GPON networks**.**

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محاكاة أداء نظام الاتصالات الضوئية للمنازل لأطوال مختلفة *FTTH/GPON* باستخدام برنامج *OptiSystem*

حمزة عبد السلام سعود

المركز الليبي للبحوث الهندسية وتقنية المعلومات / جامعة بني وليد

الملخص

يعد نقل البيانات بسرعة عالية عبر مسافات طويلة تحديًا كبيرًا في عالم الاتصالات، لذلك هناك حاجة إلى شبكة اتصالات موثوقة لتوفير هذا النوع من الخدمة للمشتركين. تعتمد الألياف الضوئية على شبكة الوصول من الألياف إلى المنزل، وهي بنية الألياف الضوئية التي تستخدم كابلات الألياف كقنوات الوصول بمنازل العملاء أو مكاتبهم. في هذه الورقة المقترحة، تصميم وتحليل الالياف البصرية الي المنازل بأطوال مختلفة (5 –35 كم) نوقشت وقدمت. تم ضبط طاقة الإرسال على 5 ديسيبل، من نتائج أدوات نظام محاكاة التصميم، عندما كان طول الألياف الضوئية 5 كم، تم الحصول على أدنى معدل خطأ بت منخفض صفر، تم تغيير الطول إلى 35 كم، زاد معدل خطا بت وقل معامل جودة الإشارة بزيادة اطوال الالياف. يمكن تطبيق شبكات الألياف الضوئية في المدن وبيئات العمل لتوفير حلول فعالة من حيث التكلفة وزيادة معدلات نقل البيانات.

الكلمات الرئيسية: الألياف الضوئية إلى المنزل؛ الألياف الضوئية؛ اقل معدل خطا بت؛ شبكات الألياف الضوئية السلبية.

I. INTRODUCTION

Fiber optic communication systems have been deployed since 1980[1] and have indeed revolutionized the technology behind telecommunications in order to meet the demands of higher band width for data traffic over long distance [2]. Optical fiber cable has low loss compared to electrical transmission lines. Optical fibers have many properties such as immunity, data security, and data reliability which are suitable for applications of optical fiber communication systems [3].

In modern access networks, these cables are used to transmit signals to subscribers with home access technology through switches and distributors at high transmission rates to enable subscribers to receive multimedia services. Therefore, fiber to the home (FTTH) cables achieve to meet the needs of users according to the increased bandwidth. The user on the FTTH will get more than 1.0 Gbps bandwidth [4]. PON access networks is the fact that only a single shared optical fiber can support multiple users through the use of inexpensive passive components where up to 256 optical terminals can share one fiber connection to the ends of the network. For upgrading their network performances, particularly in high-density urban areas [5]. The most obvious advantage of Passive optical networks (PON) is that a single shared optical fiber can support multiple users using inexpensive passive optical splitters. In GPON architecture, up to 64 ONTs [6]. Many researchers they published papers in this technology, A paper was presented by the researcher discussing the demand of high bandwidths by the customers due to introduction of new techniques had been discussed like Television (IPTV) and Video on demand (VoD) over internet in addition to High-Speed Internet access (HIS) [7,8]. Another article, had described Gigabit PON that can provide error free long-distance communication by using distributed Raman amplification for the distance of 60 km. (2017) article described a field implementation design for a GPON Network using computing tools such as GIS and Auto CAD [9,10]. In this paper, are to conduct a design of optical communications system at specified distances different lengths of optical fibers are used, and build simulation models using opti- system software's for evaluating and performance analysis of the optical signals transmitted over optical fibers in FTTH/GPON communication networks as shown in figure(1).

Then compare the simulation results and evaluate the quality factor, effect of loss and attenuation for selected lengths of the fiber to achieve the requirement of the customers of the network. This work can meet the requirements of modern construction of fiber optic networks within modern cities ensures optimal use of the fiber infrastructure.

1.1 FTTH/GPON fiber access network

FTTH deployment PON (passive optical network) networks (Figure.2) based on passive optical splitters to distribute bandwidth to each subscriber using fiber splitters that provide ratios of up to 1:64 or even 1:128, through it, it is possible to expand the frequency range for subscribers to meet the expansion of their networks and provide point-to-multipoint PMP communication.

Main components of OLT, ONU or ONT, the GPON system [11] are widely used in FTTH networks. The optical line terminal OLT is the main element of the communication network and it is usually placed in the local exchange. It is the engine that drives FTTH system. The optical splitter splits the power of the signal to number of users 1:32 ,1:64. In GPON technology the transceiver in the ONT is the physical connection between the user's premises and the central office OLT. Therefore, the use of GPON technology to provide data transmission speeds of at least 1.2 Gbit/s. It handles 1.24 Gbps upstream and 2.44 Gbps downstream data transmission.

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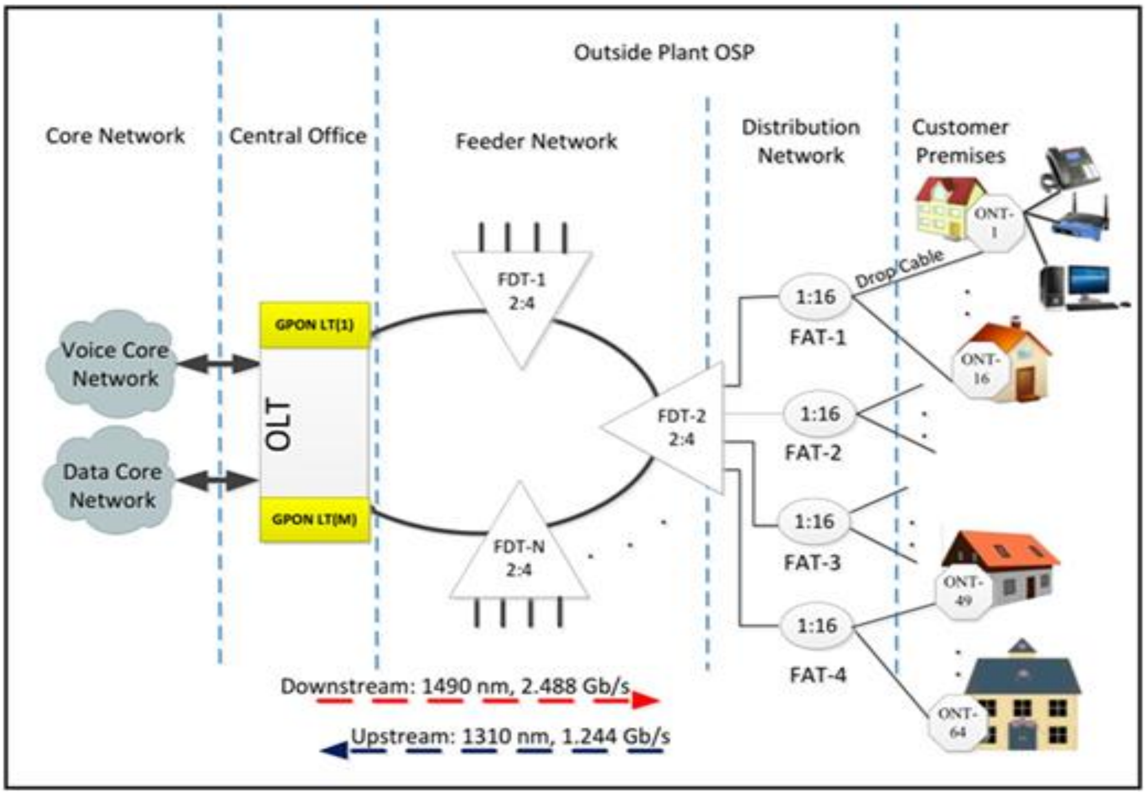

Figure:1 GPON/ FTTH access network.

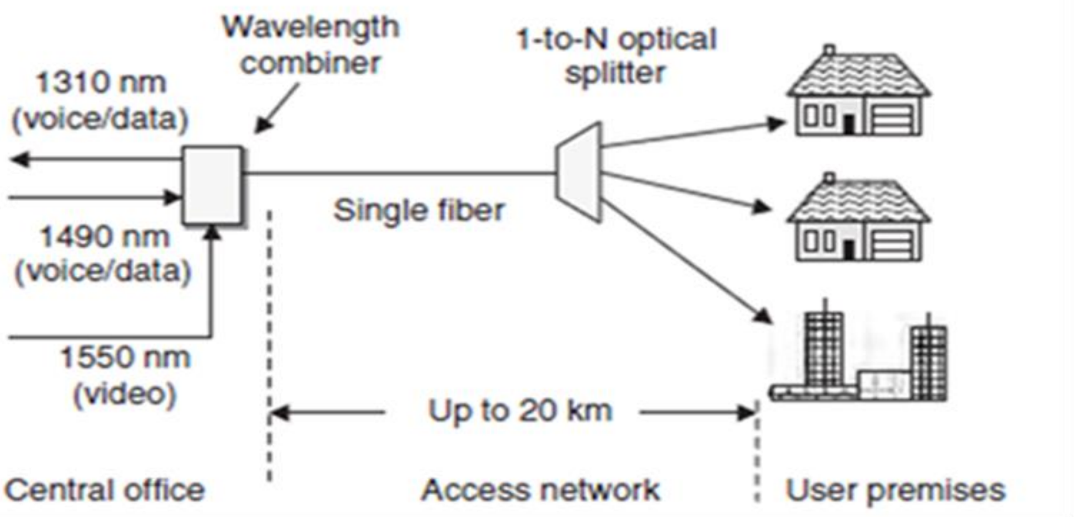

Figure 2: Shows architecture of a typical passive optical network [2].

From the international Telecommunication Union Telecommunication (ITU-T) and IEEE Institute of Electrical and Electronic Engineers standards for the standardization of PON networks as shown in Table I [12].

TABE I: International Network Standards Table.

Characteristics	GPON
Standard	ITU-T G.984 (2003)
Date Rate	2.5 up /1.25 Gbps
Wavelength	1310 up / 1490 nm
Splitting Ratio	Up to 1:64

II. GPON/ FTTH ACCESS NETWORK: SYSYEM DESIGEN

Opti system tools is a simulation program used to simulate the circuits and electronic devices that are used for designing and connecting the optical fiber e.g[13]. It supports a wide range of optical communication devices as fiber to the home, and Transmission line cost calculations used. This program includes passive optical network &active optical network (PON & AON).The figure 3 below shows light wave system desigen components.

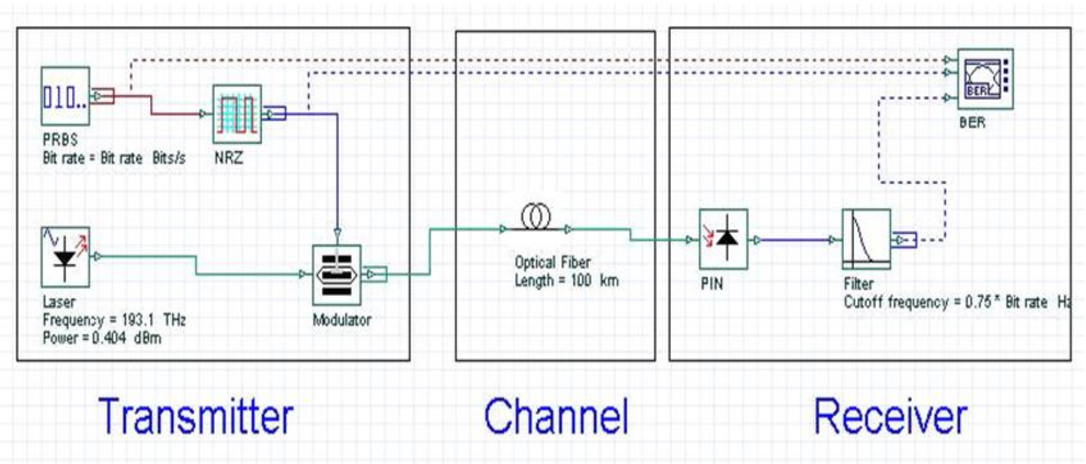

Figure 3: Light wave system components.

The transmitter takes electrical signals from the transmission sources and converts them into audio signals. The optical signals are then passed through the fibers to the receiving devices. The receiver converts the audio signals through the processors, which are read and detect error bits.

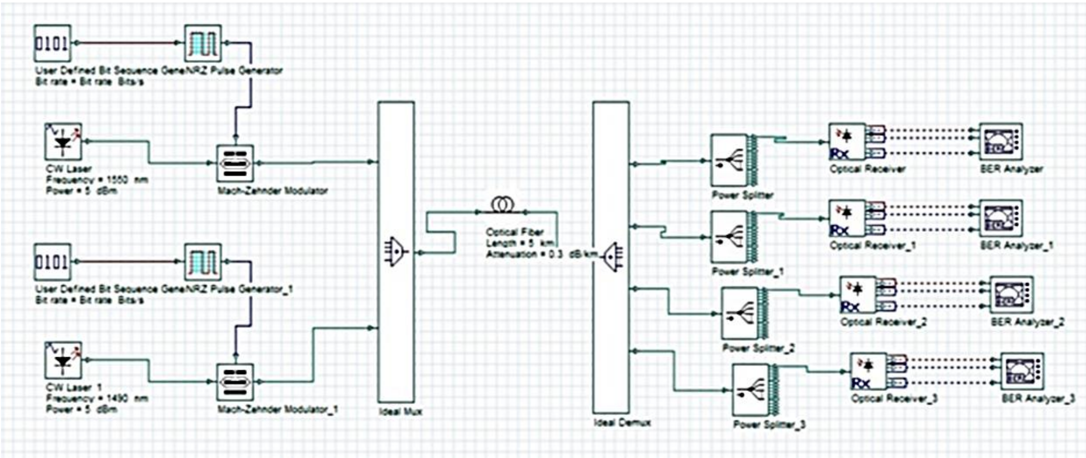

Figure 4: Shows a 2.5Gbps downstream FTTH/GPON simulation model.

Figure 4 is the designed model of the FTTH/ GPON optical transmission system for the downstream service. The simulation was conducted for several optical fiber lengths. These lengths are 5, 15, 25 ,30 and 35Km. GPON provides 2.5Gbps of bandwidth downstream shared by a maximum of 64 customers homes (GPON uses 2.44 Gbps downstream and 1.24Gbps upstream data transmission.). The signal wavelengths used are 1490nm for voice/data and 1550 nm for video (long distance). The GPON model assumes that the splitters are located close to all users that they provide the service to, so distribution and drop sections of the cables are short, and attenuation of the signal during its propagation through them is negligible, so in these points no simulators of the optical fiber were set. The transmission system was simulated for one transmission power value of 5 dBm. The optical fiber attenuation was set to 0.3 dB/km and the chromatic dispersion was set to 16.75 PS/nm/km**.**

III. Discussion of simulation results.

After running the simulation, several important parameters such as quality factor and Bit error rate (BER) were obtained. The light signals encounter several impairments, which cause degradation, and weakening of the signal level, this in turn limits the speed of transmission. This degradation exaggerates as the optical fiber becomes longer. The eye patterns for one user for the transmission distances of 5km, 15 km and 25km are shown in figures 5, 6 and 7 respectively. Note the distortion and noise in the received signals as the eye is closed in the diagram.as closure of the eye pattern**.**

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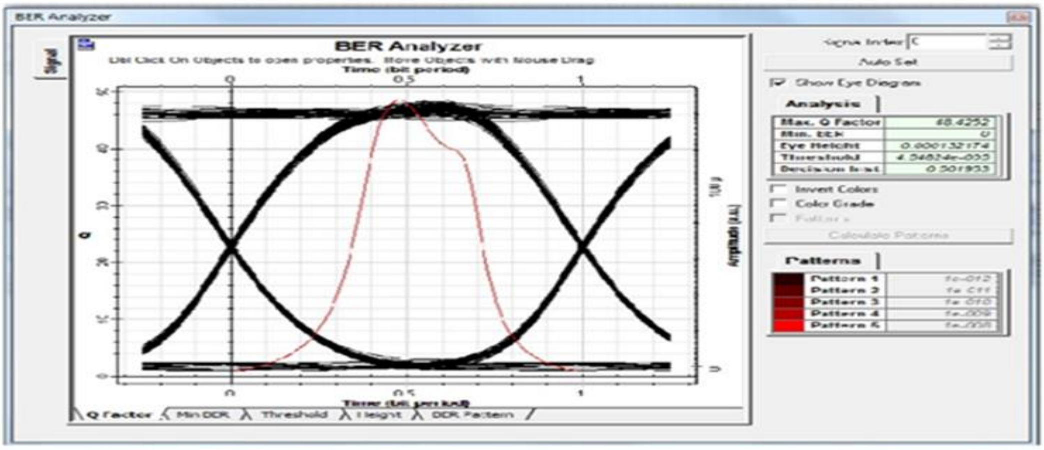

Figure 5: Eye diagram for a single user for 5km fiber length.

From Figure 5 it can be seen that the received signals have minimal signal distortion for a 5km optical fiber link, a good quality factor Q = 48.425, BER= 0 and a minimal amount of Jitter (time deviation from the ideal timing of a data bit event). Also, it can be observed that eye opening is at its largest where best sampling time is 0.501953 and a little overshoot which means that the wasted power is small. From simulation, at 5km a transmission has a BER of 0, meaning that, there are no errors in the transmission bits. From the figure Eye diagram is open ≥ good

From the figure 5,6,7 we noticed that the signal quality decreases due to the long distance used as a result of the loss in signals. For a workable satisfactory performance of the passive optical networks, the BER of 10-9 is the minimum acceptable BER [14].

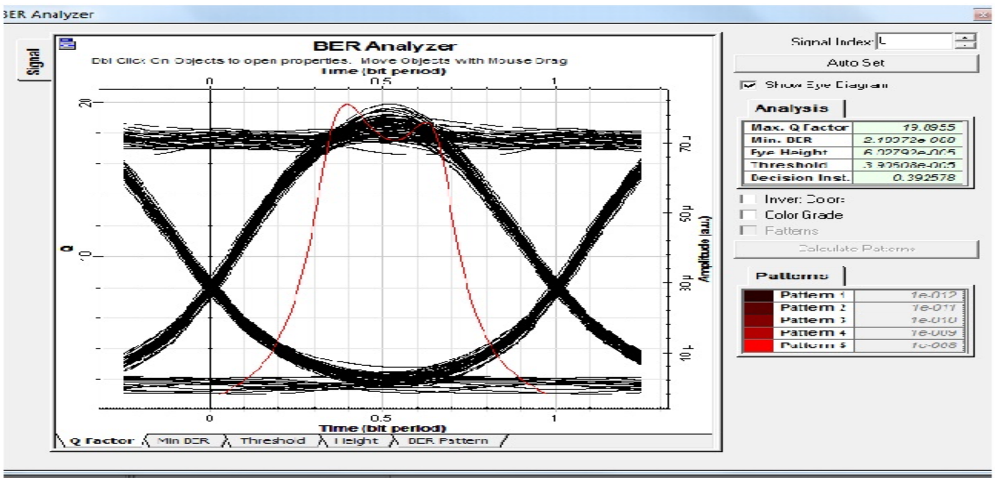

Figure 6: Eye diagram for a single user for 15/km fiber length.

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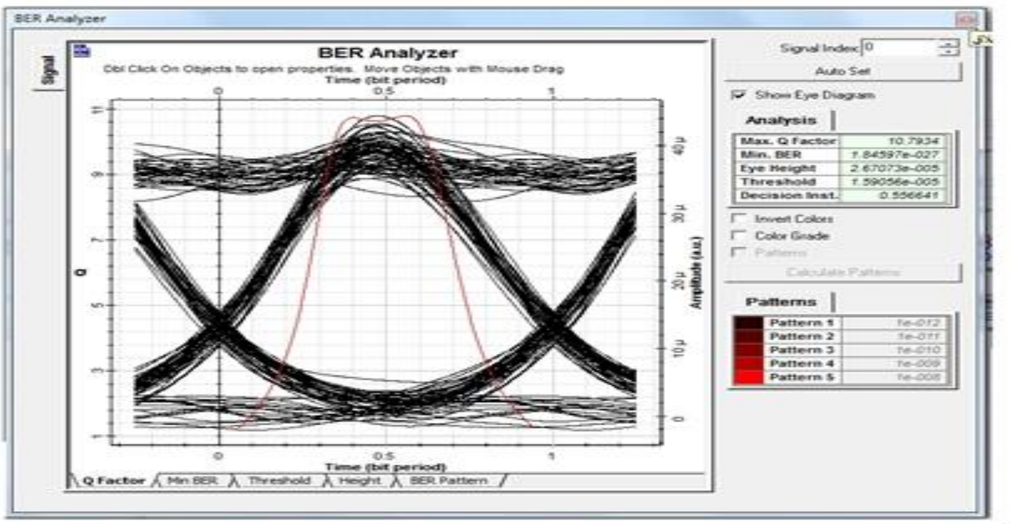

Figure 7: Eye diagram for 25/km a single user .

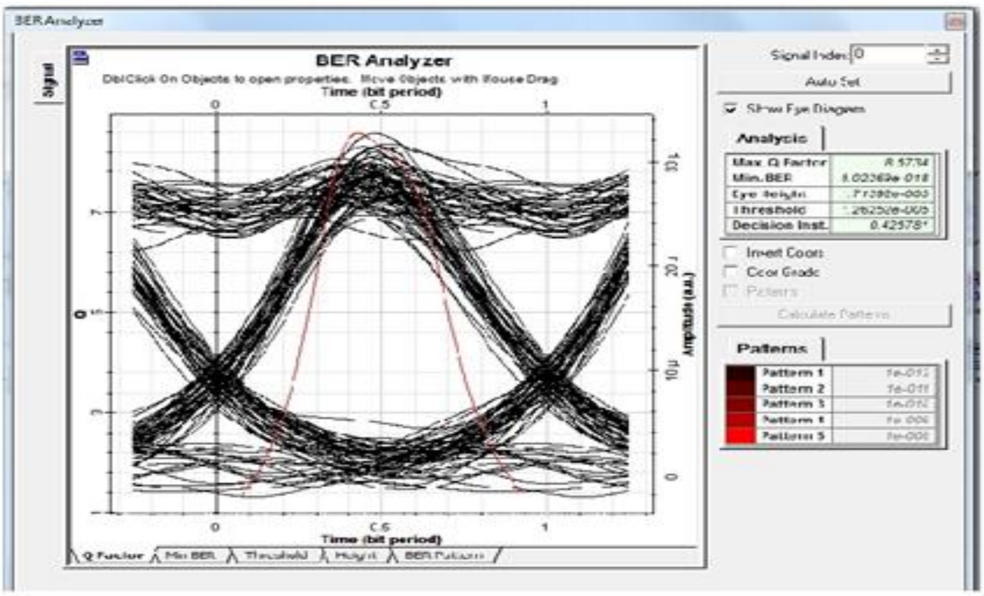

Figure 8: Eye diagram for a single user for 30km fiber length.

The eye diagram in figure 9 below, the result BER with maximum distance of 35 Km . We notice, when the optical fiber length was increased gradually to 35 km as , the power loss, attenuation and dispersion levels increased. This reduces the data rate and the BER becomes higher especially. (It indicates a number of incorrect bits). As the fiber lengths increases, the signal quality degrades hence repeaters and transmission amplifiers are needed at certain point. Reduced signal quality and transmission rates affect the performance of the optical fibers used when information transmission distances increase more than 30km. According to the figures, the distortion that we notice in the eye diagram is the presence of more than one signal inside the fibre, such that many signals reach the receiver that are difficult to distinguish and affects the sensitivity of its receiver and weakens its strength.

In general waveform distortion will cause inter-symbol interference, reduce the sensitivity of light receiving, and affect the relay distance of the optical communcation system.

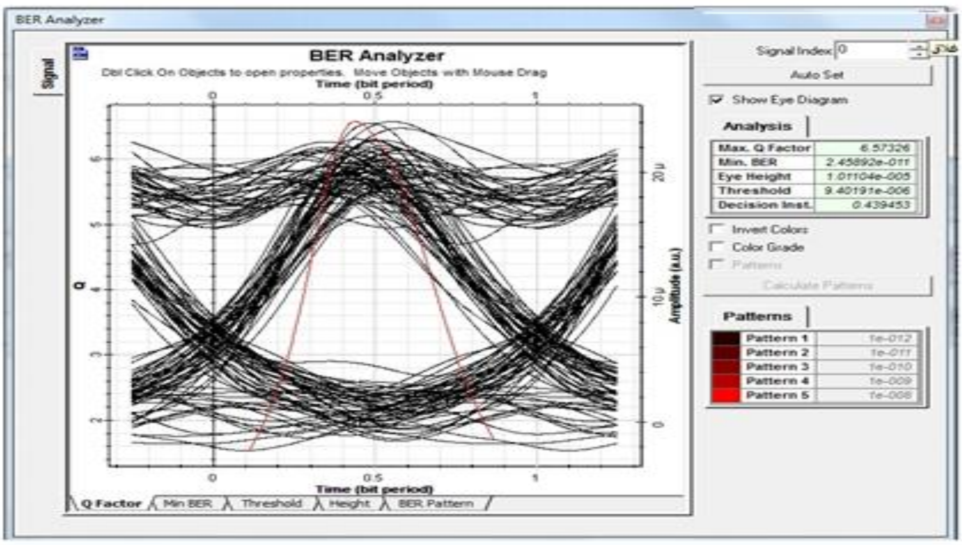

Figure 9: Eye diagram 1550nm for a single user for 35km fiber length.

We conclude that with increasing distance, loss and attenuation increase and the strength of the received signals becomes weaker as after a distance 30km the signal quality decreases, and at small distances at 15-20 km the performance of the signal and its reception is better and the dispersion is less.

Table II below, shows the simulation results with different fiber lengths.

TABLE II. Measured length comparison results

Distance / km	BER	Q/ Factor
5Km	0	48.425
15Km	$2.10 * 10^{01}$	19.09

25Km	$1.84 * 10^{-27`}$	10.79
30Km	$5.02 * 10^{18`}$	8.57
35Km	$2.45 * 10^{-11`}$	6.573

Based on the above Table II of system simulation output, with increasing the length of the fiber, the data transfer rate of the transmitted signal increases and the quality factor decreases due to the loss of capacity due to errors in the transmitted bit, which affects the quality of the received signal.

VI. CONCLUSION

Optical fibers are an excellent transmission medium that guarantees the arrival of a high-speed high-quality signals toward the receiver with the lowest loss in the amount of information sent. In this paper, a downstream FTTH/ GPON link performance of 2.5Gb/s bit rate was simulated. An Opti-system simulator of the GPON optical access network was designed for this purpose, which will help in the analysis and performance evaluation of the GPON technology without the need for building prototypes. The signal transmission in the GPON optical access networks fibers do not need amplifiers which are commonly used to carry light over distances of more than 60 km and without having to re-strengthen signals using repeaters. The effect of attenuation and dispersion that degrades the signals when transmitted over several optical fiber lengths. With a transmission power set to 5dB and using an optical fiber of 5km length with four splitters of 8 ports the BER obtained = 0 which is the ideal state of the optical fiber. The quality factor was maximum at Q = 48.425. It was found that the signal at these short lengths has a low dispersion and attenuation where the signal is received with a high-power value. also, when an optical fiber length is varied to 15kms, 25, and 30km, the BER increased and the quality factor decreases gradually as the fiber length increases to reach the lowest value Q= 6.573and BER=$2.45 * 10^{-11`}$ for the length 35km. This increase affects the received signal and increases the loss and attenuation. Finally, from the simulation results we conclude that these lengths are suitable for FTTH network and interconnection of fiber networks in cities without the need for signal amplification in the GPON optical access network. the GPON optical access network.

In future work can be performed by studying the other variants of FTTH passive optical network (PON) as XGPON systems.

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