Design and Performance Analysis of Fiber Optic Network System Using FUTA as Case Study

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Abstract- In this paper, an analysis of the performance of the fiber optic network system using FUTA fibre optics networks as a case study is carried out. Network Performance evaluation can be described as the measure of the service quality of a network. Performance evaluation of Fiber Optical Network using Federal University of technology, Akure (FUTA) as case study focuses on the quality of service the network will provide its users. This research evaluates the performance of Fiber Optical Network in the light of Power Loss, Bit Error rate (BER), and Q-factor. A network simulation software called OptiSystem was used to simulate the network design. The model design consists of a Transmitter at the central office, a distribution link and Receiver at the end user terminal. Different parameters were used to analyse the network design. The performance of the network was satisfactory.

Indexed Terms- PON, OLT.ONU, bit error rate, eye diagram, quality factor

I. INTRODUCTION

A computer network is built through the connection of two or more computers linked in order to share resources (software and hardware), exchange files, or allow electronic communications. Computers on a network are referred to as nodes and are linked via wired (coaxial cable, optical fiber or copper wire) or wireless (radio, microwave or infrared) technologies. Networks can be private or public, which may require the user to be granted permission to access the network or may be open to all users. Network can be categorised by their size or the geographical area they cover; local area network (LAN), is limited to a geographical area such a school or a building, while wide area network (WAN) connects more than one local area network, across cities or even across the world.

Fibre-optic communication systems are light-wave systems that employ Optical Fibres for information transmission. Fibre optics communication systems consist of three elements:

1. Optical transmitter
2. Optical fiber link
3. Optical receiver

Figure 1: Optical Communication System

PON consists of three main parts:

1. Optical Line Terminal (OLT)
   OLT is located at the service provider's central office. It provides the interface between PON and the backbone network and is responsible for the enforcement of any media access control (MAC) protocol for upstream bandwidth arbitration.
2. Optical Network Unit (ONU)
   The ONU is located close to the users. It provides the service interface to end users. It also works hand-in-hand with the OLT in order to control and monitor all PON transmission and to enforce the MAC protocol for upstream bandwidth arbitration.
3. Optical Distribution Network (ODN)
   ODN connects the OLT at the central office and ONUs close to the user. ODN consists of the distribution fibres and all the passive optical distribution elements, mainly optical splitters and/or Wavelength Division Multiplexing selective elements (WDM filters), that are located in sockets or cabinets.

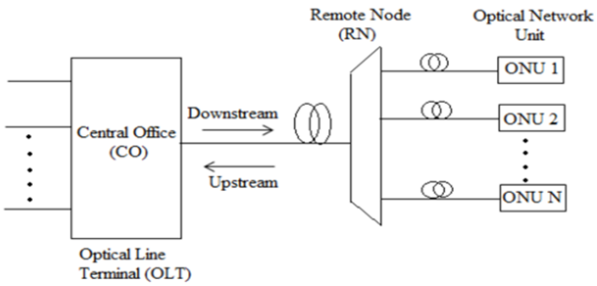

Figure 2: Diagram passive Optical Network

II. RELATED RESEARCH

Surbhi and Brintha (2014) presents Design and Performance Evaluation of Hybrid WDM/TDM Passive Optical Networks Using Star Topology. The motivation for the work is to use OptiSystem network simulator to design and carryout performance evaluation of hybrid wavelength division multiplexing/time division multiplexing passive optical network (WDM/TDM PON) system using the star topology architecture Optical Network.

The researchers used simulation method, to compare the performance of the hybrid wavelength division multiplexing/time division multiplexing passive optical network for the different data rates and distance by simultaneously varying the number of transmitters at OLT. They analysed the performance of hybrid WDM/TDM passive optical network using star topology in OptiSystem software and compared the various parameters. It has been observed that BER increases with the increase in data rate and distance and the quality factor and eye height decreases. There is much more scope for the further work so as to increase the number of users, achieve longer distances and simultaneously improving the performance of the network The limitation of the system is that it is time consuming and requires more cost when running.

Anjaley, John, and Gokul (2015) carried out Performance Evaluation and Simulation of OFDM in Optical Communication Systems. Optical Orthogonal Frequency Division Multiplexing is considered as a promising technology to satisfy the increased demand for bandwidth in broadband services. The objective of the research is to investigate the architecture of single channel and four channel direct detection and coherent detection optical OFDM systems and carryout performance analysis based on the bit error rate and the Q-factor. The researchers used simulation method to design an Orthogonal Frequency Division Multiplexing (OFDM) optical communication system, using OptiSystem. The limitation. It has been found that the single channel systems have a higher Q-factor and a lower value of BER when compared to 4-channel systems. Therefore as the number of channel increases Q-factor decreases and BER increases. When comparing direct and coherent detection systems, the latter one has a better performance. The performance can further be improved by using an equalizer before the receiver section. Also 16-QAM or higher bit rates may be used as transmission length increases to improve the signal quality.

Solanki, Gupta and Lavingia, (2016) carried out Simulation & Performance Evaluation of Optical Access Network Based on WDM–PON. The motivation for the work is that WDM-PON with its low energy consumption and huge bandwidth availability has been considered to construct an optical access network.The architecture of WDM-PON is been introduced and its performance characteristics is analysed. The WDM-PON architecture is a bidirectional high-speed system consisting of passive components such as circulators and MUX/DEMUX. The introduced system is used to obtain a system bit rate of 40 Gbps. To reduce the overall cost of the proposed system, the bidirectional multiplexed technique is used. Quality factor, bit error rate, and eye diagrams are derived for different transmission distance as well as at various input power level and then it is used to compare the results in order to select the transmission distance that gives the best performance. The pulse shapes used in this paper are non-return to zero pulse. Upstream and downstream data are analysed using bit error rate analyser.

WDM-PON with its low energy consumption and huge bandwidth availability has been proved as an efficient solution for the future access networks. In this paper, a bidirectional high speed WDM-PON is designed using single fiber based on circulator. A simulation and impact analysis is carried out As the power increases, performance gets better for longer distance. In addition, reasonable design of parameters i.e., input optical power helps to achieve better performance and reduce energy consumption and the cost.

The limitation is that it required more time and effort in designing the system.

Kumar et al. (2014) carried out Design and Performance Analysis of Optical Transmission System. The researchers discussed a simulated long haul optical transmission system over the single mode fibre which is prove to the linear chromatic dispersion as well as Non linearity. The objective of this work is to analyse the performance of two different modulation schemes i.e. RZ and NRZ modulation format at 10GB/s. RZ and NRZ modulation format is the scheme used to avoid inter symbol interference on an optical carrier wave for transmission over optical fibre. Each modulation method has its own advantages and disadvantages for the particular channel conditions. To do this, A radio over fibre system was designed and simulated using the OptiSystem software. The system performance based on RZ and NRZ formats were analysed taking into consideration subsequently, comparative analysis of the simulated designed system were carried out. The performance of RZ and NRZ based simulated optical communication system with single channel over single mode fibre is investigated. Based on modulated outputs of RZ and NRZ codes, a comprehensive comparison is developed in terms of Q factor BER , eye diagrams and average input power to establish the merits and demerits of the RZ formats in short as well as long haul optical communication system. The Observation through Q factor, BER revealed that R Z modulation has best performance for long distance optical communication system because of low Bit Error rate. NRZ is used for small distance communication system at low bit rates .An advantage of the NRZ format is that the bandwidth associated with the bit stream is smaller than that of the RZ format.

Singh and Sharma, (2018) carried out Performance Evaluation of Different Channels in Optical Communication Systems using Optisystem Simulator. It is recognised that increasing multimedia hungry applications requires high speed data transmission from source to destination. The recent advancement in optical technology such as WDM, DWDM and the recent orthogonal frequency based Elastic Optical Networks (EONs) have paved way for efficient resource allocations. This paper presents a comparative performance evaluation of three different optical channels single mode fiber, Free Space Optics (FSO) and optical wireless communication Channel (OWC) using non return-to-zero (NRZ) modulation scheme at 10Gbps. The performance of designed system is on the basis of Q-factor using Optisystem Simulator. The performance of three optic communication channels was evaluated using OptiSystem. For SMF and OWC, the communication range of 25, 50, 75 and 100km is taken. For FSO, the performance is evaluated at transmission range of 250, 500, 750 and 1000meter. From simulative results, OWC and SMF channel give the best results i.e. reduced the value of minimum bit error rate the best channel and increased the values of signal output power and the quality factor when compared with other channels FSO channel for long distance communication. It was noted that

Performance varies with range. Therefore junction boxes are required over long range distance.

III. DESIGN AND SIMULATION SETUP

Computer simulation plays a vital role in the process of engineering new technology and to understand the operations of the systems. The network simulator used to model the optical fiber network is "OptiSystem". With advancements in computer networks, optical communication system is increasing in complexity on a daily basis.

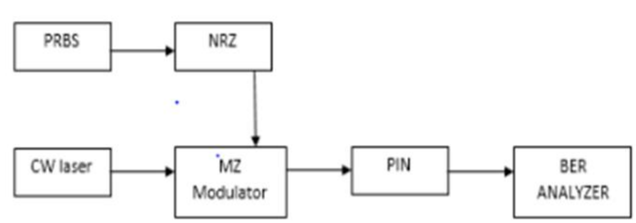

Figure 3: Schematic diagram of network setup

IV. SIMULATION SETUP

The system is divided into three parts; one is transmitter in constricted form, the Pseudo-Random Bit rate refers to message signal and non-return to zero, which translate the message to unipolar signal format and laser source, which originates laser and MECAH ZENDER modulator which modulate the electrical signal into optical signal.

Then signal goes to receiver, which consist of PIN (APD) with cut off frequency (0.75-bit rate). Finally, the signal is detected at BER analyser to observe BER, Q factor, Eye diagram.

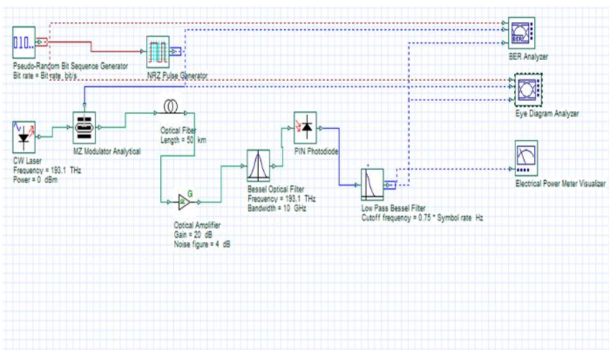

Figure 4: Simulated Network design

- PERFORMANCE PARAMETERS

I. Bit Error Rates

Error rates describe the number of bit errors in the number of received bits of the data in communication system due to noise, interference or distortion. In telecommunication transmission, the bit error rate (BER) is the percentage of bits that have errors relative to the total number of bits received in a transmission. Too high BER may indicate that a slower data rate would actually improve overall transmission time for a given amount of transmitted data so the BER indicates how often data has to be retransmitted because of an error.

$$BER = E/N \quad (1)$$

Where E is the Errors and N is the Total Number of Bits transmitted.

BER also defined in the terms of probability of error (POE) as:

$$BER = \tfrac{1}{2}(1-erf)\sqrt{Eb/N0} \quad (2)$$

Where erf is the error function, Eb is the energy in one bit and N0 is the noise power spectral density (noise power in a 1 Hz bandwidth).

II. Eye Diagram

The Eye diagram shows the superposition of all maturity overlapping bits in the signal. The Eye opening indicates the differentiability of the logic one from the logic zero. The more the Eye is widely open, the greater the differentiability is, because of this it is better signal to noise ratio. There are other readable parameters from this diagram like jitter which is the delay in sending packet data that varies over time. It can also be said that it is a variation in delays. Figure 5 shows the eye diagram.

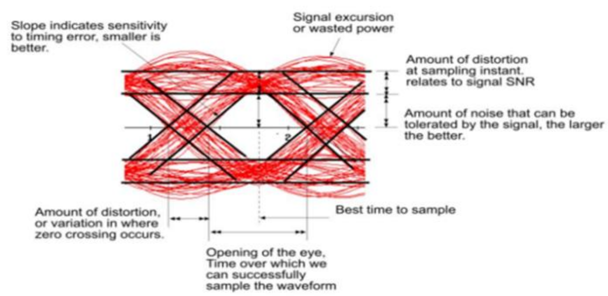

Figure 5: Eye Diagram Interpretation

III. Quality Factor

The quality factor represents the loss in energy of the signal. Maximum Q factor has less loss of energy.

Q-factor is a convenient measure of overall system quality provided when two SNRs can be combined into a single quality. There are only two possible signal levels in binary digital communication systems and each of these signal levels may have a different average noise associated with it. This means that there are essentially two discrete signal-to-noise ratios one is electrical SNR and the other is optical SNR, which is associated with the two possible signal levels. In order to calculate the overall probability of bit error, we must account for both of the signal-to-noise ratios.

Q factor defined according to the following formula:

Q= $((Ii - Io)/(\alpha i + \alpha o)$ (3)

Where Ii is a logic level "1", Io is a logic level "0", αi is a standard deviation of a logic level "1", αo is a standard deviation of a logic level "0". Figure 6 shows the Bit Error Rate versus the Q-Factor.

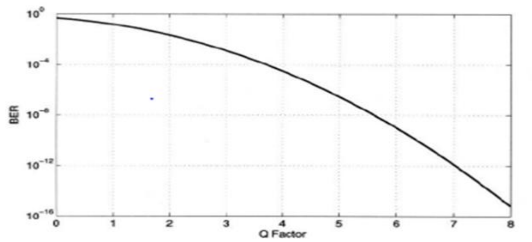

Figure 6: BER versus the Q-Factor Parameter

IV. RESULT AND DESCRIPTION

In this project, analysis of the parametric performance in optical fiber transmission is done using opti-system simulation tool. Q factor increases initially with launched power, reaches a peak value of 30dB.

Q FACTOR: Figure 7 shows the Q-factor

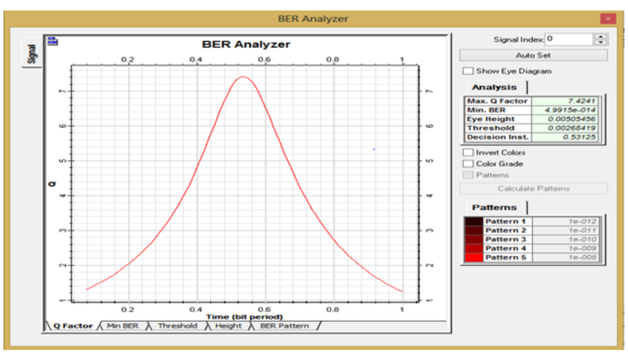

Figure 7: Q-Factor diagram

EYE DIAGRAM:The model eye-diagram

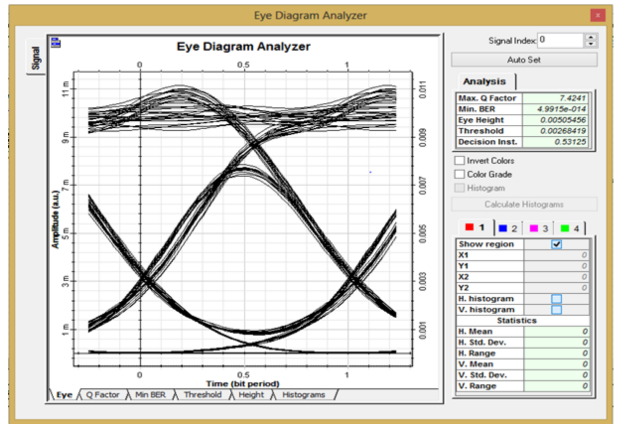

Figure 8 the model eye-diagram

BER ANALYSER

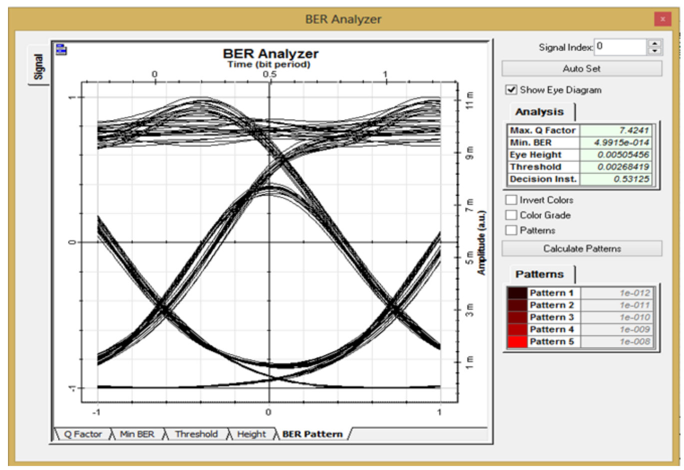

Figure 9: BER Analyser

POWER METER VISUALIZER

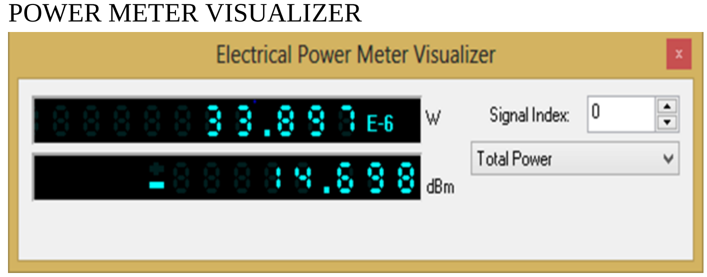

Figure 10 Simulation Result

PERFORMANCE WITH VARIATION OF INPUT POWER

INPUT POWER (dBm)	MAXIMUM Q-FACTOR
5	7.4241 7.72273
10	7.88342
15	9.32675

20	6.09093
25	3.1973

PERFORMANCE WITH VARIATION OF LENGTH

FIBER LENGTH (Km)	MAX Q-FACTOR
2	10.0384
4	10.5392
6	10.352
10	10.4966
12	9.63105

V. CONCLUSION

This research has successfully carried out performance analysis of Fiber Optical Network using FUTA as a case study. The work made use of a network simulator called OptiSystem-Optiwave version 15.2 to model and analyse the network. The study designed and analysed the network performance using the standard metrics such as bit error rate for optical fiber communication. The objective is achieved by using OptiSystem software program. Results were obtained. The parameters which were taken into consideration of the simulation are network, optical fiber length and power detection. The observation through Q factor, BER revealed that the lower the power input from the central office (OLT) the better the quality of service at the receiver (ONU).

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