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Research paper

Performance Analysis of Different Electrical Filters in 10G Hybrid Passive Optical Network

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Abstract

With growing number of applications and network traffic, optic fibers are extensively used in the access part of the network. Passive Optical Networks (PON) in particular, Ethernet PON (EPON) networks based on Time Division Multiple Access (TDMA) are more prominently used in many parts of the world. Though Wavelength Division Multiplexing (WDM) PON has its own advantages, considering the cost and utilisation of such networks in the access part makes it less useful. On the other hand, Hybrid PON network combines the advantages of both EPON and WDM PON Networks. The objective of this paper is to identify suitable electrical filters for a 16-channel Hybrid Passive Optical Network with a transmission rate of 10Gbps per channel, by analysing their performance in terms of Q factor and Bit Error Rate. Different filters like the Bessel filter, Gaussian filter, Raised Cosine Filter, Rectangular filter, Butterworth filter, Chebyshev Filter are compared and their performances are evaluated. DB Modulation format that provides a longer reach is used at the transmitter to evaluate the different scenarios and the simulation is carried out using Optisystem.

Keywords: *Access Network; Passive Optical Networks; WDM-PON; Hybrid PON; Electrical Filters*

1. Introduction

The part of the telecommunication network between the Central Office (CO) and a subscriber is known as the access network. Before the use of fiber, the CO and the subscriber were connected by copper cables which had a number of limitations. They had limited bandwidth and are less reliable. They also involved high installation time and high maintenance cost. Security was also limited and had higher electromagnetic interference. Later, Digital Subscriber Lines (DSL) was used to provide high bandwidth to homes and small business users, instead of copper lines. There were a number of variants of DSL such as ADSL (Asymmetric Digital Subscriber Line), HDSL (High Bit rate Digital Subscriber Line) and RADSL (Rate Adaptive Digital Subscriber Line), SDSL (Symmetric DSL), VDSL (Very High DSL). It enabled continuous transmission of motion video, audio and data at the rate of 1.544Mbps to 512Kbps downstream and 128Kbps upstream[1]. Though DSL offered more bandwidth, it was less, compared to the demands from HDTV, video on demand and internet telephony. A number of applications evolve day by day and the traffic in the access part also is growing with the emergence of different types of applications [2]. According to Cisco Visual Networking Index: Forecasting and Methodology 2016-2021, the Global Internet traffic in 2021 will be equivalent to 127 times the volume of the entire global Internet in 2005. Consumer Video-on-Demand (VoD) traffic will nearly double by 2021. The number of devices connected to IP networks will be three times as high as the global population in 2021. Annual global IP traffic will reach 3.3 ZB (ZB; 1000 Exabytes [EB]) by 2021[3].

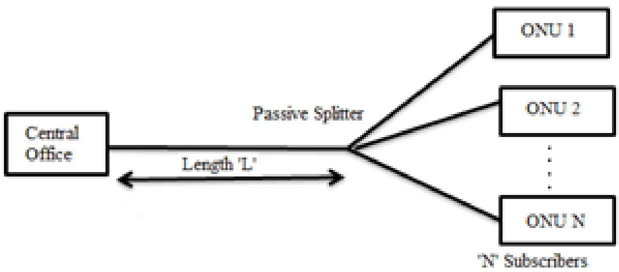

Figure 1: PON Network

As access network started to evolve using optical fiber, it seemed to be a probable solution to the problems that existed[4]. The access network which uses only passive optical components is called the Passive Optical Network (PON). It consists of a Central Office (CO) connected to a number of subscribers through the Optical Distribution Network (ODN). Fig.1 shows a PON Network. The Central Office comprises of the Optical Line Terminal (OLT) and the subscribers are called the Optical Networking Terminals (ONT) or the Optical Networking Units (ONU). All the elements used in the ODN are passive. The Optical Networking Unit (ONU) provides a number of services to the subscriber like voice, video and data services etc[5].

There are a number of advantages of using PON as it uses lesser fibre and the equipment in the Central Office is shared by a number of subscribers. Different variants of PON like the EPON (Ethernet

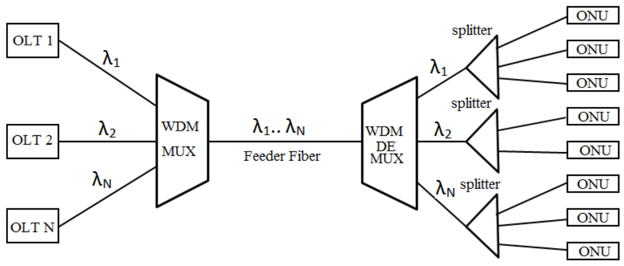

Figure 2: Hybrid PON Network.

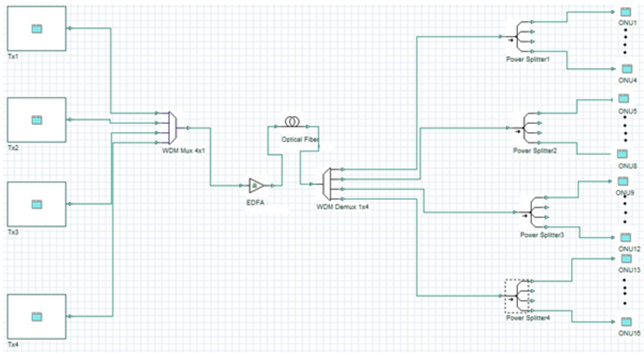

Figure 3: Hybrid PON Network with 4 transmitters and 16 subscribers.

PON), WDM (Wavelength Division Multiplexing) PON and the Hybrid PON exists. EPON is based on Time Division Multiplexing in which 1310nm is used for downstream traffic, 1490nm is used for upstream traffic and 802.3 frames are used for transmission. The signal is broadcasted downstream to all ONUs and the ONUs retrieve their specific information from the signal. In the upstream direction, Time Division Multiple Access(TDMA) based on Multiple Point Control Protocol (MPCP) is used[6]. In WDM PON, each user is assigned a specific wavelength for its upstream and downstream transmission [7]. This increases the complexity in the OLT and in the subscriber units. Enormous amounts of bandwidths is available but is unutilised by many ONUs. It also provides better security and achieves scalability[8]. The cost of the components and the initial set up cost is very high[9]. It is also susceptible to temperature variations. Hybrid PON combines the benefits of both EPON and WDM PON[10]. In Hybrid PON, a group of ONUs share a single wavelength and thus can combine the advantage and overcome the limitations of EPON and WDM PON[11].The Cost is shared by the subscribers in the network[12]. Fig.2 shows a hybrid PON Network.

Modulation formats, Optical fibers, Optical amplifiers and other optical components have been proved to play an important role to provide longer reach and higher spectral efficiency [13, 14]. A number of Low Pass electrical filters like the Bessel filter, Butter worth filter, Chebyshev filter, Raised Cosine filter, Rectangular filter, RC filter exist. This paper focuses on the study of the effect of the receiver sensitivity by using different Electrical filters in the receivers at the ONU. Section 2 specifies the commonly used Electrical filters and describes their characteristics, Section 3 discusses about the Simulation Model, Section 4 discusses the results obtained and Section 5 concludes the paper.

2. Electrical Filters

The Butterworth filter has a maximally flat response in the pass-band. In the stop-band it rolls off towards zero at -20dB per decade and at –40 dB per decade for a second order and so on. When compared to other filters like Chebyshev filter, they have a slower roll off and thus requires a higher order to implement a specific stop-band but ripple is absent. In pass-band and stop-band, it has a slightly non- linear phase response and a monotonic amplitude response in both pass band and stop band. The roll off is also quick around the cut off frequency and this is seen to improve with the order of the filter. In Chebyshev filters, roll-off is steep but more ripples are present when compared to Butterworth filters. Their property is that they can minimize the error between the ideal and the actual filter characteristic over the range of the filter. Bessel filter provides a maximally flat group delay or propagation delay across the frequency spectrum, but the rate of roll off from pass band to stop band is slow when compared to other filters of the same order. This is the most commonly used filter due to its linear phase characteristics. It doesn't give any overshoot for a square wave input as all the frequencies are delayed by the same amount. Gaussian filters are ideal filters that have a smooth transfer function without dispersion. They do not overshoot to a step function. It also has a minimum rise time and fall time. Rectangular filter has zero attenuation in pass band and has a random attenuation beyond the bandwidth. It is an ideal filter with a flat magnitude and phase response. Raised Cosine filter is used for the elimination of Inter Symbol Interference. Its impulse response is zero at all nT where n is an integer and T is the symbol period except n=0. Therefore if the signal transmitted is sampled at the correct instant in the receiver, the actual symbol values can be completely recovered.

3. Simulation Model

A Hybrid PON model was constructed for simulation. OLT which connects the access network with the core network houses the Central Office (CO) and the optical receiver is placed at ONU in the subscriber's premises. OLT consists of four optical transmitters. The Model consists of 4 channels for transmission. Duobinary (DB) Modulation is used in the transmitter as it provides longer reach[14]. The signals are multiplexed and sent through the Single Mode Fibre (SMF). The Optical Distribution Network also contains a WDM Demultiplexer and four passive splitters. Each of these passive splitters is connected to a number of ONUs. For the purpose of simulation, we have considered 16 ONUs and are shown in Fig.3. Each transmitter transmits at a rate of 10 Gbps and has the central frequency as 193.1 THz. The channel spacing is 100 GHz, according to ITU-T G.694.1 recommendation. An insertion loss of 3dB is provided by the multiplexer and demultiplexer. Transmitters employing Duo Binary (DB) Modulation format is shown in Fig.4. Duo binary modulation format is chosen as it has been proved to increase the reach of a WDM system [14-18]. It also provides a large dispersion tolerance and a narrow spectral width. It is also simple and cost effective. It uses a pre-coder and a duo binary pulse generator and an NRZ duobinary signal is first generated. The output then drives the first Mach Zender Modulator (MZM) modulator which is then followed by a second MZM modulator. To drive the second modulator a sinusoidal signal is used. At the ONU side, the receivers are constructed as shown in Fig.5. The receiver consists of a PIN Detector, Electrical Filter, 3R regenerator and the BER analyser. The Electrical filter block is replaced with Low pass filters such as Bessel Filter, Butterworth Filter, Chebyshev Filter, Gaussian Filter, Rectangular Filter, Raised Cosine Filter of order 4 and the simulation is carried out.

4. Results and Discussion

In this paper we have analysed 6 different electrical low pass filters with an objective to identify the most suitable electrical filter for Hybrid PON. The Bit Error and the Q factor is analysed for different lengths from 10Km to 100 Km for each of the electrical filter and is shown in Fig.6 and Fig.7. The BER of less than 10^{-9} is used for evaluating the performance of the network. The BER is plotted against the Length of the fiber. The BER patterns at 20Km, 60Km and 100Km length of fibres for the low pass Chebyshev filter are

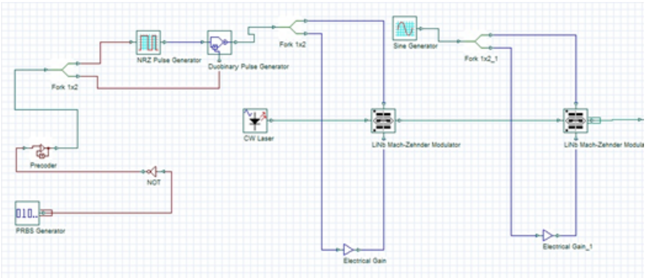

Figure 4: Optical Transmitter in a Hybrid PON using Duobinary Modulation Format.

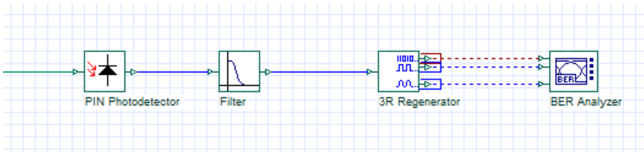

Figure 5: Optical receiver with Low Pass Filter.

shown in Figs. 8-10.

The DB modulation Format is used for the simulation purpose unlike the NRZ format used in literature. An EDFA of +20dBm output power is also used. The optimum length of EDFA was selected based on the optimisation results in Optisystem [19]. Chebyshev filter is found to give the best result when compared to all other filters for the DB Modulation format and can be used for long distances even up to 100Kms in a 10Gbps Hybrid PON network. It has a Q factor well above 6, up to 100km. Gaussian filter, Butterworth filter and Bessel filters can be used up to 95kms but their Q factor values are low when compared to Chebyshev Filter. Rectangular filter provides the worst result. The BER pattern for Butterworth, Bessel, Gaussian, Raised cosine and rectangular filters for a length of 60km is shown in Figs.11-15.

5. Conclusions

The maximum coverage distance depends on a number of factors such as the fiber type, light sources used, frequency of transmission and bandwidth. For simulation purposes, we had chosen a single mode fiber with a laser source and transmission of frequencies in the range of 1300nm to 1580nm. As it is a an hybrid network , the bandwidth is shared by a number of ONUs and this made it necessary to analyse the electrical filter's role in determining receiver sensitivity and hence the transmission distance of the fiber. Low pass

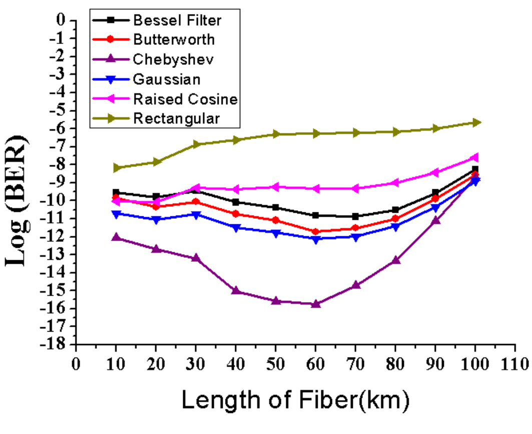

Figure 6: Length of Fiber vs. Log of BER.

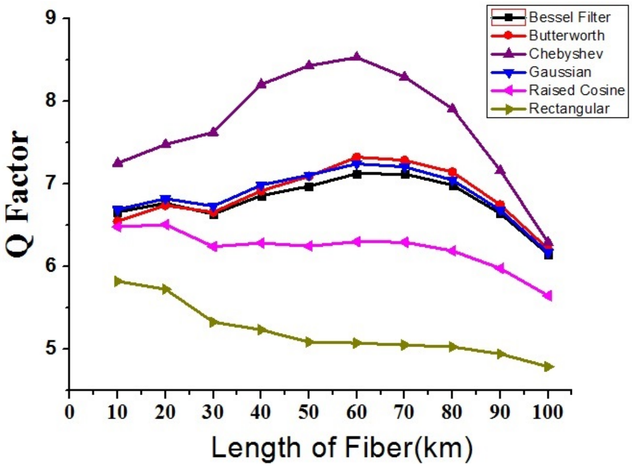

Figure 7: Length of Fiber vs. Q factor.

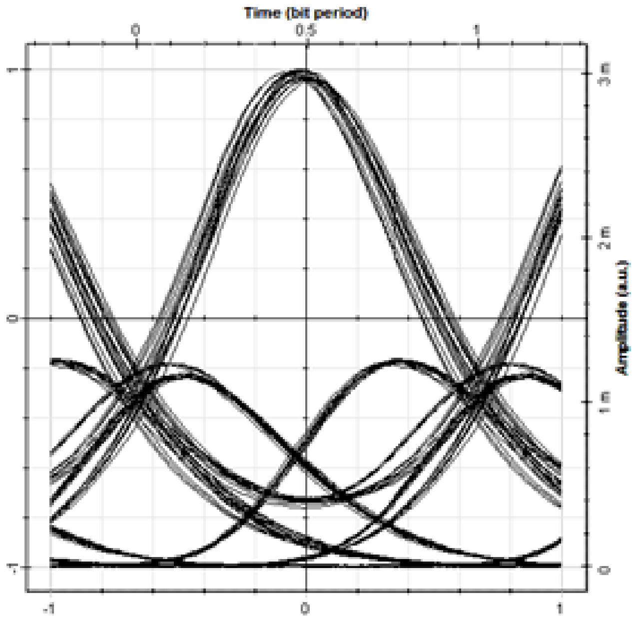

Figure 8: Bit error rate pattern of receiver with Chebyshev filter at 20Km distance.

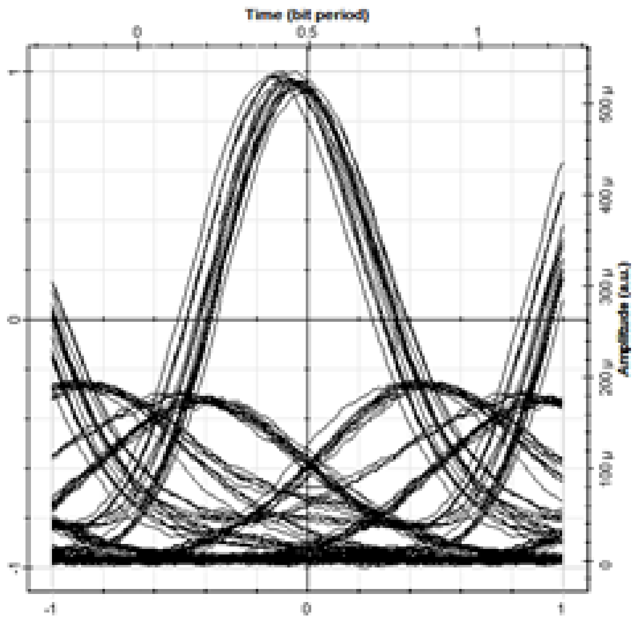

Figure 9: Bit error rate pattern of receiver with Chebyshev filter at 60Km distance.

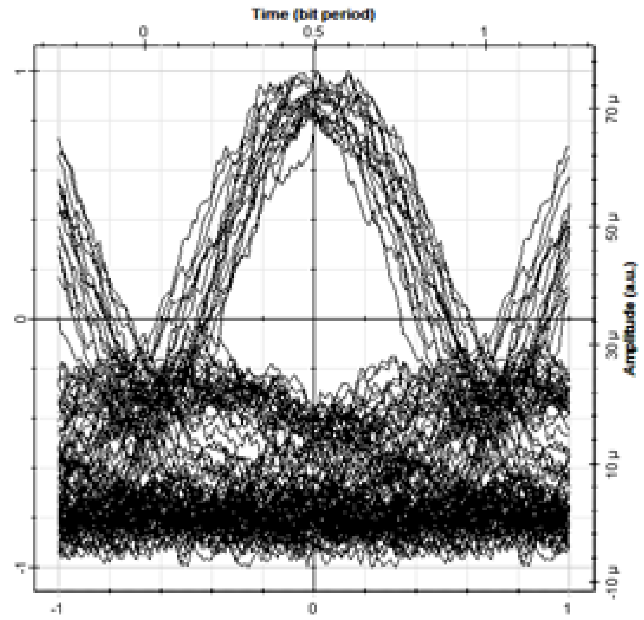

Figure 10: Bit error rate pattern of receiver with Chebyshev filter at 100Km distance.

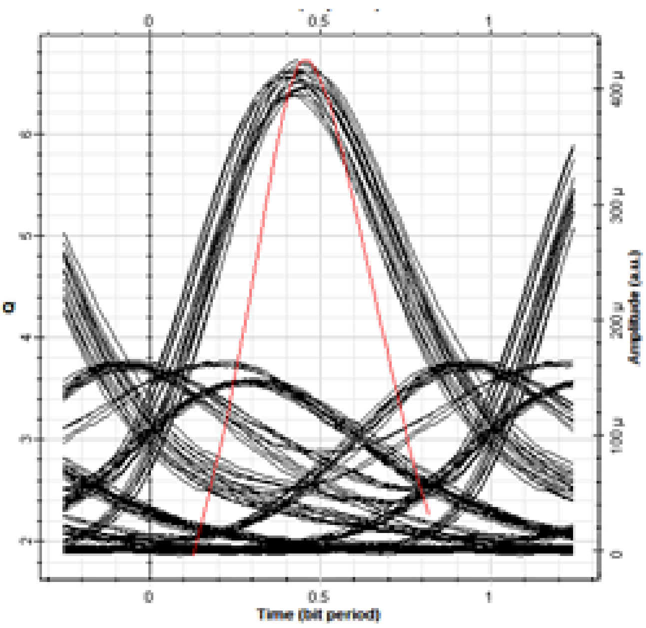

Figure 12: Bit error rate pattern of receiver with Bessel filter at 60Km distance.

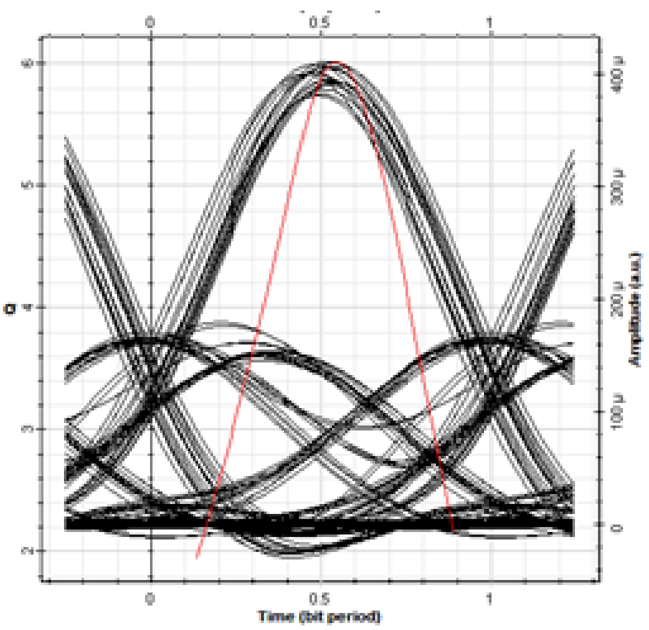

Figure 11: Bit error rate pattern of receiver with Butterworth filter at 60Km distance.

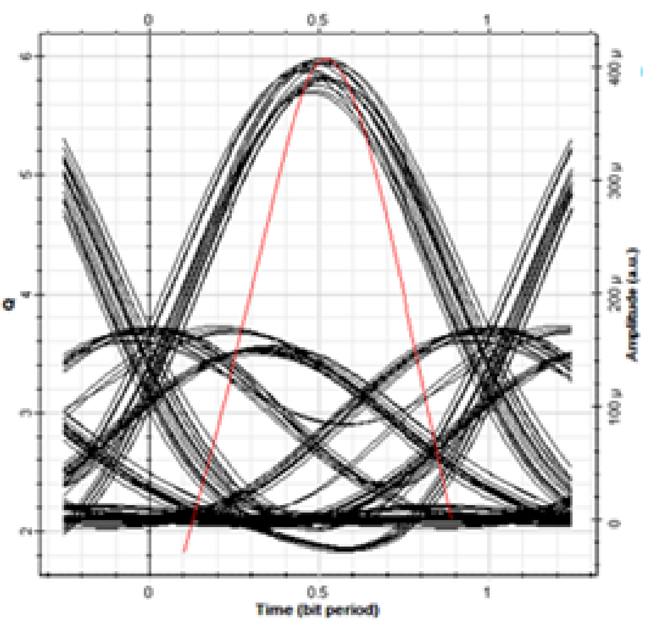

Figure 13: Bit error rate pattern of receiver with Gaussian filter at 60Km distance.

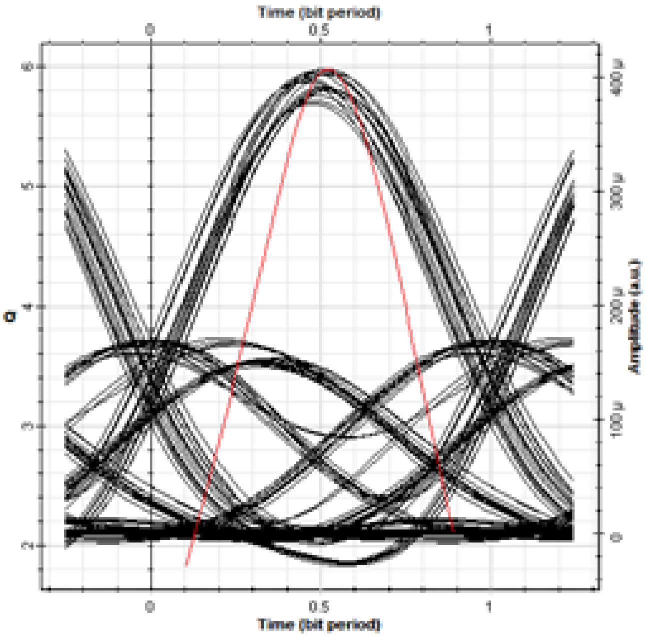

Figure 14: Bit error rate pattern of receiver with Raised Cosine filter at 60Km distance.

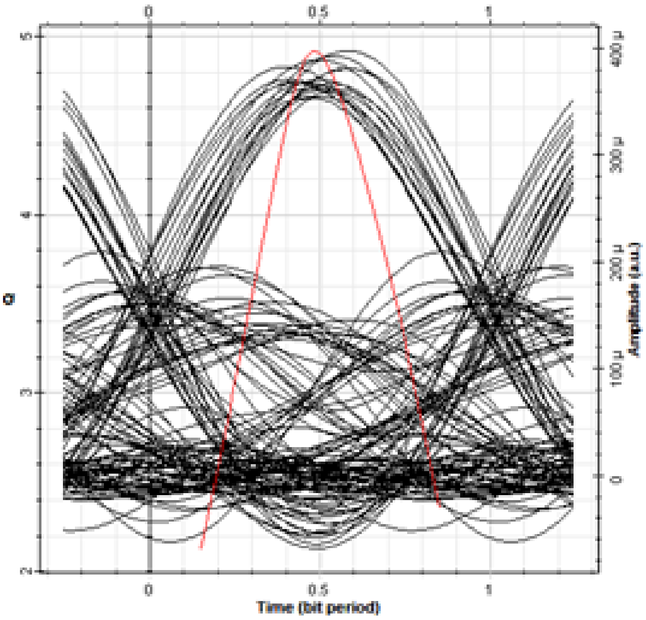

Figure 15: Bit error rate pattern of receiver with Rectangular filter at 60Km distance.

Chebyshev filter provides a superior performance over other filters in a hybrid PON. It helps to achieve the longest transmission distance of up to 100 kms with BER as low as 10^{-15} and Butterworth, Gaussian and Bessel Filter also fares good up to 95 kms.

References

[1] F.Effenberger, T.S. El-Bawab,Passive optical networks (pons): past, present, and future, *Optical Switching and Networking*, Vol. 6,No.3,(2009),pp 143-–150.

[2] G.Kramer and G.Pesavento,Ethernet Passive Optical Network (EPON): Building a Next-Generation Optical Access Network, *IEEE Communications Magazine*,Vol. 40, No.2,(2002), pp 66–73.

[3] Cisco,VNI, Cisco Visual Networking Index: Forecast and Methodology 2016–2021, (2017).

[4] F.Effenberger,G.Kramer, B.Hesse, Passive optical networking update [pon update], *IEEE Communications Magazine*, Vol.45, No.3, (2007),ppS6-–S8.

[5] Kramer, G., Mukherjee, B., Pesavento, G. , Ethernet pon (epon): Design and analysis of an optical access network, *Photonic Network Communications*,Vol. 3, No.3, (2001),pp 307-–319.

[6] Miyata, S., Baba, K.-I., Yamaoka, K. , Exact mean packet delay for delayed report messages multipoint control protocol in epon, *IEEE/OSA Journal of Optical Communications and Networking*, Vol.10,No.3,(2018),pp209-–219.

[7] K. Grobe, M.Eiselt,Wavelength Division Multiplexing: A Practical Engineering Guide,*John Wiley & Sons*,(2013).

[8] Banerjee, A., Park, Y., Clarke, F., Song, H., Yang, S., Kramer, G., Kim, K., Mukherjee,B. , Wavelength-division-multiplexed passive optical network (wdm-pon) technologies for broadband access: a review', *Journal of optical networking*, Vol.4, No.11,(2005),pp 737—758.

[9] Dhaini, A. R., Assi, C. M., Maier, M. and Shami, A. Dynamic wavelength and bandwidth allocation in hybrid tdm/wdm epon networks,*Journal of Lightwave Technology*, Vol.25, No.1,(2007), pp 277—286.

[10] Kramer, G., De Andrade, M., Roy, R., Chowdhury, P., ”Evolution of optical access networks: Architectures and capacity upgrades”, *Proceedings of the IEEE*,Vol.100, No.5,(2012),pp1188—1196.

[11] J.Kani, Enabling Technologies for Future Scalable and Flexible WDM-PON and WDM/TDM-PON Systems , *IEEE Journal of selected topics in Quantum Electronics*, Vol. 16, No. 5, 2010,1290–1297.

[12] Wong, E. , Next-generation broadband access networks and technologies', *Journal of lightwave technology*,Vol.30,No.4,(2012),pp 597–608.

[13] T.Ivaniga, P. Ivaniga, Comparison of the Optical Amplifiers EDFA and SOA Based on the BER and-Factor in C-Band, *Advances in Optical Technologies*, Vol. 2017, 2017.

[14] I. Kurbatska, S.Spolitis, V.Bobrovs, A. Alsevska, G.Ivanovs,” Performance Comparison of Modulation Formats for 10 Gbit/s WDM-PON Systems” , *Proceedings of Advances in Wireless and Optical Communications (RTUWO), 2016*,(2016), pp.51–54.

[15] E. Lach, W. Idler, Modulation formats for 100G and beyond , *Optical Fiber Technology*, Vol. 17, No. 5, 2011,377-386.

[16] R. Hui, S. Zhang, B. Zhu, R. Huang, C. Allen, D. Demarest, Advanced optical modulation formats and their comparison in fiber-optic systems , *The University of Kansas and Sprint Corporation, USA*, 2004.

[17] D. Lavery et al, A comparison of modulation formats for passive optical networks, *Optics express*, Vol. 19, No.26,2011, pp B836–B841.

[18] J. Latal, J. Vitasek, P. Koudelka, P. Siska, R. Poboril, L. Hajek, A. Vanderka, V. Vasinek,” Simulation of modulation formats for optical access network based on WDM-PON” , *Proceedings of 16th International Conference on Transparent Optical Networks (ICTON). Graz*,(2014), pp.1–7.

[19] J.Taylor,S.Tanev, Photonic simulation software tools for education, *Education and Training in Optics and Photonics,Optical Society of America*, (2007).