Investigation of Mode Division Multiplexing, Long Reach PON using RoF Technology

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Abstract— **Multiplexed PONs are very scalable and through this method flexible network architectures are possible. In this project, the system proposes a downstream link, using the radio over fiber (RoF) technique in PON network architecture. The PON downstream traffic is handled by broadcasts from the OLT to all connected ONUs. The system uses the mode division multiplexing architecture combined with RoF technology, and compare the performance of network for, several data rates of 25 km optical fiber. To increase the capacity LRPON is used and the outputs are referred. The performance analysis is based on eye diagrams, constellation diagrams and BER. Variations in multiplexing techniques are done and the results are analyzed. Passive components highly control the noise and the results are investigated. Optisystem software is used for simulation. These results can be extended for future applications of optical control unit in non-linear studies.**

Index Terms **- PON, Passive, ONU, MDM, Downstream, LRPON, BER**

I. INTRODUCTION

Time division multiplexing (TDM) and wavelength-division multiplexing (WDM) are examples of parallel transmission which have been successfully employed in single mode fiber system[1,2]. To further increase the number of parallel channels mode division multiplexing technique is exploited[5,6,7,9]. There has been a steady increase for the demand of broad-band services and hence the consequent increase in the volume of generated traffic in our communication networks. The system may have the potential for the integration of the in-built wireless networks with the fiber access networks Radio - over -fiber technology (RoF) which allow it to use as direct transmission of radio frequency (RF) through the fiber without the need of frequency conversion at the receiver. Whilst these first generation PONs offer significant bandwidth increases compared to copper-based approaches, they may not provide the best ultimate solution for service providers seeking to significantly reduce the cost of delivering future broadband services to residential and business customers in order to sustain profit margins. As a result research attention has recently turned to more radical network solutions based on new types of optically amplified, large split (~1000), long reach (~100km) PONs (LR-PONs), which are designed to allow individual customers to directly access bandwidths of up to 10 Gbit/s upstream and downstream [10,12,14]. These LR-PONs would replace the separate metro and access portions of the current network with a single, integrated, all-optical communication system[13,14]. The power loss budget of optical distribution network significantly increases by complete suppression of the reflection noise. This is achieved by using passive components. In this project, we use the MDM- PON architecture combined with RoF technology, and compare the performance of network for 8-DPSK and 16-QAM digital modulation, for 25 km optical fiber[1,5,8]. New business models based on novel telecommunication technologies continue to dramatically change the way people live and work nowadays.

II. RADIO OVER FIBER

Radio over fiber (RoF) refers to a technology where light is modulated by a radio signal and transmitted over an optical fiber link to facilitate wireless access [3]. In RoF systems, wireless signals are transported in optical form between a central station and a set of base stations before being radiated through the air. It greatly reduces the equipment and maintenance cost of the network[3,4].The next generation of access networks is rushing the needs for the convergence of wired and wireless services to offer end users greater choice, convenience, and variety in an efficient way. This scenario will require the simultaneous delivery of voice, data, and video services. Due to increase in the implementation of optical access networks and surplus availability of advanced and cost-effective Optoelectronic system technologies, a unified optical feeder network could provide continuous integration of both broadband optical and wireless access networks. ROF transmission can be used for various applications in the GSM and WIMAX networks, the error-free results can be achieved. The **r**adio-**o**ver-**f**iber (RoF) technology represents a key solution for satisfying these requirements, since it jointly takes

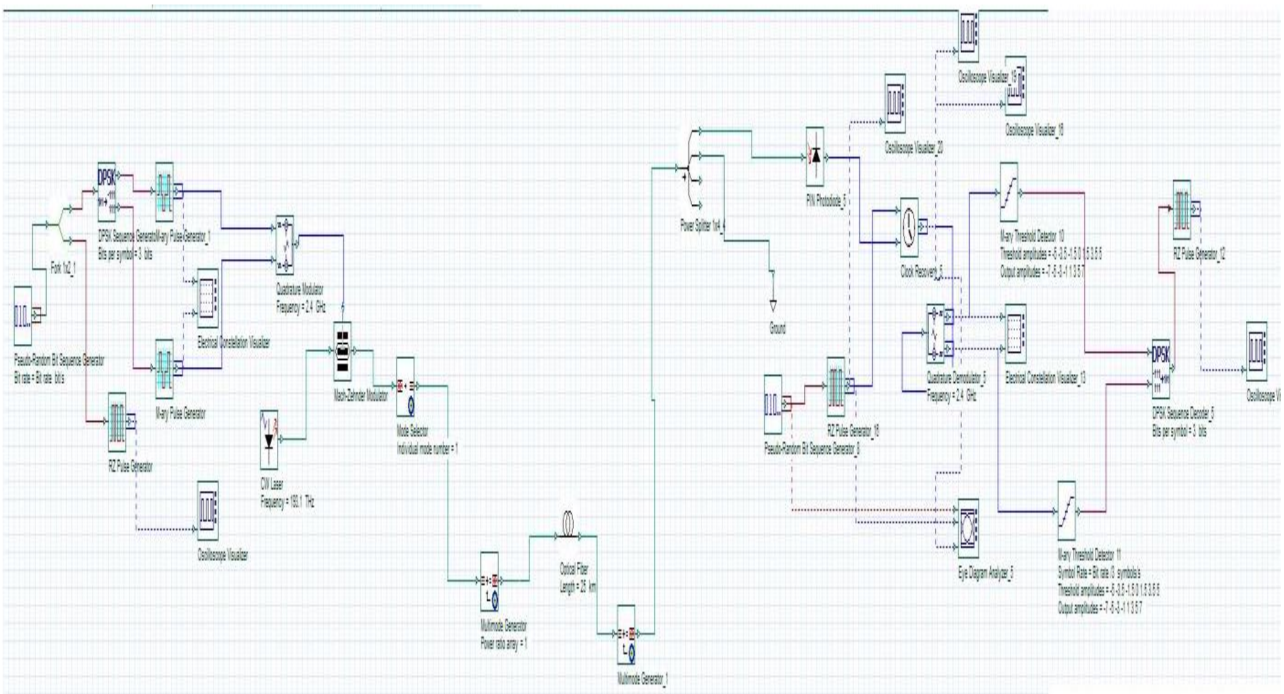

Fig 1.Mode Division Multiplexing layout using Optisystem 13.0

an advantage of the huge bandwidth offered by optical communications systems with the mobility and flexibility provided by wireless systems [5].Furthermore, RoF technology enables centralization of network management, processing, and radio functions. It supports current and next generation wireless network deployment and management strategies.

III. Long Reach Passive Optical Network

As broadband uptake increases globally, the services offered are becoming increasingly bandwidth-intensive. A service that continues to increase bandwidth requirements is high-definition television (HDTV), which requires in the region of 8 Mbps per channel. For telecommunication networks to support a single channel of HDTV plus data and telephony services simultaneously, the minimum bandwidth required is approximately 10 Mbps. Currently, telecom operators face a significant problem in that the cost of the capital expenditure to deploy traditional networks to support next generation, bandwidth-intensive services is higher than the revenues that these services generate[13,14]. A passive optical network (PON) offers a different network architecture that enables the essentially unlimited bandwidth of fiber to the home (FTTH) to be utilized. PONs use a point-to-multipoint architecture to reduce cost by sharing a significant portion of the network among all customers rather than each customer having a dedicated connection as in the current point-to-point architecture[11]. LR-PON extends the coverage span of PONs mentioned above from the traditional 20 km range to 100 km and beyond by exploiting Optical Amplifier and WDM technologies[13,14,15]. A general LR-PON architecture is composed by an extended shared fiber connecting the CO and the local user exchange, and optical splitter connecting users to the shared fiber. Compared with traditional PON, LR-PON consolidates the multiple Optical Line Terminals (OLTs) and the Central Offices (COs) where they are located, thus significantly reducing the corresponding Operational Expenditure (OpEx) of the network[16].

IV. Passive Components For Noise Removal

Nowadays, passive optical network (PON) is widely used by people as a promising solution for modern access telecommunication networks. With the developing of technology, we need more creative and cost-effective PON systems which are no longer limited by the basic elements. A optical circulator is usually a three-port circle device designed serving as optical one-way streets so that light entering any port exits from the next port. The principle of optical circulators is using the Faraday rotators A fiber optic filter is a component with two or more ports that provides wavelength sensitive loss, isolation and return loss. Fiber optic filters are in-line, wavelength selective, components that allow a specific range of wavelengths to pass through with low attenuation for classification of filter types. Bessel filter filters out the component noise. For filterization purpose, ONU is used.

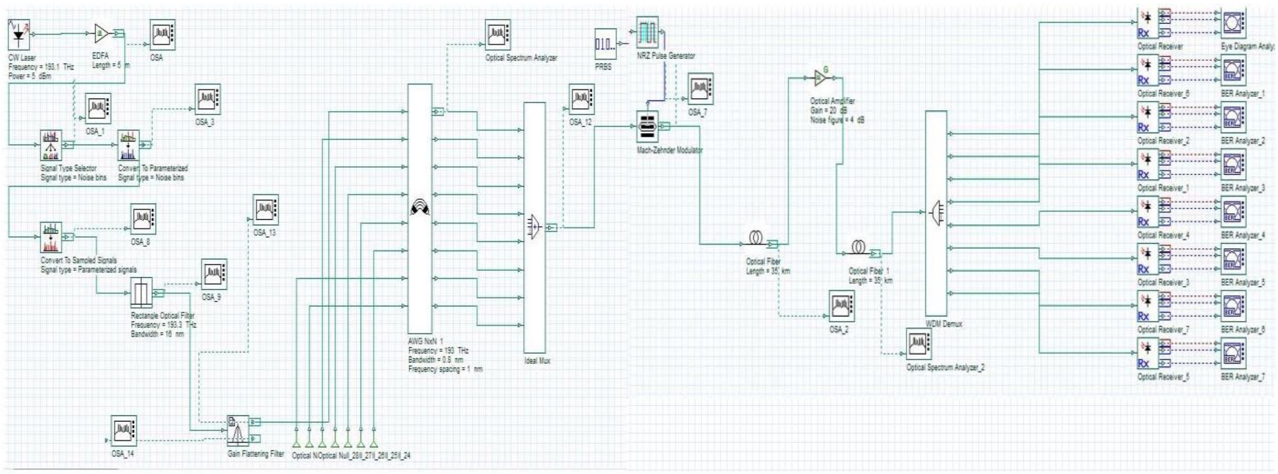

Fig.2.Long Reach PON layout using Optisystem 13.0

V. Simulation

Fig.1 shows that Mode Division Multiplexed model has been successfully simulated and analyzed by a commercial optical system simulator Opti System 13.0.From the transmitter the signal is passed. The mode selector selects the necessary mode. Here the individual mode number can be varied. The mode generator operates before and after the optical fiber. The optical fiber of length 25km is provided[5]. Finally the signal is passed to the receiver. The output can be viewed by eye diagram visualizer.Fig.2 shows the long reach PON layout. The signal from CW laser is passed to EDFA of length 5km.The NxN arrayed waveguide collects the signal and passes it to optical fiber via ideal MUX and an optical modulator[12]. The signal is demodulated and the output is viewed via eye diagram analyzer and BER.Fig.3 shows the passive components for noise removal layout. The WDM transmitter with frequency of 1550nm is provided. The extinction ratio is set as 15dB.The data is modulated by a NRZ modulation type. The three port circulator is used in which one port is connected to the transmitter and the other to the PIN photo detector and the third port to the optical delay. Circulators achieve bi-directional transmission over a single fiber. Because of their high isolation of the input and reflected optical powers and their low insertion loss, optical circulators are widely used in advanced communication systems. The Bessel filter removes the unwanted noise present in the circuit. The buffer selector is also present in order to select the necessary signal. A bidirectional optical fiber of length 50km is used to carry the signal. A 1XN splitter splits the signal for several ONUs. The output is passed to the regenerator and thereby visualized using eye diagram analyzer and BER analyzer.

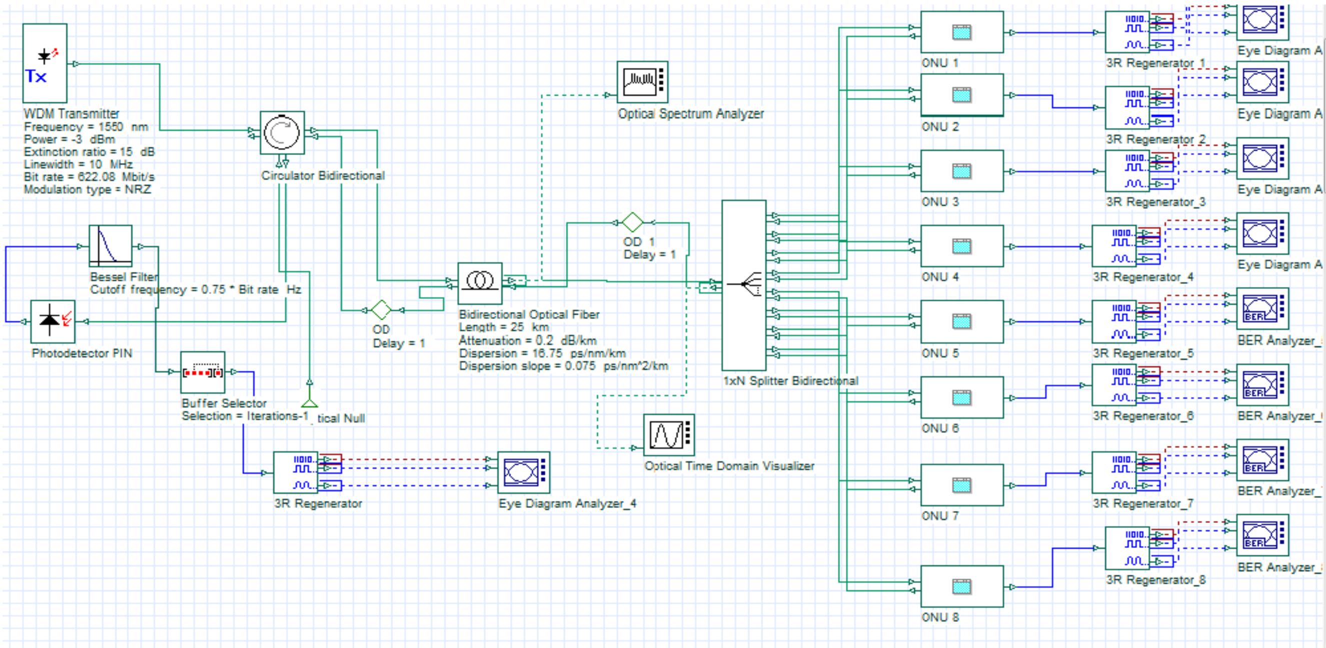

Fig.3.Passive Optical Components for noise removal

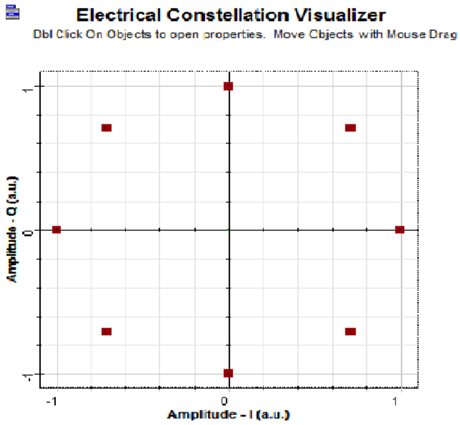

Fig 4. Constellation at the transmitter

VI. Results and Discussions

In this simulation, the number of bits in each symbol is 3, and the constellation result is given by formula 2n. Fig.4 shows the signal constellation of the transmitter and is taken from the output of M-ary pulse generator. A convenient way to measure the performance of the system is by using an eye diagram. .Fig 5 shows the received eye pattern at the transmitter for mode division multiplexing. The eye opening clearly indicates that the system performance is good. For long reach PON, the eye opening is viewed in fig 6. Q value is 29.2975.BER value is also measured from fig 7. The performance of the noise removal system is also measured. The eye opening is good clearly indicating that the noise removal is accurate and it is clearly viewed in . The better noise removal system increases the performance and efficiency of the system.

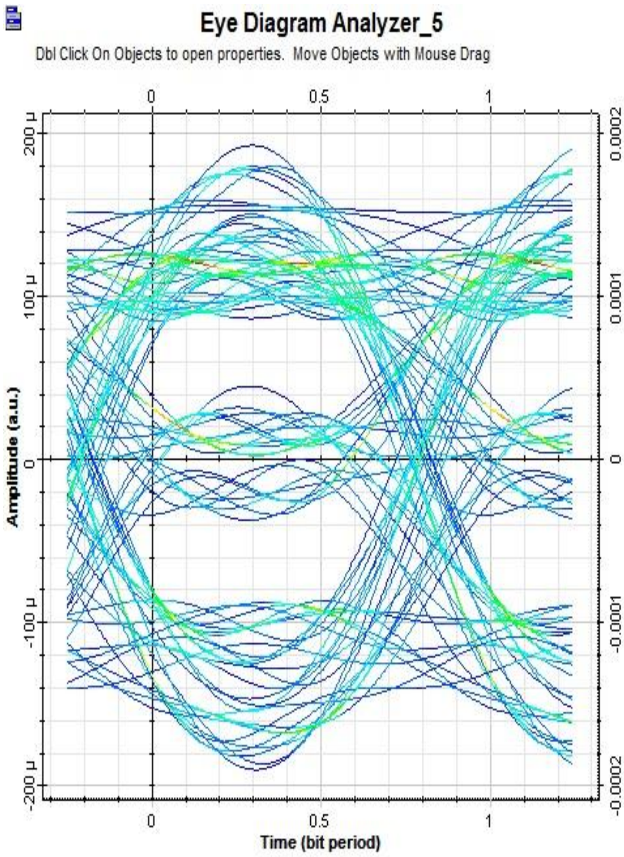

Fig.5 Eye diagram for mode division multiplexing

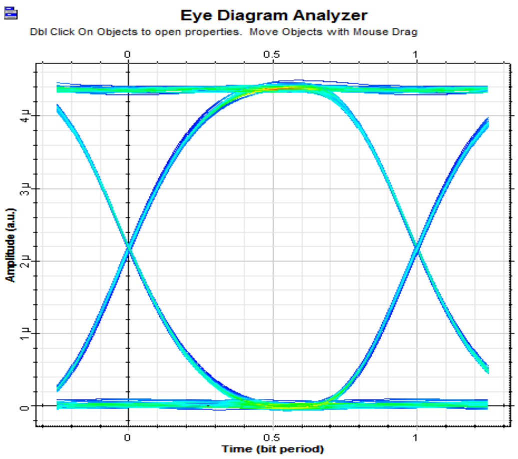

Fig. 6 Eye diagram for Long Reach PON

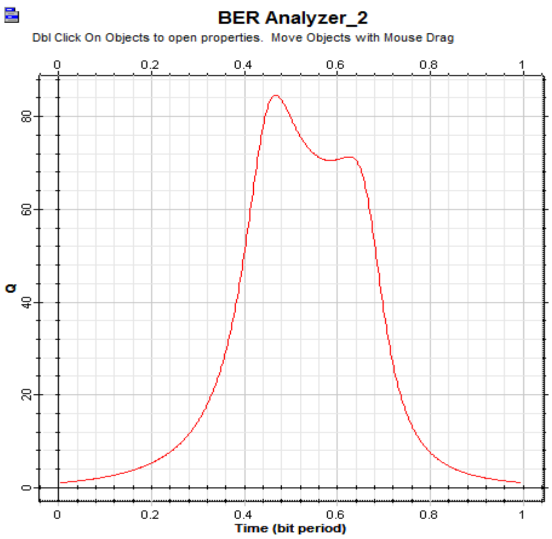

Fig. 7 BER pattern

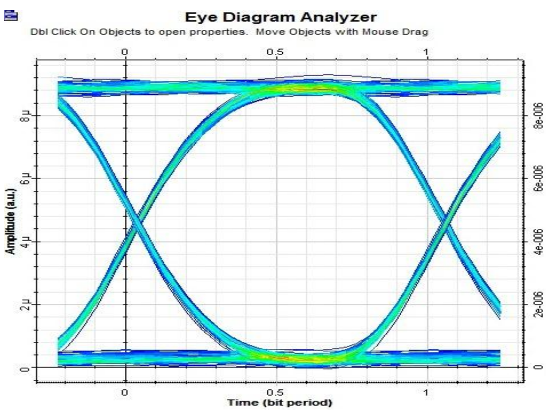

Fig. 8 Eye diagram at the transmitter end

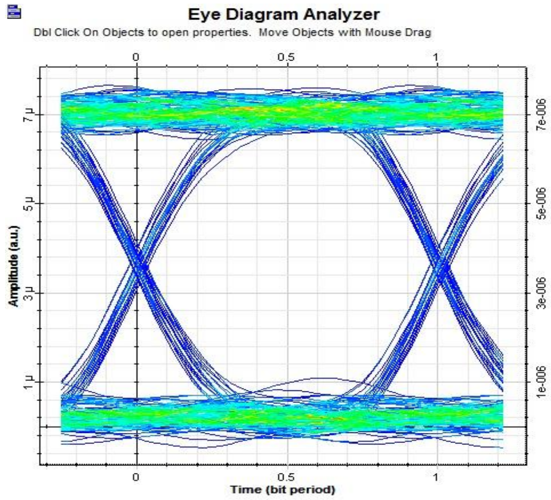

Fig 9.Eye diagram at the receiver end

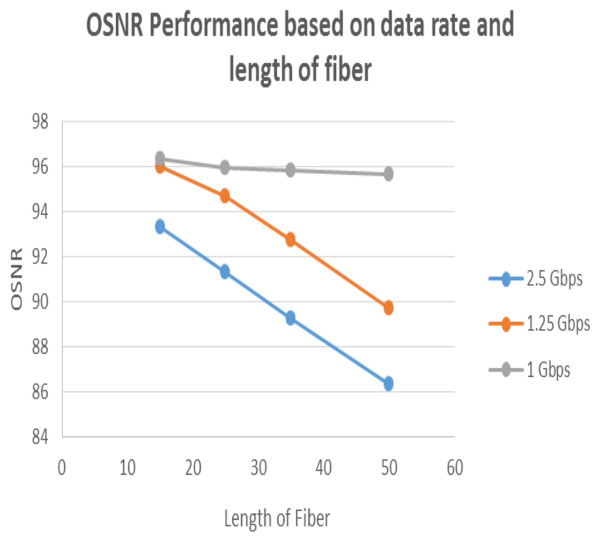

Fig 10. OSNR Versus Length of fiber

The OSNR is greater over small distances and is reduced over large distances. The OSNR is also reduced fractionally while the data rate increased because of increased noise. The OSNR performance for the varied fiber length and data rates is shown .It can be seen that the OSNR at 0.1nm bandwidth displays a decreasing pattern along the length of the fiber. In certain optical systems, the maximum value of OSNR, for 2.5 Gbps is 40 dB and the minimum is 35.2 dB

VII. Conclusion

The Mode Division Multiplexing PON using RoF, with 8 - DPSK and 16-QAM techniques were designed [1, 12]. The performance is investigated. The spectral efficiency is improved. The noise is highly reduced by using passive components. The OSNR and received optical power are similar for both modulation schemes. QM offers a better performance, indicated by eye -diagrams, which is noticeable at higher data rates [9]. Thus, a passive optical network model with high spectral efficiency using Long Reach PON is realized . Hence it is shown that digital modulation techniques using RoF technology are suitable schemes for MDM PONs[10,11].The simulation results show that the Long Reach PON with 2.5 Gbps, 8DPSK and 2.4 GHz, gives a good performance for 32–64 users over 25 km fiber length.The eye opening is clearly viewed with better Q-value and BER value. Good OSNR and power budget have been calculated for the proposed Long Reach PON. The OSNR is reduced while the number of wavelengths increased as a result of channel interference. Power receiver reduced to −24 dBm at 50 km fiber length. The results show that the Passive Optical Networks offers a promising noise-free solution for today's communication to support the continuous increase in the number of wireless internet users and demands on bandwidth.

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