Middle-East Journal of Scientific Research
24 (Special Issue on Innovations in Information, Embedded and Communication Systems): 265-271, 2016
ISSN 1990-9233; © IDOSI Publications, 2016
DOI: 10.5829/idosi.mejsr.2016.24.IIECS.23171

Implementation of Hybrid WDM-TDM PON Using Radio over Fiber

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Abstract: Combining wavelength division multiplexing (WDM) with (TDM) PONs is very scalable and flexible network architectures are possible. In this project the system proposes a GPON downstream link, using the radio over fiber (RoF) technique in GPON network architecture. Within each group, four Onuses share one wavelength in a TDM mode. The TDM-PON downstream traffic is handled by broadcasts from the OLT to all connected ONUs. The system uses the hybrid-WDM-TDM PON architecture combined with RoF technology and compare the performance of network for 8-DPSK and 16-QAM digital modulation, for four data rates (2.5 Gbps, 1.5Gbps and 1.25 Gbps,1 Gbps), for 25 km optical fiber. The performance analysis is based on eye diagrams, constellation diagrams, OSNR and received optical power. Variations in length and power of several ranges are done and the results are analyzed. Optisystem simulation software package is used for simulation. These results can be extended for future applications of optical control unit in non-linear studies.

Key words: Wavelength Division Multiplexing · Time Division Multiplexing · PON · ONU · Hybrid · Downstream

INTRODUCTION

Hybrid WDM/TDM Passive optical networks (PON) combine both wavelength division multiplexing (WDM) and time division multiplexing (TDM) into a single PON, offering reduced cost, high scalability and increased data rates, hence hybrid PONs are currently effective solutions. 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. Digital modulation techniques like QPSK, M -PSK, M-QAM provide high spectral efficiency and better utilization of bandwidth [1]. The characteristics of GPON technology has been standardized by International Telecommunication Union -T (ITU-T) in Recommendation G.984 series[2]. GPON architecture has been integrated with RoF technology, demonstrating a cost -efficient solution for 3G BSs. A 2.5 Gbps GPON downstream link was analyzed using RoF technology in GPON network architecture where differential phase -shift keying (8DPSK) modulation is used which supports up to 64 users, for a range of 25 km of 2.5 Gbps. Hybrid WDM–TDM PON that use wavelength-independent or colorless ONU technologies will further reduce implementation and maintenance expenses. The power loss budget of optical distribution network significantly increases by complete suppression of the reflection noise. Advanced multilevel modulations like quadrature phase shift keying (QPSK), M-PSK (M-ary PSK) and quadrature amplitude modulation (QAM) have been proposed to increase the bitrate while keeping the signal bandwidth as low. In this project, we use the hybrid-WDM-TDM PON architecture combined with RoF technology and compare the performance of network for 8-DPSK and 16-QAM digital modulation, for three data rates (2.5 Gbps, 4 Gbps and 5 Gbps), for 25 km optical fiber [1, 3, 4]. New business models based on novel telecommunication technologies continue to dramatically change the way people live and work nowadays.

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ROF Technology: 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 [5]. 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 [6]. 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 radio-over-fiber (RoF) technology represents a key solution for satisfying these requirements, since it jointly takes an advantage of the huge bandwidth offered by optical communications systems with the mobility and flexibility provided by wireless systems [7]. The use of optical fiber links to distribute telecommunication standards is the more successful application of RoF technology, usually known as hybrid fiber-radio (HFR) networks. HFR networks have been deployed in the last decade due to the increasing demand of high-bitrate communication services in today’s access network. The transmission is performed by directly or externally modulating lasers by the analogous radio frequency signal. On the receiver side, the transmitted signal is recovered by using a photodiode [1, 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.

Passive Optical Network: PON uses only fiber and passive components like splitters and combiners rather than active components like amplifiers, repeaters, or shaping circuits [3]. The passive optical access networks (PONs) support a maximum data rate of 100 Gbps by using the Orthogonal Frequency Division Multiplexing (OFDM) technique in an optical access network. Hybrid WDM–TDM PON applies wavelength-independent or colorless ONU technologies will further reduce implementation and maintenance expenses. An optical network unit (ONU) terminates the PON at the customer’s home [8, 9]. The ONU usually communicates

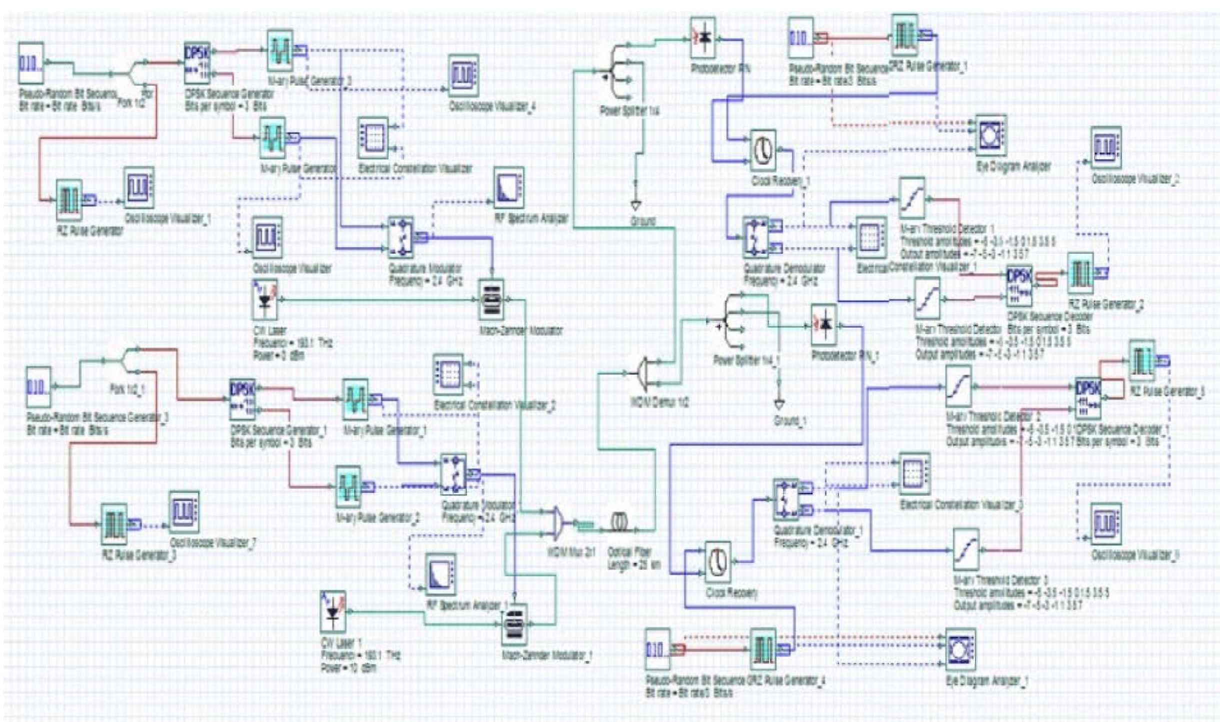

Fig. 1: Hybrid WDM-TDM PON layout using Optisystem 13.0

with an optical network terminal (ONT), which may be a separate box that connects the PON to TV sets, telephones, computers, or a wireless router. PON uses optical wavelength division multiplexing (WDM) so a single fiber can be used for both downstream and upstream data. The OLT determines the distance and time delay of each subscriber. The typical split of a single fiber is 1:32 or 1:64 which indicates that each fiber can serve up to 32 or 64 subscribers. Point-to-point fiber networks have a low market penetration mainly due to the additional cost it adds over a shared fiber infrastructure [10]. A PON has a higher reliability and the most crucial features of a PON-based access network is its signal rate and format transparency. GPON is one of the type of PON most widely deployed in today's fiber-to-the-home (FTTH) networks [11]. The operating wavelength range is 1480-1500 nm for the downstream direction. In addition, the wavelength range of 1550-1560 nm can be used for downstream RF video distribution. The amount of redundant information is small so forward error correction doesn't introduce a lot of overhead. The objective of PON is to get the fiber optics as close as possible, ideally right into the subscribers 'houses and apartments. PON architecture system includes three important units: optical line terminals (OLT), optical network units/optical network terminals (ONU/ONT) and optical distribution network (ODN) [8]. The transmitters at the OLT side generate a single wavelength carrying the data destined for a particular ONU. In OLT the RF signal is modulated by a DPSK sequence generator and combined with CW laser at wavelengths starting from 193.1 THz to 193.8 THz. The access networks are called WDM-PONs, which employ several independent wavelengths [12] which can carry data at rates of a few Gbps for electronic processing limits.

Simulation: Figure 1 shows that Hybrid WDM/TDM model has been successfully simulated and analyzed by a commercial optical system simulator Opti System 13.0. The electrical data signal is generated by the pseudo-random bit sequence Generator (PRBS), with 2.5 Gbps bit rate. The data is modulated by a differential Phase Shift Keying (8DPSK) sequence generator and an M-ary pulse generator producing M-ary signal. The M-ary signal is fed into a quadrature modulator (QM) at 2.4 GHz combined with A CW laser diode (LD) at a frequency 193.1 THz by Mach–Zehnder Modulator (MZM) to convert the electrical signal to an optical signal for transmission through a 25 km SMF. At the ONU in receiver, the signal is detected by a photodiode and fed to clock recovery in order to recover the data stream, before it is passed to a quadrature demodulator. In order to discover the signal by a DPSK sequence decoder and pulsed by RZ pulse generator to get the binary signal, the QM is connected to an M-ary threshold detector; to quantize the signal based on a suitable value of threshold amplitudes.

RESULTS AND DISCUSSIONS

In this simulation, differential phase-shift keying (8DPSK) signal which uses 8 bits per symbol is used. The number of bits in each symbol is 3 and the constellation result is given by formula 2n.

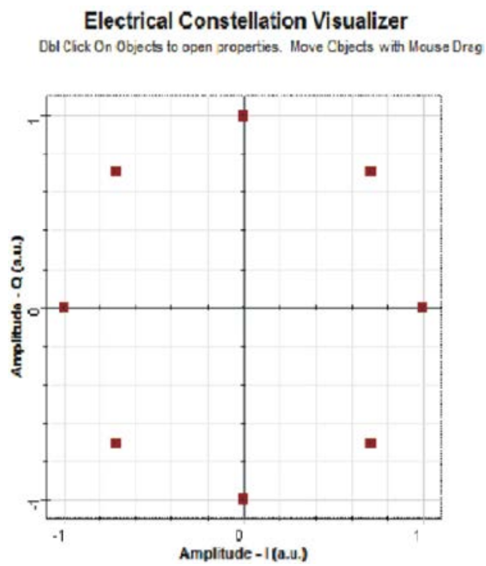

Fig. 2: Constellation at the transmitter

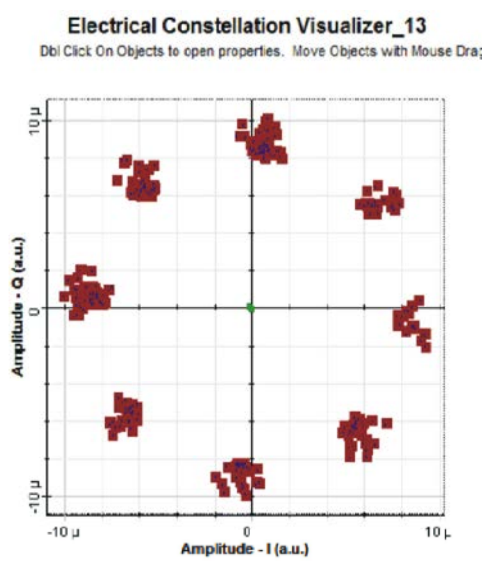

Fig. 3: Constellation at the receiver

The signal constellation of the transmitter is taken from the output of M-ary pulse generator. Fig. 3 shows the received signal at the receiver.It can be clearly seen that the constellation of the output signal is similar to the input signal with some amplitude and phase errors which will be measured by the EVM. A convenient way to measure the performance of the system is by using an eye diagram. Fig 4 shows the eye diagram for this simulation. The eye opening clearly indicates that the system performance is good. The OSNR performances for the different fiber length and data rates are shown.It can be seen that the OSNR at 0.1 nm 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; and for 1.25 Gbps the maximum value of OSNR is 41.7 dB and minimum value is 36 dB, while the maximum value for OSNR at 1Gbps is 44 dB and minimum value is 37.6 db.

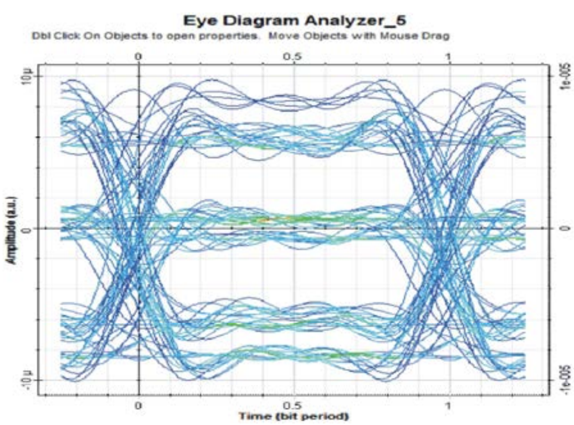

Fig. 4: Eye opening at the receiver

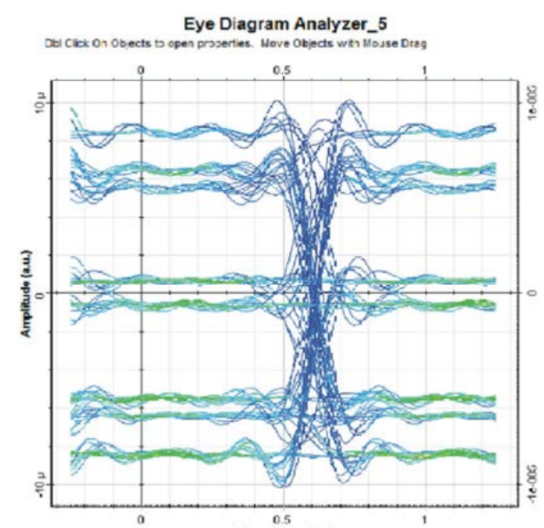

Fig. 5: Eye diagram at 1.5Gbps

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 power is found to be reduced linearly with increasing fiber length due to attenuation. It can be seen that, the received optical power is -19 dBm for 25 km fiber, which means we can increase the number of wavelengths for each splitter to eight or extend the length of fiber.

Eye Diagram for Varying Bit Rates: The eye diagram output is taken by varying the bit rates in order of 1 Gbps, 1.25Gbps, 1.5Gbps, 2.5Gbps.When compared with other bit rates the eye opening is good at 2.5 Gbps. Hence the system performance is also good.

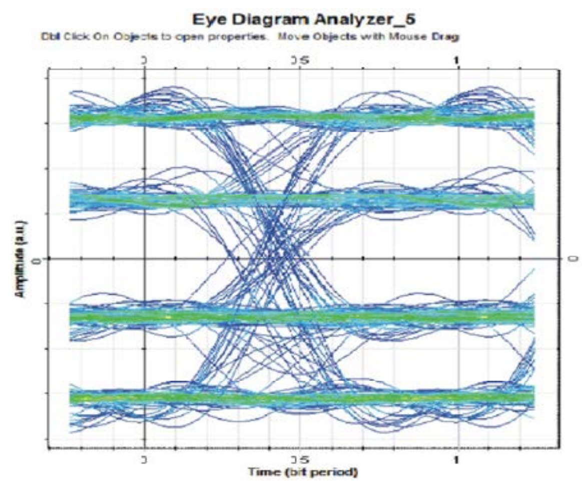

Fig. 6: Eye diagram at 1.25 Gbps

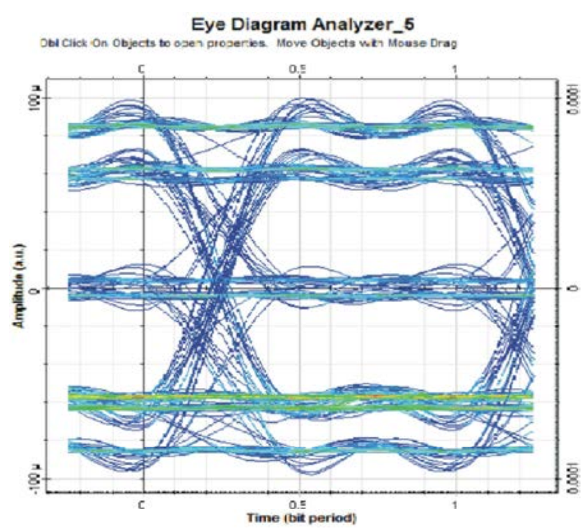

Fig. 7: Eye diagram at 1Gbps

Eye Diagram for Varying Length

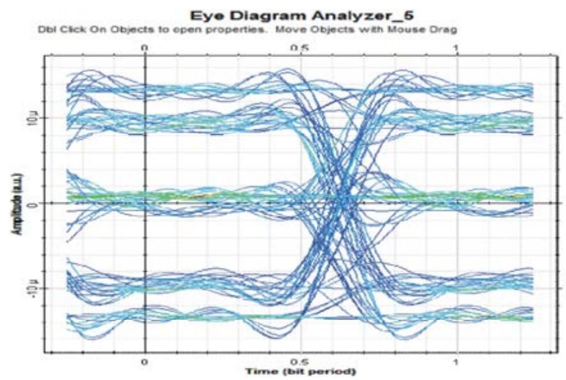

Fig. 8: At 15 km length

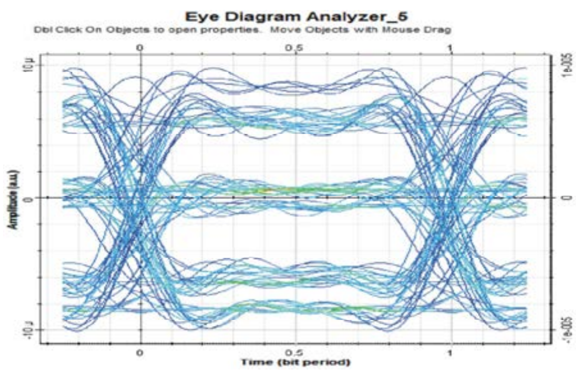

Fig. 9: At 25 km length

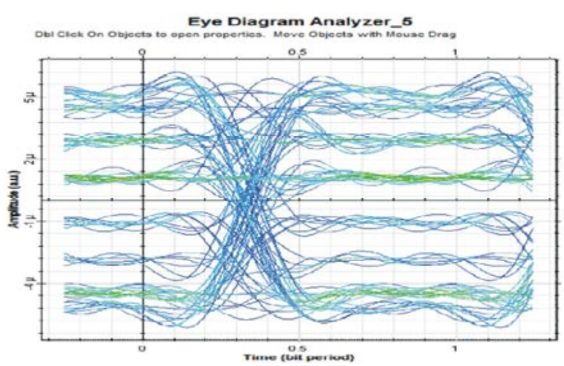

Fig. 10: At 35 km length

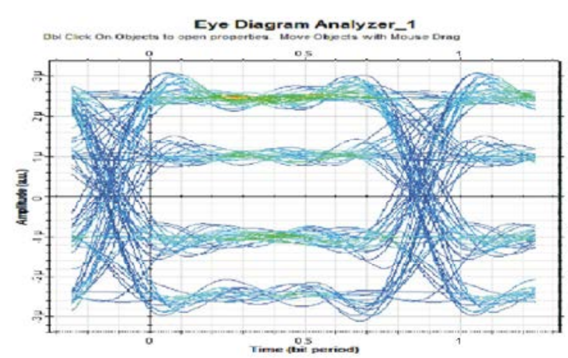

Fig. 11: At 50 km length

Eye Diagram for Varying Power

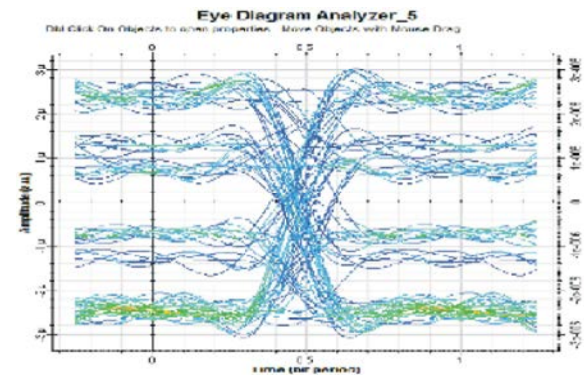

Fig. 12: At 5 dBm power

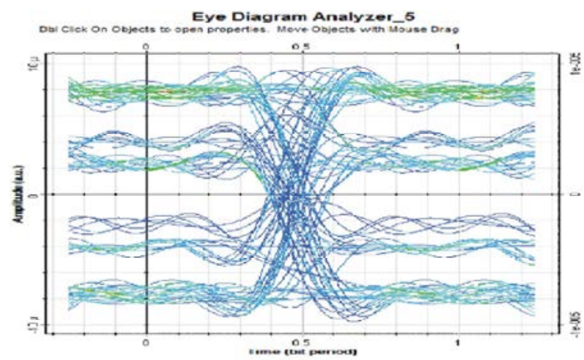

Fig. 13: At 10dbm power

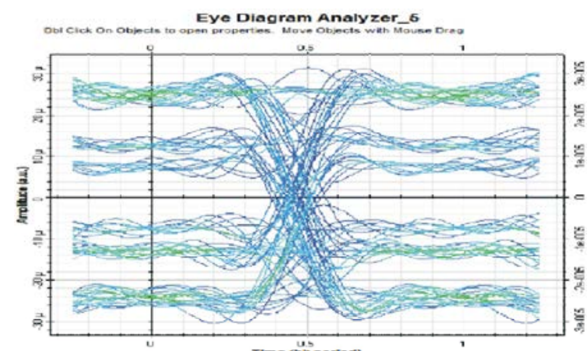

Fig. 14: At 15dbm power

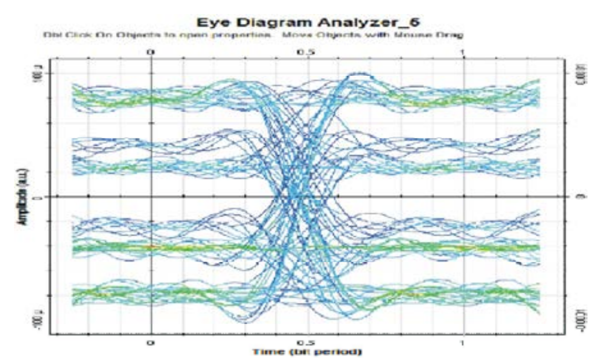

Fig. 15: At 20dbm power

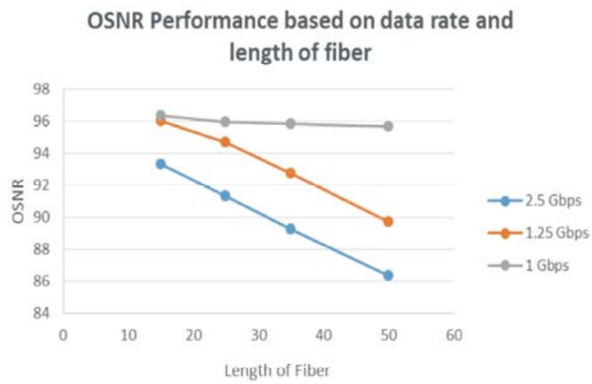

Fig. 16: OSNR Versus Length of fiber

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

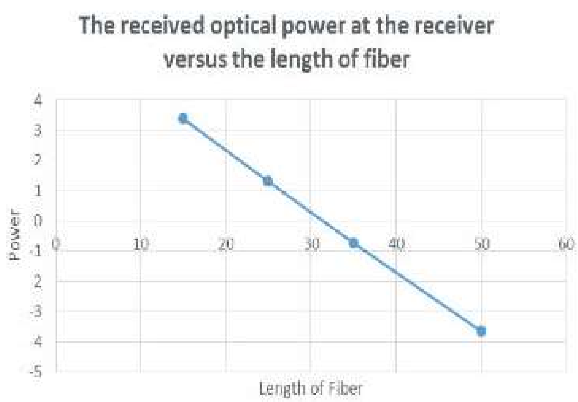

Fig. 17: Received Power Versus Fiber Length

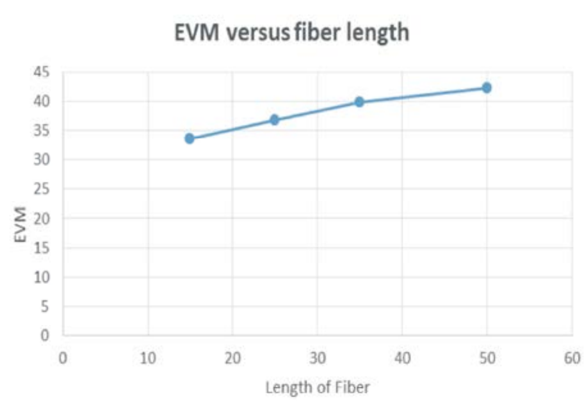

Fig. 18: EVMVersus Fiber Length

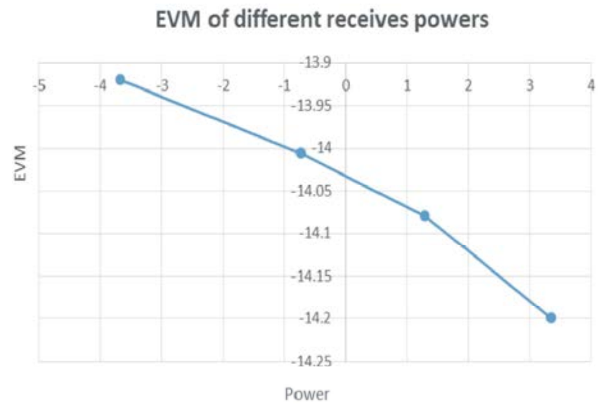

Fig. 19: EVM Versus Received power

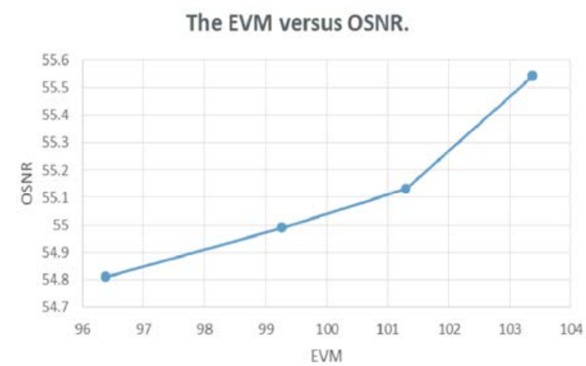

Fig. 20: EVM Versus OSNR

CONCLUSION

The Hybrid WDM-TDM PON using RoF, with 8 -DPSK and 16-QAM techniques were designed [1, 12]. The performances of the two methods were compared. The spectral efficiency is improved. The OSNR and received optical power graphs are similar for both modulation schemes. 16-QAM offers a better performance, indicated by eye -diagrams, which is noticeable at higher data rates [13]. Thus, a passive optical network model with high spectral efficiency and relatively lower cost than traditional PONs can been realized [6]. Hence it is shown that digital modulation techniques using RoF technology are suitable schemes for hybrid WDM-TDM PONs [3]. The simulation results show that the Hybrid WDM/TDM GPON with 2.5 Gbps, 8DPSK and 2.4 GHz, gives a good performance for 32–64 users over 25 km fiber length. The value of EVM is increased as the distance increases, reaching to 30.3% at 50 km. In contrast, the OSNR is reduced to 35 dBm as the distance is increased to 50 km. Good OSNR and power budget have been calculated for the proposed 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. This can be extended in future using various multiplexing techniques in order to increase the number of channel [3, 4]. The results show that the Hybrid WDM/TDM GPON offers a promising 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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