

Investigation of radio over fiber wavelength division multiplexed passive optical network using subcarrier multiplexing/amplitude shift keying technique

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The idea of Radio over fiber (ROF) is integrated with Wavelength Division Multiplexed Passive Optical Network (WDM-PON) keeping in mind the end goal to exploit the benefits of high information rate and expanded versatility. In this paper, we propose a full duplex ROF WDM-PON framework utilizing Subcarrier multiplexing (SCM)/Amplitude Shift Keying (ASK) strategy. The proposed framework depends on wavelength re-modulation which makes utilization of bidirectional intelligent channel having the same wavelength for uplink and downlink. Recreation of the framework exhibits 1 Gbps uplink and downlink information for 17 channels. A limited separating of 0.4 nm is kept up between the channels to enhance the capacity. The execution of framework is controlled by examining the variation in Quality factor (Q-factor) component and Bit Error Rate (BER) when an optical fiber length and input power values changes. The proposed setup gives the acceptable value of Q-factor (8.91, 7.71 and 6.04) on the fiber length (10 km, 20 km and 30 km), respectively with a fixed input power of 5 dBm.

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1. Introduction

The global Internet Protocol (IP) traffic is growing at an enormous pace and is expected to increase three folds over the next five years [1]. To support this kind of growth, there is a need to design future proof network that can support large bandwidth and high data rate in a cost-effective way. If the proposed network can converge wireless and wired services together, then high data rate can also be incorporated with increased mobility [2]. RoF is the technique that combines both the optical (wired) and microwave (wireless) networks [3]. A RoF network involves transmission of Radio Frequencies (RFs) over an optical fiber link in order to support several wireless applications. PON is already being deployed in several countries over the globe to meet the growing internet bandwidth demand [4]. WDM-PON offers several advantages including an increase in coverage range, effective bandwidth utilization of optical fiber, transparency and upgradability [5].

WDM-PON is an efficient and cost-effective solution for the future high-speed access networks [6]. Integration of WDM-PON with RoF leads to significant increase in the coverage area and overall capacity of the current optical networks. This has eradicated the need to design and install two separate networks [7-8]. Many researchers have already addressed the same problem and made progress to provide a solution. Singh et al. [5] proposed a WDM-RoF system transmitting 1 Gbps downlink and

uplink information stream over a length of 25 km with the aim to acquire an adequate Q-factor. Aldhaibani et al. [9] exhibited a 2.5 Gbps Gigabit PON (GPON) downlink signal utilizing RoF technique as a part of GPON framework proliferating over a 25 km optical fiber link. Won et al. [10] showed the synchronous transmission of a 1.25 Gbps wired and 1.25 Gbps wireless information stream over a WDM-RoF access system.

Previously proposed architectures involve transmission of signal at a short distance and suffered from the shortcoming where the number of channels were to be reduced in order to increase the fiber length. Different plans are required to bigger channel dividing, for example, 0.8nm to work or required additional optical bearers keeping in mind in order to achieve full duplex model with acceptable value.

In this paper, the main focus is on transmission of downlink and uplink information streams over a scope of optical fiber lengths utilizing wavelength reuse scheme using ASK modulation format. This modulation represents digital data as variations in the amplitude of a carrier wave. The channel spacing is set to 0.4 nm and the input power is varied in order to analyze the performance of WDM-RoF network.

After introduction, the paper is sorted out as follows: In section II, the system setup of proposed framework is discussed. In section III, results and discussion is clarified and conclusion is drawn in section IV.

2. Simulation setup

Fig. 1 shows the block diagram of the proposed WDM-RoF system. The transmitter comprises of 17 channels and all channels on the transmitting side have their own particular working wavelength (for channel 1 ~ 1552.52 nm with a linewidth of 10 MHz). In like manner, a wavelength separating of 0.4 nm is kept up among ensuing channels for smooth and low loss transmission. The narrow separation also helps to support huge number of clients and accomplish a high information rate. The input power of every channel is changed from -15 dBm to 15 dBm with a step of 5 dBm. The WDM multiplexer (with a bandwidth of 10 GHz) combines the signal coming from each input channel and transmits over the optical fiber link via a bidirectional circulator. The length of

optical fiber is varied from 5 km to 50 km with a step of 5 km. Erbium doped fiber amplifiers (EDFAs) are used in optical communication links to enhance the power of signal on all the channels simultaneously. EDFAs operate in the wavelength window of 1550 nm and demand dispersion management. For this reason, we have used a dispersion compensating fiber (DCF) for decreasing the overall dispersion of the fiber link.

On the transmitter side, a Gaussian pulse generator converts the binary data delivered by pseudo-random bit generator into Return-to-Zero (RZ) super Gaussian electrical pulses and thus, the baseband signal is generated. The information rate for reenactment of both the downlink and uplink sign is set to 1Gbps.

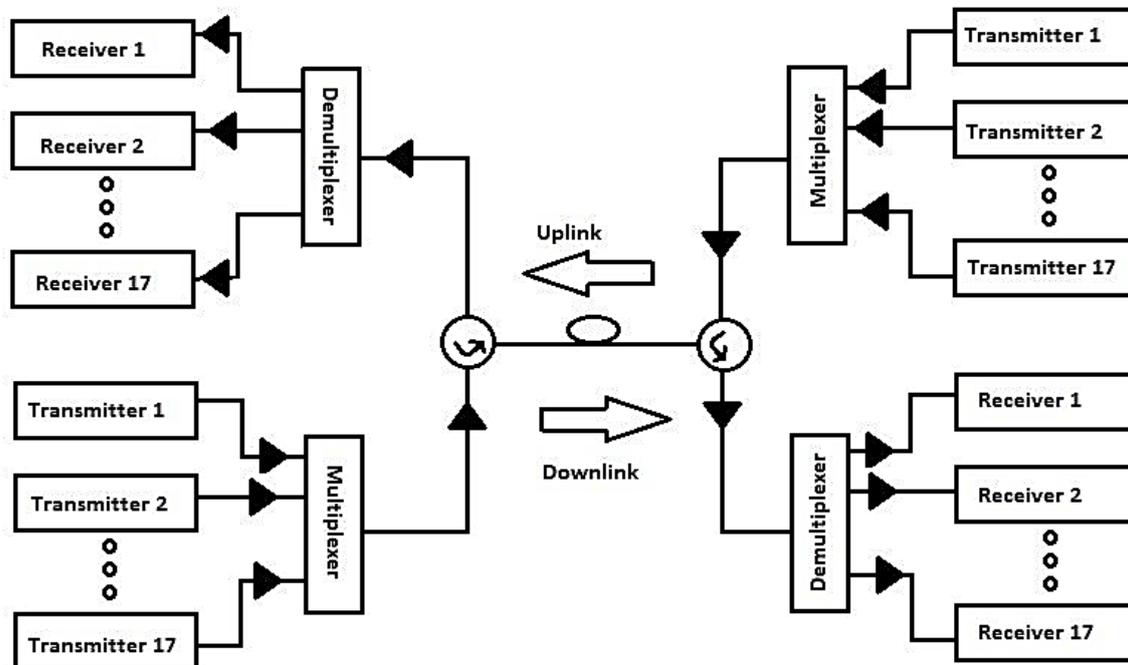


Fig. 1. Block diagram of proposed RoF WDM-PON system

Every single other parameters are appropriately changed in accordance with get a worthy estimation of Q-value. An electrical amplitude modulator having carrier frequency of 1.7 GHz is used to convert the baseband signal frequency to the frequency of RF clock. The RF signal is connected to 90° hybrid coupler after SCM carrier generator as shown in Fig. 2. Further, the outputs of hybrid coupler are connected to dual port dual drive LiNb Mach-Zehnder modulator (MZM). MZM is used for the transformation of microwave signal into optical signal. MZM has four ports out of which three are used as input port and one as output port. Subsequently, Port 1 of MZM

is driven by the amplitude modulator and Port 2 by 1 Gbps baseband signal. The optical signal obtained on the output port of MZM further which is transmitted over the optical fiber link.

On the receiver side, a bidirectional circulator is used to stay away from optical obstructions happening amongst downlink and uplink signal. A WDM de- multiplexer (with a bandwidth of 16 GHz) de- multiplexes the received signal and then further distributes to the respective receivers. The main component used here is a bidirectional reflective filter for the purpose of wavelength reuse.

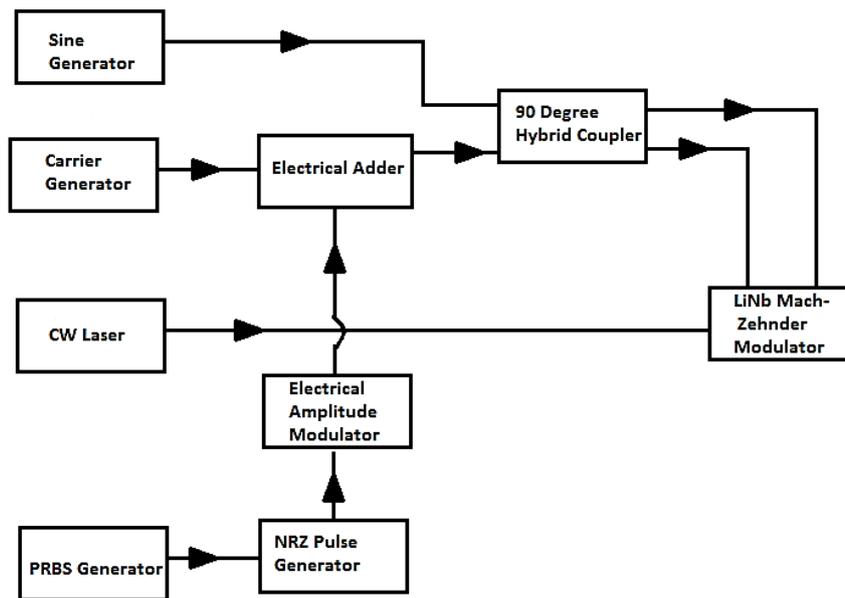


Fig. 2. Internal structure of transmitter

This filter permits a bit of signal to go through and reflects the remaining data carrying signal for demodulation. The reflected signal is demodulated by a PIN diode which is followed by a band pass filter and an analyzer is used to investigate the received signal.

The portion of received signal passed through the bidirectional reflective filter is modulated by amplitude modulator which is driven by 1 Gbps baseband signal. WDM multiplexer (with a bandwidth of 70 GHz) multiplexes the signal coming from each channel which is sent again to the transmitter side as uplink signal. On the transmitter side, the uplink signal is de-multiplexed by WDM de-multiplexer (with a bandwidth of 55 GHz) and is further demodulated by going through a PIN diode and Bessel filter.

3. Results and discussion

The proposed WDM-RoF network is positively simulated and analyzed using OptiSystem 7.0, a commercial optical system simulator. Fig. 3 shows the optical spectrum after getting multiplexed by WDM multiplexer.

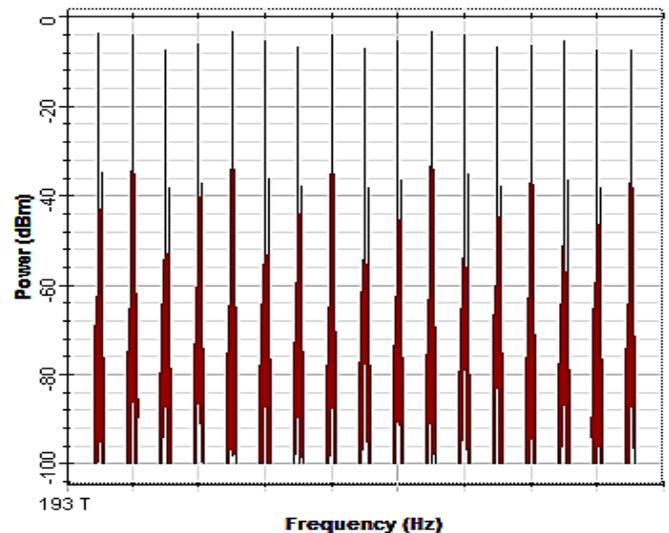


Fig. 3. Optical spectrum after multiplexing

Fig. 4 graphically shows the variation of Q-factor and BER against the optical fiber length (i.e 5 km, 10 km, 15 km, 20 km 25 km, 30 km, 35 km, 40 km, 45 km, and 50 km) on different input power (such as -2 dBm, 2 dBm and 6 dBm). From the results, we have observed that as the length of fiber is increases, the Q-factor decreases as shown in Fig. 4(a). This is attributed to attenuation and dispersion losses which increase with the fiber length. In our simulation setup, when the input power is increased from -2 dBm to 2 dBm and 6dBm, the value of Q-factor also increases from 8.79 to 9.12 and 9.31 respectively with the fixed fiber length of 5 km. From Fig. 4 (b), we observe that the BER increases as the length of fiber is increased from 5 km to 50 km. This variation of BER with fiber length has been recorded at three different values of input

power. For instance, the BER decreases from 3.6262×10^{-15} to 2.14651×10^{-16} and 1.4565×10^{-17} when the input power is increased from -2dBm to 2 dBm and 6 dBm respectively, with a settled fiber length of 15 km. Fig. 5 demonstrates the variation of Q-factor and BER as a function of channel input power at three diverse lengths of optical fiber. The input power is changed from -15 dBm to 15 dBm with a step of 5 dBm and the estimations of Q-factor are taken.

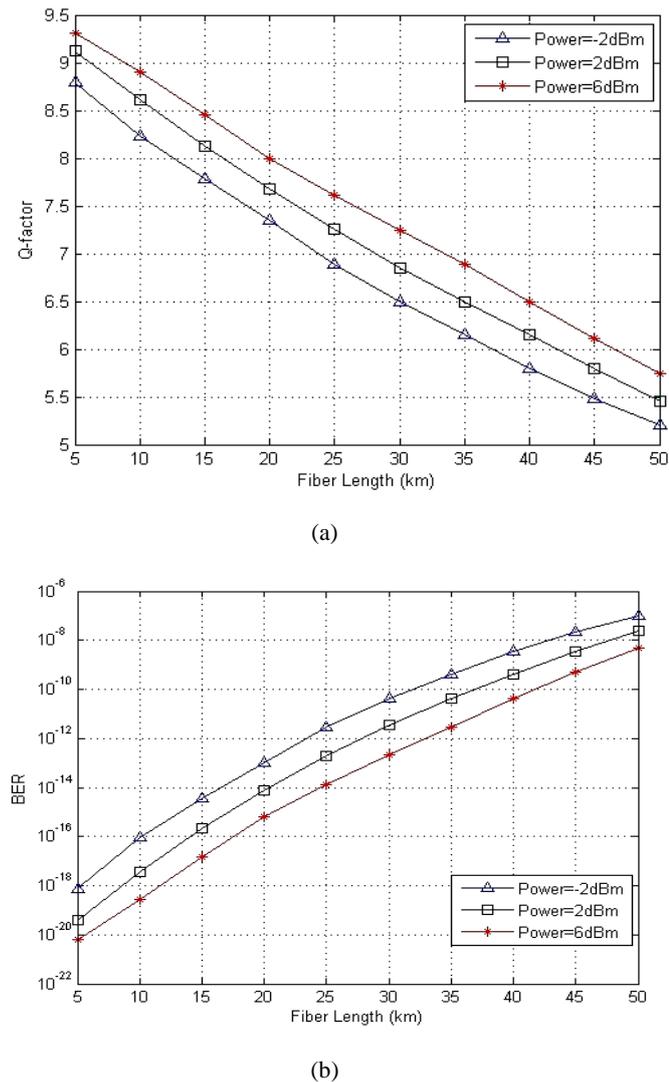


Fig. 4. Variation of Q-factor and BER with the length of fiber for different input power, -2 dBm, 2 dBm and 6 dBm (a) Q-factor (b) BER

In Fig. 5(a), we observe that as the input power is increased, the Q-factor also increases. This is because as the input power of channel is increased, the inter-channel distortion and other nonlinearities are avoided. The proposed setup gives the acceptable value of Q-factor (8.91, 7.71 and 6.04) on the fiber length (10 km, 20 km and 30 km), respectively with a fixed input power of 5

dBm. Fig. 5 (b) portrays the BER execution of the framework as an element of input power of channel for various length of fiber. It is observed that BER decreases with the increase in input power of channel.

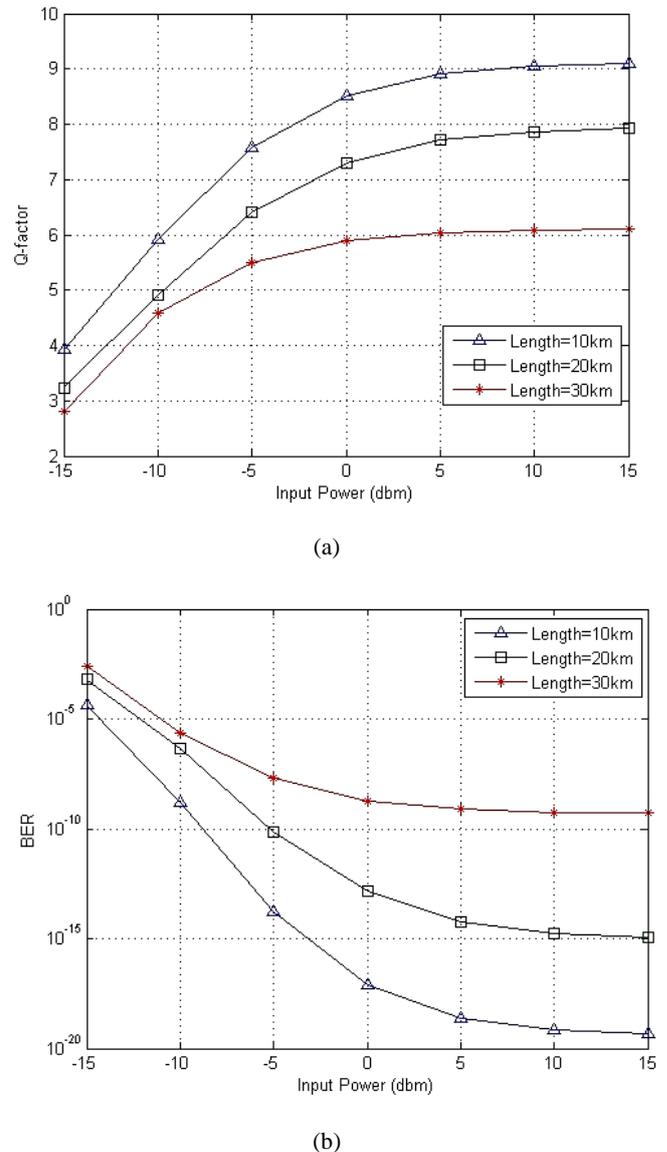


Fig. 5. Variation of Q-factor and BER as a function of input power at different optical fiber lengths, 10 km, 20 km and 30 km (a) Q-factor (b) BER.

The three lines in Fig. 5(b) show the variation of BER with input power for different fiber lengths (10 km, 20 km and 30 km). For example, the BER comes out to be 6.9629×10^{-20} , 1.8206×10^{-15} and 5.7036×10^{-10} for a fiber length of 10 km, 20 km and 30 km respectively with the value of input power fixed at 10 dBm. Fig. 6 depict the eye diagrams for downlink signal at three distinct optical fiber lengths, 5 km, 10 km and 50 km. Fig. 7 show the eye diagrams for uplink signal at a fiber length of 5 km, 10 km and 50 km.

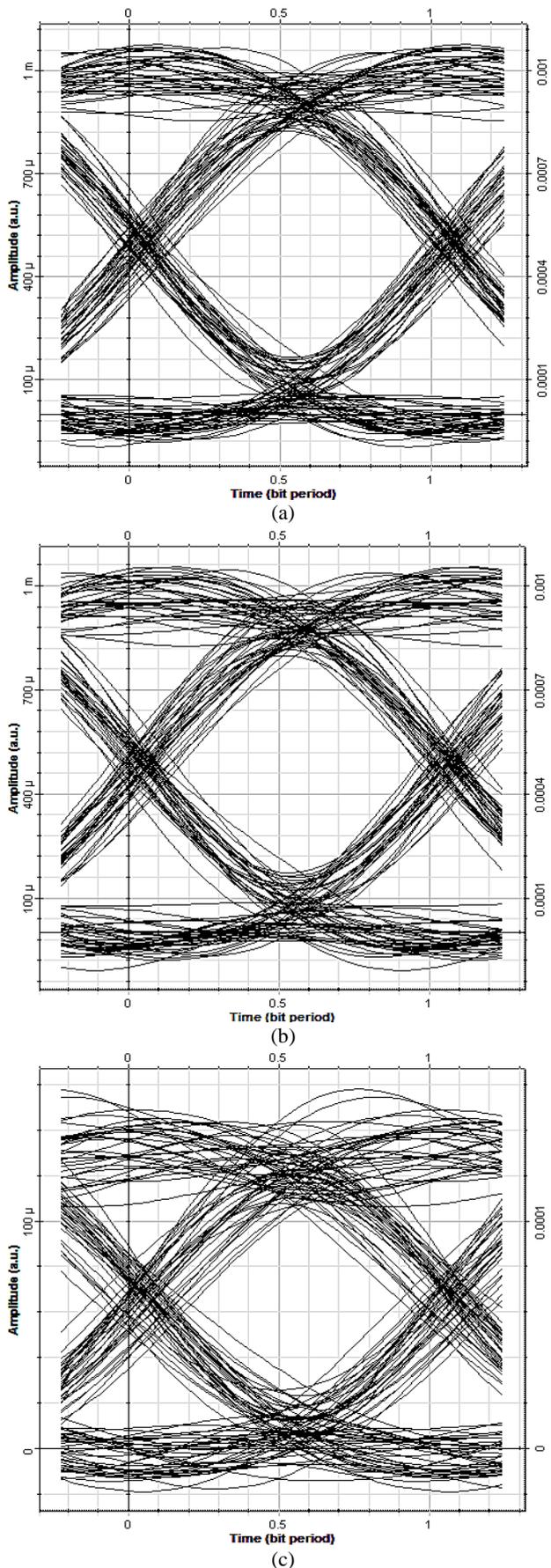


Fig. 6. Eye diagram for downstream signal when (a) fiber length is 5 km (b) fiber length is 10 km and (c) fiber length is 50 km

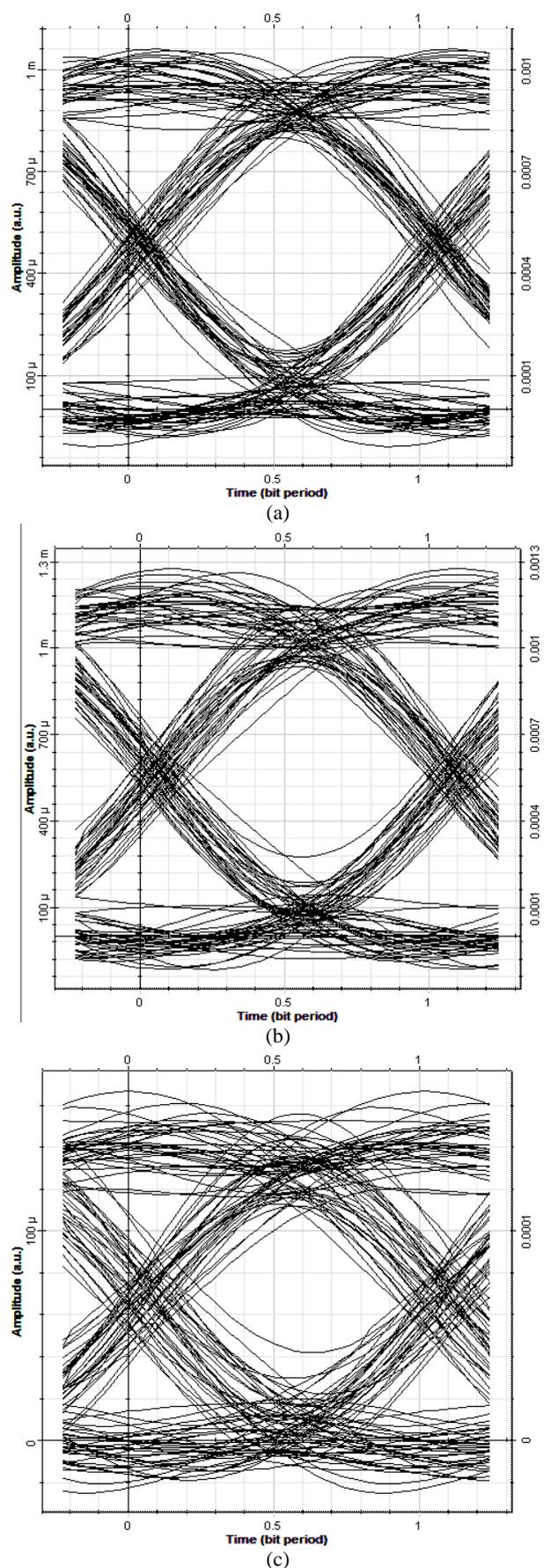


Fig. 7. Eye diagram for upstream signal when (a) fiber length is 5km (b) fiber length is 10 km and (c) fiber length is 50 km

A framework execution can be measured effortlessly with the assistance of an eye diagram. An eye diagram shows the signal quality amid fast advanced signal transmission. The closure of eye diagram represents distortion in the signal waveform due to noise and inter-symbol- interference. In this way, an open eye diagram corresponds to minimum signal distortion. The educational in every figure unmistakably demonstrates that the framework indicates great execution up to a distance 50 km of optical fiber.

4. Conclusion

In this paper, a full duplex RoF WDM-PON is proposed and investigated. The proposed system consists of 17 channels with a spacing of 0.4 nm between subsequent channels. The narrow channel spacing offers the benefit of supporting a high data rate and enormous number of clients. In this paper, the execution of framework is investigated on the premise of two critical parameters, Q-factor and BER. The results show that the proposed framework offers acceptable value of Q-factor and BER for both uplink and downlink signals upto a transmission distance of 50 km. The proposed setup gives the acceptable value of Q-factor (8.91, 7.71 and 6.04) on the fiber length (10 km, 20 km and 30 km), respectively with a fixed input power of 5 dBm.

Future Scope:

The WDM-RoF network provides a reliable communication for a large number of users in order to meet up with the growing demand of internet bandwidth. This technology can be used to provide the wireless coverage in the area where wireless backhaul link is not possible. It can also use in future wireless systems, such as 5G and 60-GHz networks.

References

- [1] J. Prat, Next-Generation FTTH Passive Optical Networks, Springer Science+ Business Media BV, 2008.
- [2] C. F. Lam, ed., Passive optical networks: principles and practice, Academic Press, 2011.
- [3] G. Cheng, B. Guo, S. Liu, W. Fang, Optik-International Journal for Light and Electron Optics **125**(15), 4072 (2014).
- [4] C. W. Chow, C. H. Yeh, Photonics Journal **5**(2), 7900407 (2013).
- [5] H. Singh, M. L. Singh, R. Singh, Optik-International Journal for Light and Electron Optics **125**(14), 3473 (2014).
- [6] R. Goyal, R. S. Kaler, Optical Fiber Technology **18**(6), 518 (2012).
- [7] H. S. Kim, T. T. Pham, Y. Y. Won, S. K. Hani, Journal of Lightwave Technol. **27**(14), 15 (2009).
- [8] J. M. Kang, S. K. Han, IEEE Photon. Lett. **18**(3), 502 (2006).
- [9] O. Aldhaibani, S. Yaakobb, R. Q. Shaddada, S. M. Idrusa, M. Z. Abdul Kadirb, A. B. Mohammad, Optik-International Journal for Light and Electron Optics **124**(18), 3678 (2013).
- [10] Y. Y. Won, H. S. Kim, Y. H. Son, S. K. Han, Journal of Lightwave Technol. **28**(16), 2213 (2010).

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