Indian Journal of Pure & Applied Physics
Vol. 58, November 2020, pp. 787-794

Performance Evaluation of a novel dense hybrid passive optical network for acceptable modulation technique using EDFA amplifiers

Ghanendra Kumar* & Sandeep Kumar

Department of Electronics & Communication Engineering, National Institute of Technology, Delhi-110 040, India

Received 3 April 2019; accepted 21 September 2020

Good rating services in terms of high speed data rate, good quality video signal and high speed telecommunication is the prime requirement for the current customers which have resolved in this research work for the first time best of our knowledge for 200 customers with the power amplification from EDFA optical amplifiers. Further, transmission of three play services signals have carried out from different modulation techniques (RZ, NRZ, Manchester, DBPSK and DQPSK modulator) to get the best outcomes. Furthermore, analysis of recommended dense hybrid passive optical network (DHPON) has also done in terms of bit error rate (BER), quality factor (Q-factor), and jitter. Final evaluation has recommended that RZ modulation technique is the acceptable choice to deliver the best services for the customers end.

Keywords: DHPON, RZ modulator, NRZ modulator, Manchester modulator, DBPSK modulator, DQPSK modulator, BER, quality factor, PON

1 Introduction

The requirement of good rating services has been shown the attention of the researcher to develop high bandwidth passive optical network (PON) to fulfill the requirement of current users[1-4]. Various researches have been shown suitable solutions for power efficiency to control the expenses of the networks[5-7]. In fact, no single technology and approach is capable to fulfill the requirement of current users because they have their limited outcomes and rating which could not exceed beyond the limits. Further, requirement of high speed data rate and services are the prime concerned for future optical communication so researchers have been developed the new way of transmission network which is called hybrid passive optical network (HPON)[8]. Acceptable rating services with suitable capital are also the main requirement to support high speed data rate and various techniques[9]. PON is the arrangement of OLT (optical line terminal), ONU (optical network unit), and ONT (optical network terminal) throughout the communication process which also capable to reduce the requirement of highly costly component[10]. Transmission of signals is occurs in downstream and upstream. Transmission of signals from ONLT to ONU is called the process of upstream transmission and transmission of signals from ONU to OLT is called the process of downstream transmission respectively[11-12]. The main theme of this proposed research work is to design the dense hybrid passive optical network system for the betterment of received optical services with good rating data rate. Furthermore, some of the research group has been explored the remarkable impact in PON with advance technologies to upgrade the transmitting services which are given below.

Patryk *et al.*[13] examined the performance of hybrid passive optical network. Data rate of 1.25 Gbps has been transmitted with the support of two channels with single mode fiber. Further, this experiment has been carried out with the support of reflective semiconductor optical amplifier (SOA) and simple add-and-drop multiplexer which has not affected the expenditure of the recommended technology.

Hwan *et al.*[14] studied the 26 channels PON system with the support of tunable laser (TL) and luminescent diode (LD). Further, use of polymer reflector at the channel spacing of 100 GHz for 26 channels has been recorded the suitable outcomes with the data rate of 2.5 Gbps for the transmission distance of 21.5 km.

Rajneesh *et al.*[15] have been recommended a new PON system with the arrangement of Giga bit Ethernet passive optical network (GEB-PON). Transmitting data rate has also been set at 12 Gbps with various lengths of optical fibers to achieve the

*Corresponding author (E-mail: gkumar3c@gmail.com)

suitable bit error rate (BER) for the communication distance of 16.7 km.

Amit *et al.*[16] recommended a algorithm for wavelength division passive optical network (WDM-PON) to control the blocking probability of the system. Further this proposed algorithm has also been compared with other existing techniques for different aspect of parameters.

Over all, all these proposed literature works have only shown the presentation of PON with limited number of users and no further techniques in terms of modulation for upgrading the data rate have been shown which is main acceptable issue for future dense PON to fulfill the requirement of customers end. So in this recommended research work, we have preceded our research work with considering the main aspect for good number of users with the acceptable power amplification from erbium-doped fiber amplifiers (EDFAs). Further, a new dense hybrid passive optical network has also recommended for 200 end customers with data rate of 1.50 Gbps.

Furthermore, this paper is analyzed in four parts. First part of this paper is shown the introductory technology related to recommended research work. Simulation of recommended dense hybrid passive optical network (DHPON) for 200 customers is examined in part two which is linked to results and discussion in part three. And over all conclusions is also made in part four respectively.

2 Simulation of Recommended Dense Hybrid Passive Optical Network

Recommended simulation setup of dense hybrid optical network for upgrading the performance of three play services means, video, voice and transmitting data is shown in Fig. 1 for 200 customers. Central office (OC) is the main controlling section to transmit the services which are linked with optical line terminal (OLT). Voice signals are generated with the support of frequency modulator which further converted into optical domain with the support of laser source as shown in the Fig. 1. Further, video signals are generated with the modulation of differential shift keying at the wavelength spectrum from 1551 nm to 1555 nm. Optical network unit (ONU) is just like the optical network terminal (ONT) which helped out to convert received optical signals to back in electrical domain. Distribution of optical fiber is mainly done with the support of tree and point-to-point topologies. In this proposed simulation setup OLT has capacity to split the fiber up to 40 times to connect the different customers end with ONTs. CO is linked with Remote node and signal mode fiber of 20 km length. Remote node (RN) is split the signals with the support of 1 x 8 splitter, which is connected to fiber length of 5 km and then connected to another RO with the splitter of 1x 20 respectively. Output from the RO splitter is also connected to first 25 customers with ONT through terminated cable with the length of 120 to 850 feet.

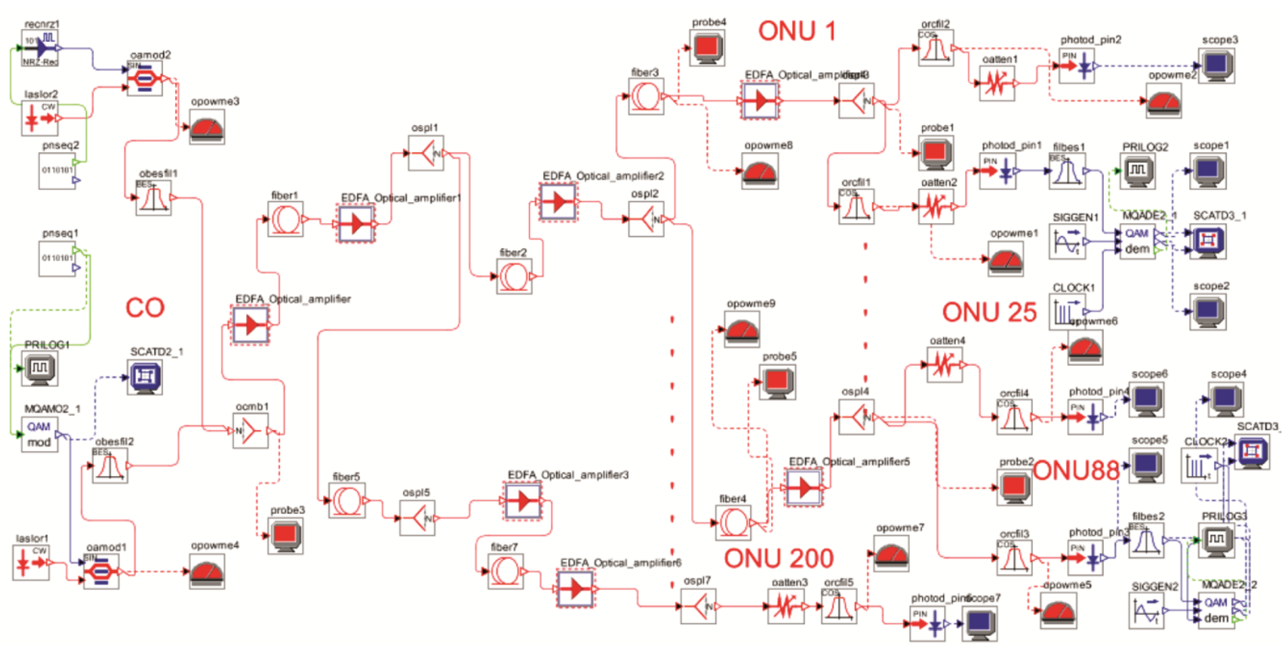

Fig. 1 — Simulation set up of dense hybrid passive optical network for 200 customers

Three play services (voice, data and video) are generated with different source of techniques at central office (CO) which required high spectral data speed of 1.50 Gbps. Signals of three play services are combined with the support of optical combiner and connected with RZ, NRZ, Manchester, DBPSK and DQPSK modulator to get the acceptable outcome with good rating power retaining process from EDFA fiber amplifiers in dense hybrid optical communication process. Voice is controlled with voice over IP protocol and packet transmit protocol which is also known with the name of public change over telephone network (PCOTN) and plain recommended telephone (PRT) service for the customer support is also controlled same manner. Arrangement of video signals is also supported with 24-QAM subcarrier dense multiplexer (SDCM) system which is used for simplicity, while 64-QAM is very complex approach to transmit video and data signals in radio frequency channel[10].

Signals are received at ONU unit which is first linked to optical filter and attenuator to remove the effect of higher power in terms of attenuated signals. Signals are converted back in original electrical domain with the arrangement of APD detector and FP-filter at the optical network unit. Different measuring components such as bit error rate analyzer (BERA), quality factor analyzer (QFA), optical power meter (OPM), optical spectrum analyzer (OSA), and jitter analyzer (JA) are also used during the signals transmitting process to investigate the performance of the signals.

Moreover, the bit error rate and quality factor are the main acceptable characteristics of the optical signals which directly impact the betterment of the signals. So these features are given in Eq. 1 & 2.

$$Q = \frac{n_{1-n_2}}{s_{1-s_2}} \quad \dots (1)$$

where, n_1 and n_2 are the total average of the acceptable signals for the logic signals in terms of 1 and 0 respectively. Further, s_1 and s_2 are stood for standard deviation of the transmitting signals. In the similar manner, bit error rate is also explored by equation (2).

$$BER = \frac{1}{2} erkc\left(\frac{P}{\sqrt{2}}\right) \quad \dots (2)$$

3 Results and Discussion

Evacuation is done to design the new dense hybrid passive optical network (DHPON) for getting the acceptable modulation technique to support the three play services (voice transmission, data transmission and video signal transmission). Further, outcomes are also recorded in terms of quality factor (Q-factor), bit error rate (BER), received jitter, and acceptable power amplification from Figs. 2-10 respectively. Reduction in power signals is shown the dominating nature of fiber losses which enhance to ISI and higher level dispersion in the optical signals. Resultantly, quality of the transmitted signals is also distorted and does not receive the acceptable signals at the customer end. In this way, acceptable rating of quality factor is also main concerned which is analyzed in the presence of different modulation techniques with EDFA optical amplifiers for the proposed network and outcomes from Fig. 2 are given as 28 to 17 dB for RZ modulation technique, 24 to 10 dB for NRZ modulation technique, 20 to 8 dB for Manchester modulation technique, 18 to 11 dB for DBPSK modulation technique, and 16 to 7 dB for DQPSK modulation technique for the communication distance from 5 to 50 km respectively. In the same way, performance of customers received signals is also noticed in terms of bit error rate (BER) for the same transmission distance and outcomes are plotted in Fig. 3 as 10^{-15} to 10^{-5} for RZ modulation technique, 10^{-30} to 10^{-10} for NRZ modulation technique, 10^{-38} to 10^{-18} for Manchester modulation technique, 10^{-40} to 10^{-25} for DBPSK modulation technique, and 10^{-45} to 10^{-30} for DQPSK modulation technique respectively. Analysis is clearly come with the decision that RZ modulation technique is most suitable to maintain the least reduction of power with the support of EDFA optical amplifiers to transmit the three play services than the other modulation techniques. So far,

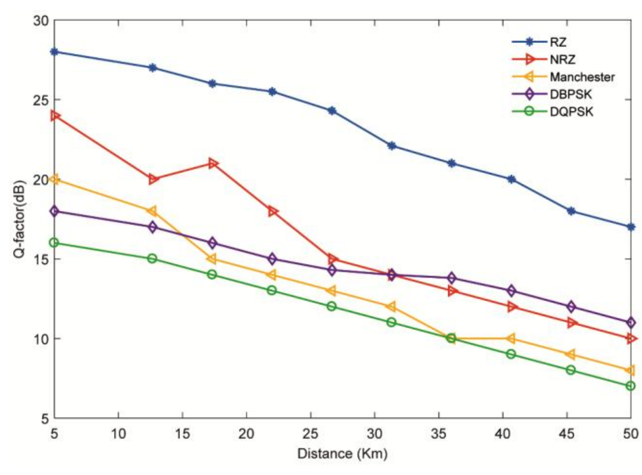

Fig. 2 — Q-factor *Vs* distance

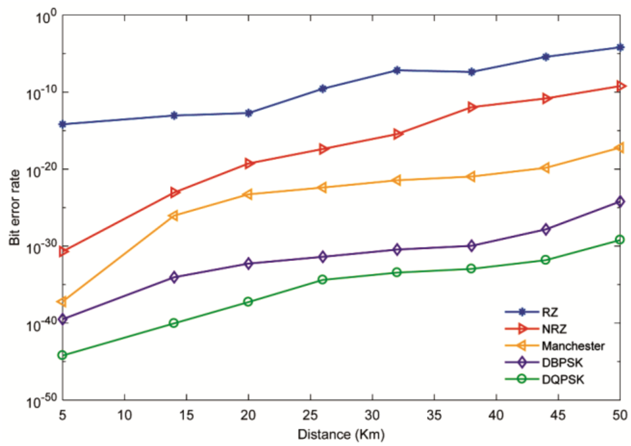

Fig. 3 — Bit error rate Vs distance

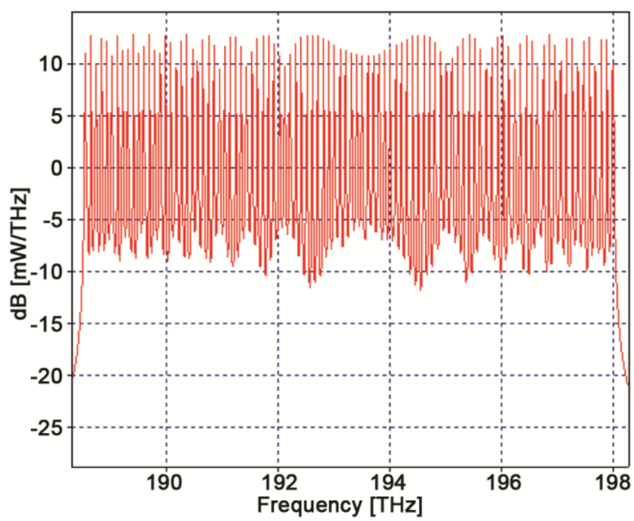

Fig. 4 — Received amplified power spectrum for 200 customers

amplification from EDFAs is also shown the supporting role to maintain the acceptable quality of the signals which are also justified from the received amplified power spectrum for 200 customers in Fig. 4.

Fig. 5 is also shown the jitter effect with respect to varying distance from 10 km to 45 km for 200 customers.

Further, investigation is also extended to observe the different modulation effect at various distance and results are received in terms of eye diagrams from Fig. 6(a) to Fig. 10(o).

Fig. 6(a) to Fig. 6(c) is shown the eye diagrams for RZ modulator at the distance of 25 km, 30 km, and 45 km respectively for 200 customers. Here, it is shown that performances of received signals are acceptable for the distance from 25 to 30 km but later it is slightly affected with power losses which can also be resolved with raising the power level of EDFA

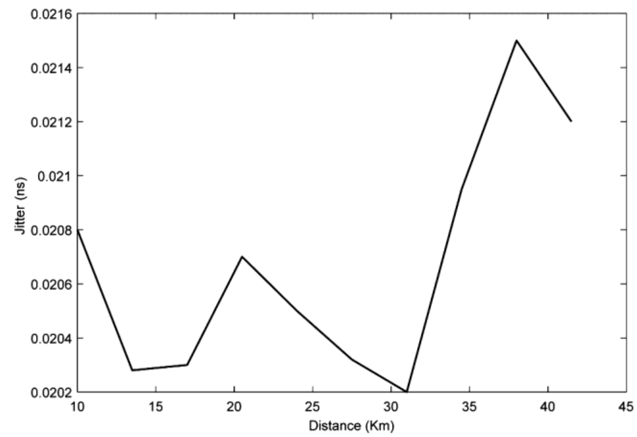

Fig. 5 — Jitter Vs distance

amplifiers. So, overall RZ modulation format is shown the acceptable approach to transmit the three play services for dense hybrid optical network.

In the same way, eye diagrams from NRZ modulation format are also recorded from Fig. 7(a) to Fig. 7(c) for the distance of 15, 27.5, and 32.4 km. And observations are come out with the analysis that NRZ modulation technique delivered the stable presentation of eye diagrams for different transmitting distance which reflected that NRZ modulation has good capacity to mitigate the effect of power reduction and dominating fiber losses for short communicating distance.

Furthermore, eye diagrams of Manchester, DBPSK, and DQPSK modulation technique are also drawn from Fig. 8(a-c) to Fig. 10(a-c) for the communicating distance from 15 km to 42 km respectively. Evaluation is shown that Manchester modulation technique is good for the distance from 15 km to 32 km, DBPSK is good for 18 km to 38 km, and DQPSK modulation technique is good for 32 km to 42 km respectively. Because optical noise influence is higher for long communication distance. In this way received bit error rate and quality factor are fully supported the rating of RZ modulation technique for acceptable transmission of three play services for 200 customers from our proposed network system.

Received values in terms of bit error rate and quality factor, and jitter are also noticed down in table 1 to table 5 for RZ, NRZ, Manchester, DBPSK, and DQPSK modulation technique for different communicating distances.

The performance of RZ modulation technique is much appropriate for long distance three play services with supporting outcomes in terms of

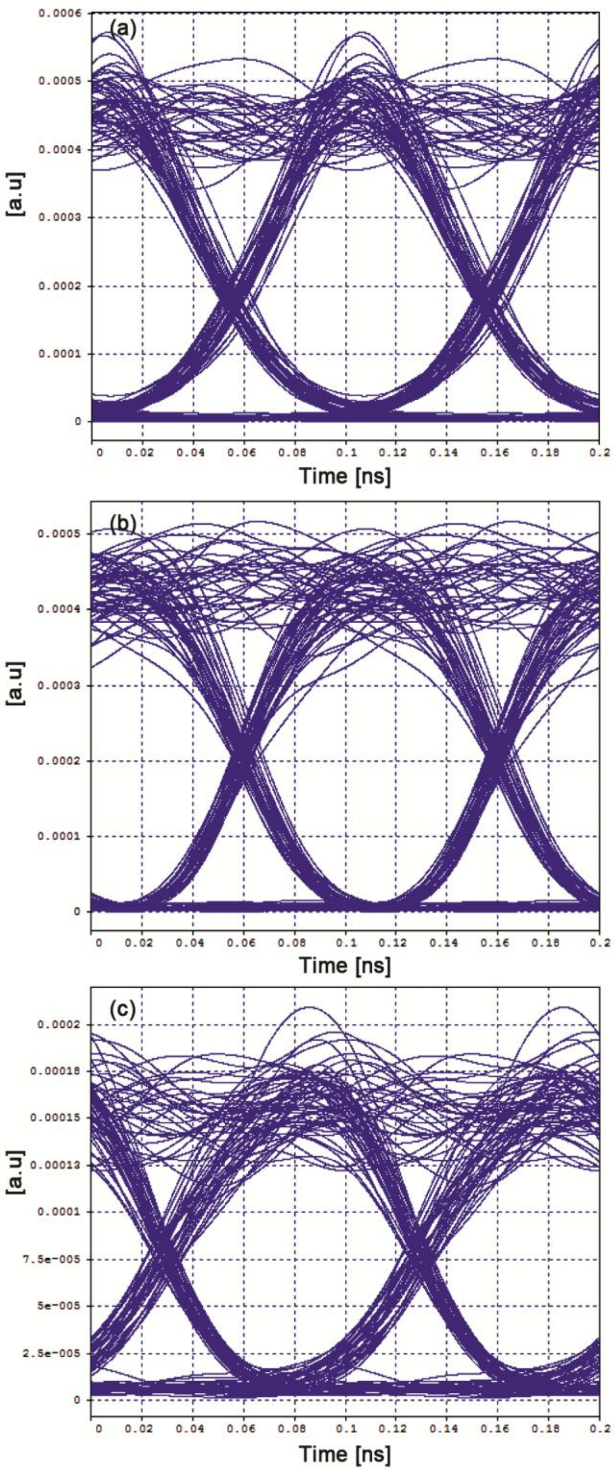

Fig. 6 — Eye diagrams from RZ modulation technique (a) For the communicating distance of 25 Km (b) For the communicating distance of 30 Km (c) For the communicating distance of 45 Km

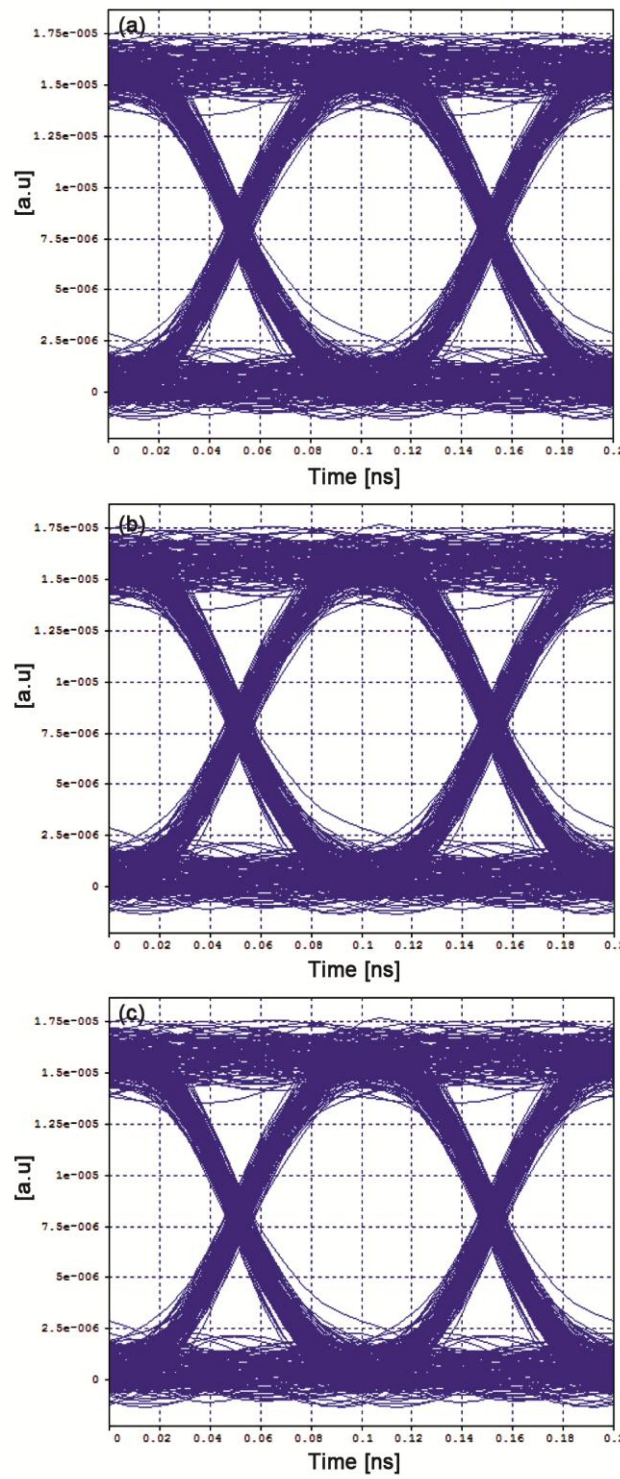

Fig. 7 — Eye diagrams from NRZ modulation technique (a) For the communicating distance of 15 Km (b) For the communicating distance of 27.5 Km (c) For the communicating distance of 32.4 Km

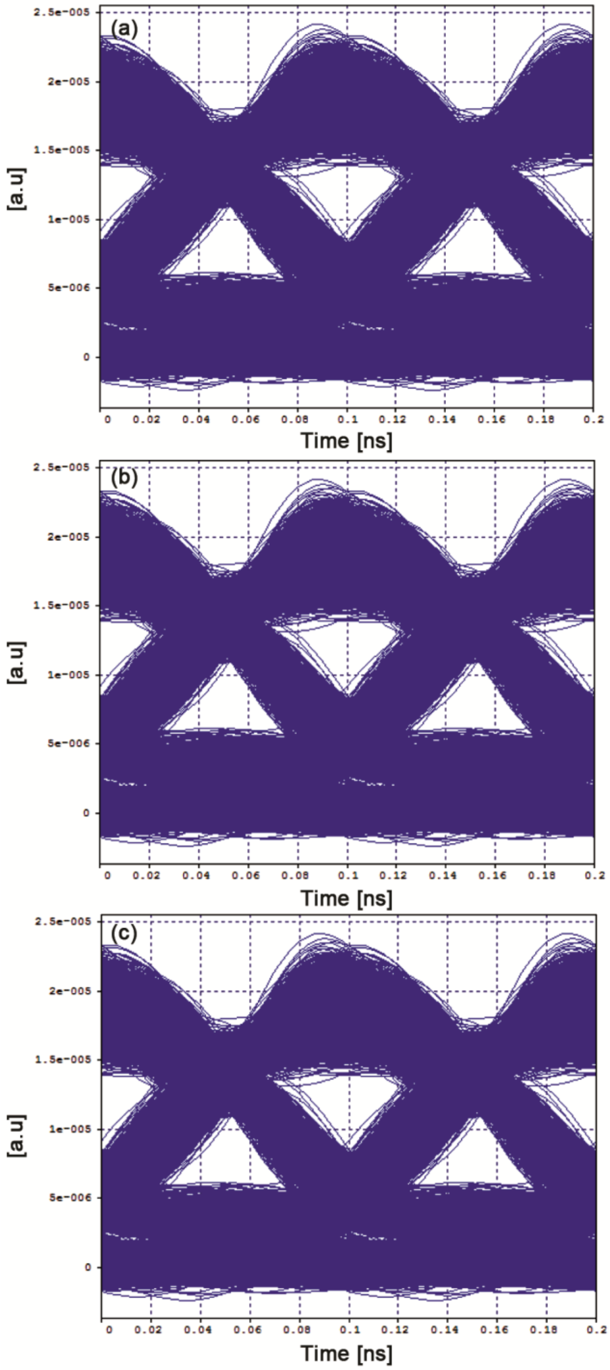

Fig. 8 — Eye diagrams from Manchester modulation technique (a) For the communicating distance of 15 Km (b) For the communicating distance of 26 Km (c) For the communicating distance of 32 Km

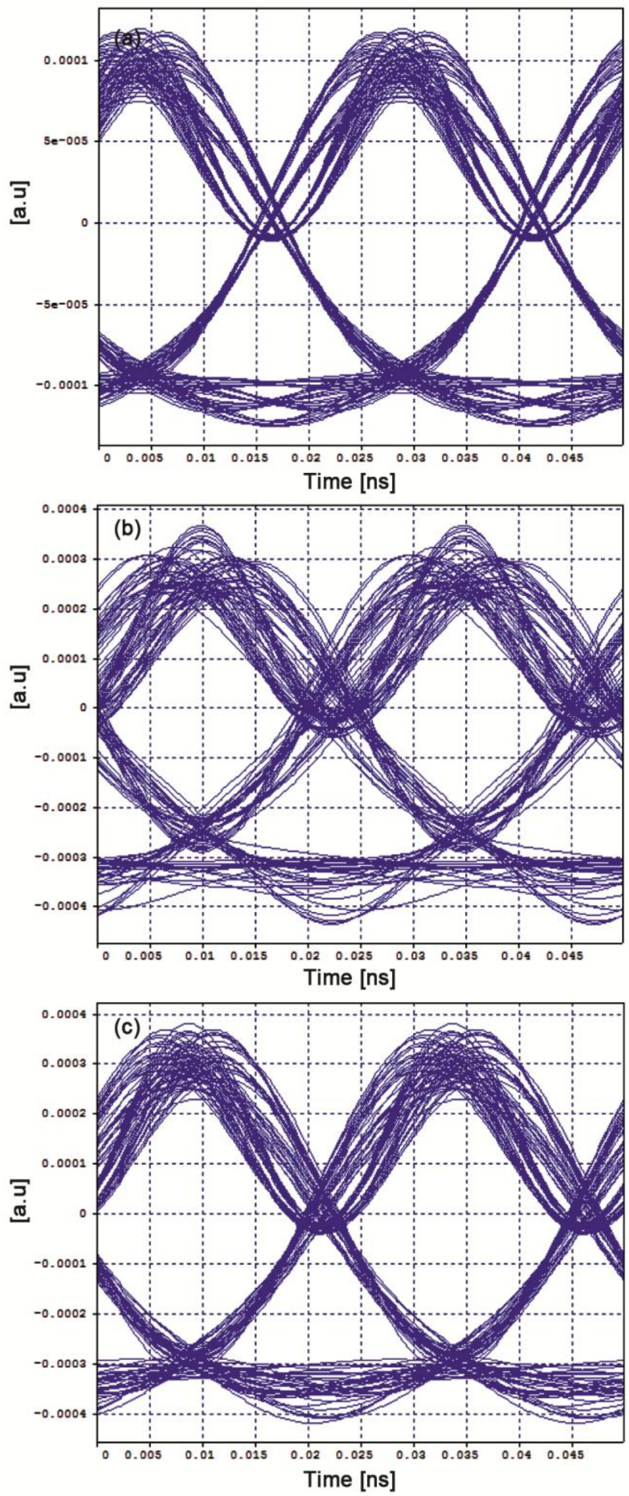

Fig. 9 — Eye diagrams from DBPSK modulation technique (a) For the communicating distance of 18 Km (b) For the communicating distance of 24 Km (c) For the communicating distance of 38 Km

quality factor, bit error rate, and jitter, while others modulation techniques are suitable for short distance to deliver the three play services. Further, our

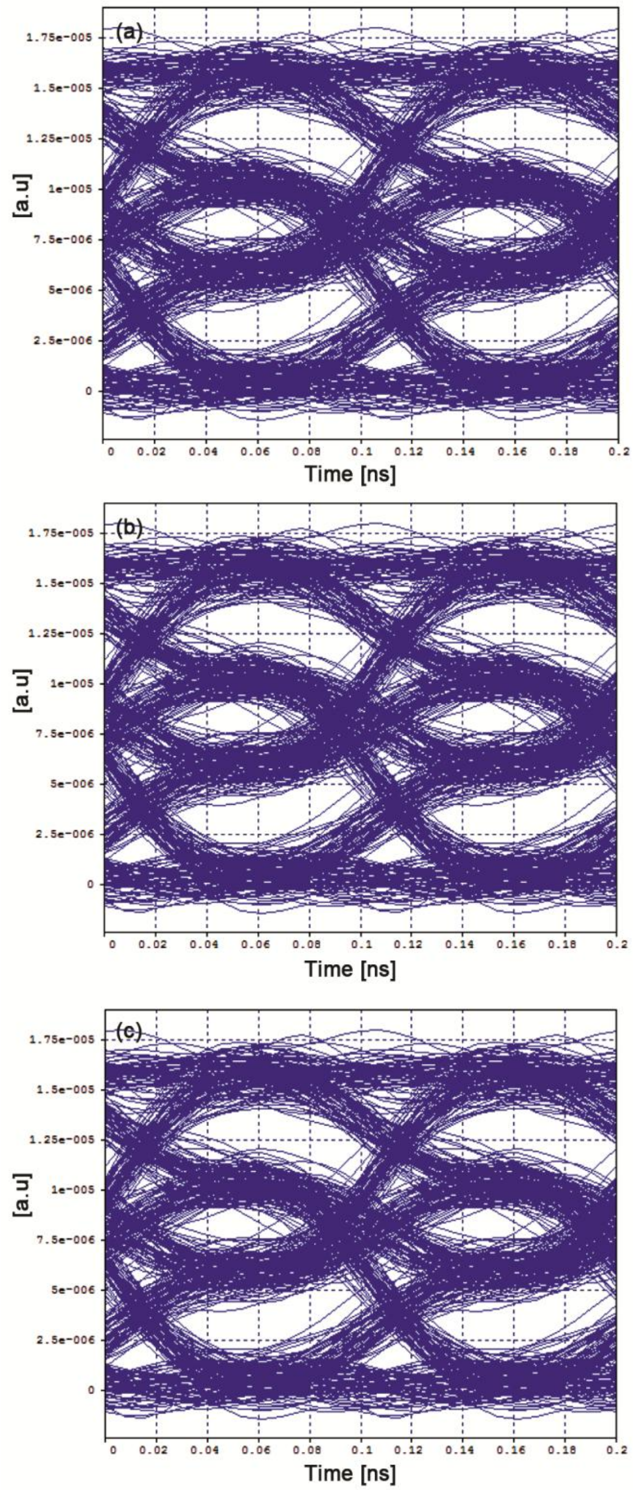

Fig. 10 — Eye diagrams from DQPSK modulation technique (a) For the communicating distance of 32 Km (b) For the communicating distance of 36 Km (c) For the communicating distance of 42 Km

Table 1 — RZ modulation technique

Communicating distance (km)	Quality factor (dB)	Bit error rate	Jitter value (ns)
25	27.01	10^{-4}	0.0201
27	25.42	10^{-6}	0.0203
30	23.85	10^{-8}	0.0205
33	22.28	10^{-10}	0.0207
35	20.71	10^{-14}	0.0208
38	19.14	10^{-12}	0.0210
41	17.57	10^{-14}	0.0212
44	16.22	10^{-12}	0.0214

Table 2 — NRZ modulation technique

Communicating distance (km)	Quality factor (dB)	Bit error rate	Jitter value (ns)
15	23.02	10^{-24}	0.1580
17	21.12	10^{-25}	0.1581
19	19.25	10^{-28}	0.1583
22	17.38	10^{-30}	0.1584
24	15.51	10^{-25}	0.1586
27	13.64	10^{-26}	0.1587
29	11.77	10^{-8}	0.1589
32	09.90	10^{-10}	0.1590

Table 3 — Manchester modulation technique

Communicating distance (km)	Quality factor (dB)	Bit error rate	Jitter value (ns)
14	19.80	10^{-37}	0.1620
16	18.10	10^{-35}	0.1619
18	16.40	10^{-30}	0.1617
21	14.70	10^{-25}	0.1616
23	13.00	10^{-24}	0.1614
26	11.30	10^{-22}	0.1613
28	9.60	10^{-20}	0.1611
31	07.90	10^{-17}	0.1610

Table 4 — DBPSK modulation technique

Communicating distance (km)	Quality factor (dB)	Bit error rate	Jitter value (ns)
11	17.10	10^{-38}	0.1550
20	16.20	10^{-37}	0.1551
23	15.30	10^{-34}	0.1553
26	14.40	10^{-33}	0.1554
29	13.50	10^{-32}	0.1556
32	12.60	10^{-20}	0.1557
35	11.70	10^{-16}	0.1559
37	10.80	10^{-17}	0.1560

proposed model is also capable to deliver the better servicers for 200 customers than the published work[10, 12].

Table 5 — DQPSK modulation technique

Communicating distance (km)	Quality factor (dB)	Bit error rate	Jitter value (ns)
31	15.50	10^{-44}	0.1670
33	14.25	10^{-44}	0.1671
34	13.01	10^{-35}	0.1673
36	11.77	10^{-34}	0.1674
37	10.52	10^{-33}	0.1676
39	09.28	10^{-32}	0.1677
40	08.04	10^{-30}	0.1679
41	06.80	10^{-30}	0.1680

4 Conclusion

This research work has recommended a new dense hybrid passive optical network to deliver the good quality three play services for 200 customers with the data rate of 1.50 Gbps. Different modulation techniques have shown different rating outcomes. Out of which RZ modulation is most appropriate modulation technique to deliver the good rating three play services with proper arrangement of EDFA optical amplifiers. Further, this recommended model is quite capable to maintain the quality factor of 28 dB with bit error rate of 10^{-5} which is most supporting outcomes for the three play services. In this way, it is concluded that this research work will be really helping to three play services deliverer to enhance the quality of the services with economically.

References

1 Grobe K, Roppelt M, Autenrieth A, Elbers J P & Eiselt M, *IEEE Commun Mag*, 49 (2011) 25.

2 Kumar C & Goyal R, *J Nanoelectron Optoelectron*, 13 (2017) 275.

3 Sankaran G C & Sivalingam K M, *Opt Switch Netw*, 10 (2013) 416.

4 Kumar C & Goyal R, *Opt Appl*, 48 (2018) 173.

5 Song H, Kim B W & Mukherjee B, Long reach optical access, in Broad Band Access Networks: Technologies and Deployments, Shami A, Maier M & Assi C, Eds Springer, (2009) 1.

6 Kumar C & Goyal R, *Performance Analysis of Hybrid Optical Amplifiers for Super Dense Wavelength Division Multiplexing System in the Scenario of Reduced Channel Spacing*, Mapan, 33 (2018) 159.

7 Kramer G, Mukherjee B & Pesavento G, *Photon Netw Commun*, 4 (2002) 89.

8 Nakayama Y, *IEEE Trans Syst Man Cybern Syst*, 45 (2015) 743.

9 Cho K Y, Hong U H, Takushima Y, Agata A, Sano T, Suzuki M & Chung Y C, *IEEE Photon Technol Lett*, 24 (2012) 209.

10 Kumar C & Goyal R, *J Russian Laser Res*, 39 (2018) 263.

11 Tsutsumi T, Sakamoto T, Sakai Y, Fujiwara T, Ou H, Kimura Y & Suzuki K I, *J Lightwave Technol*, 33 (2015) 1660.

12 Fujiwara M, Imai T, Taguchi K, Suzuki K I, Ishii H & Yoshimoto N, *J Lightwave Technol*, 31 (2013) 634.

13 Urban P J, Pluk E G C, Laat M M de, Huijskens F M, Khoe G D, Koonen A M J & Waardt H de, *IEEE Photon Technol Lett*, 21 (2009) 380.

14 Su H O, Yoon K H, Kim K S, Kim J, Kwon O K, Oh D K, Noh Y O, Seo J K & Lee H J, *IEEE J Sel Top Quantum Electron*, 17 (2011) 1534.

15 Kaler R, Teotia P & Kaler R S, *Optik – Int J Light Electron Opt*, 122 (2011) 1985.

16 Wason A & Kaler R S, *Optik – Int J Light Electron Opt*, 122 (2011) 877.