Performance Analysis of 40Gbps Symmetrical TWDM PON using different Modulation Technique

Sonakshi, DivyaDhawan

Abstract— Time and wavelength division multiplexed passive optical network (TWDM-PON) has been selected by the full service access networks as the primary solution for the next generation PON stage 2 (NG-PON2). In this paper a symmetric 40Gbps TWDM-PON is proposed with direct modulation and external modulation. The proposed system is modulated using different coding schemes like NRZ, RZ, CSRZ and duobinary. The results for various modulation techniques are compared in terms of BER, receiver sensitivity and power budget.

I. INTRODUCTION

Broadband access networks are one of the important infrastructures for the development of modern society [1], where Internet users including consumers and business organisations are sending, receiving and storing more data than ever before. These networks are used to connect users or consumers to the central office, where their traffic is accumulated and transmitted to the next level of the telecommunication network. The state of art in this field is fibre to-the-x (FTTx), where x -curb, cabinet, home or building. In this technology optical fibre is used as the transmission medium to a point close to the subscriber [2]. For such an application the requirement is a network which has a point-to-multipoint topology. The point-to-point systems (PtP) and passive optical networks (PONs) are most popular competitors. In the implementation of FTTH majority of these networks are realized in a PON technology. Passive optical networks are used in telecommunications where data is transmitted over an optical fibre medium. It is termed as passive because the splitters which are used to route the data are not powered [3]. PON has evolved continuously owing to the increase of the user bandwidth requirement. The PON has evolved from APON to latest NG-PON2.

NG-PON2 was initiated by FSAN in 2011 [4]. It provides increase of data rate beyond 10Gbps. The time and wavelength division multiplexed architecture is selected as primary solution owing to its backward compatibility and maturity. Four to eight wavelength channels can be multiplexed to obtain an aggregate data rate of 40/80Gbps [5]. In this paper a symmetric PON with 40Gbps data rate is proposed using external modulation and direct modulation, using different modulation schemes like NRZ, RZ, CSRZ and duobinary. The performance is furtheranalysed in terms of BER, receiver sensitivity and power budget.

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II. SIMULATION SETUP

In this section the simulation setup for the proposed work is presented. The symmetrical 40Gbps PON is designed using direct modulation and external modulation with different modulation scheme. The design for each is presented. Fig. 1 shows the symmetrical 40Gbps system configuration for the four wavelength stacked PON with direct modulation and NRZ coding. The aggregate data rate of symmetric PON is 40Gbps which is achieved by stacking four wavelengths both in upstream and downstream directions. A pseudorandom bit sequence generator is used to generate a 10Gbps data. The generated signal is encoded by NRZ coder which represents logic 1 with transmission of electric pulse of amplitude 2 V and logic 0 by absence of electric pulse i.e. 0 V. NRZ coded signal is modulated directly using the directly modulated laser. For the downstream direction four lasers are tuned to frequencies in L_+band 1597nm, 1598nm, 1599nm and 1600nm. A WDM multiplexer multiplexes the downstream wavelengths, which is boosted by the erbium doped fibre amplifier (EDFA) with an output power of 10dBm before being launched into the fibre of length 40 Km. The downstream signal is then broadcasted to optical network unit by the splitter. At the optical network unit the optical filter is used to select the desired channel. The filter in this design is a Gaussian filter tuned to 1599nm. The selected signal is launched to the detector.

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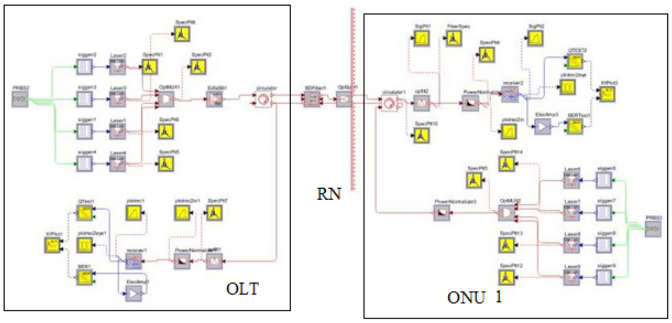
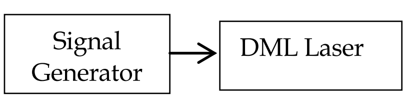


Fig. 1 Symmetrical 40Gbps PON using Direct Modulation with NRZ Coding

For the upstream direction, the pseudorandom generator generates the 10Gbs sequence which is converted to NRZ signal using NRZ coder. The generated signal is directly modulated using direct modulated laser tuned to 1530nm, 1531nm, 1532nm, and 1533nm. The generated upstream wavelengths are then multiplexed and passed through circulator to the fibre. The signal is launched into the fibre with 5dBm power. The upstream signal is finally detected at the optical line terminal. The filter at receiver is tuned to select 1532nm channel and it is detected by the PIN photodiode.

Fig. 2 shows the transmitter design for 40Gbps symmetrical PON for RZ encoded directly modulated signal and externally modulated signal. The pseudorandom bit generated is encoded to RZ format in which logic 1 is represented by electric pulse of amplitude 2V for half bit duration and logic 0 is represented by absence of electric pulse i.e. 0V.



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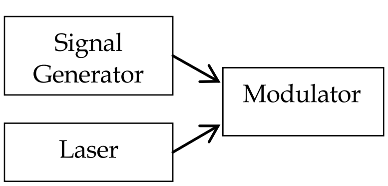

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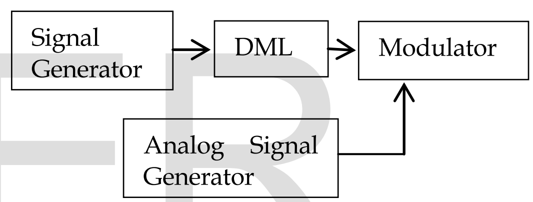
Fig. 2 Transmitter Design for 40Gbps Symmetrical PON for RZ Encoded Signal (a) Direct Modulation (b) External Modulation

The operation of modulation consists of transferring the data to be transmitted from the electrical to the optical domain. There are two ways to perform this operation. First is direct modulation in which light is emitted from a semiconductor laser (DML) only when "logic 1" is transmitted and no light should be emitted when "logic 0" is transmitted. In the second case, called external modulation, a continuous wave (CW) laser is used to emit light whose power is constant with time. A second component, known as modulator, is then used as a switch to let the light pass whenever the data corresponds to "logic 1" and to block it whenever the signal is "logic 0" [6].

Fig. 3 shows the transmitter design for 40Gbps symmetrical PON for CSRZ encoded signal for direct and external modulation. In case of CSRZ transmitter first the RZ optical signal is generated which is then phase modulated by an analog sine wave generator at frequency equal to half of the bit rate. For this system the frequency is set to 5GHz. It will introduce a π phase shift between any two adjacent bits and the spectrum will be modified such that the central peak at the carrier frequency is suppressed [7].



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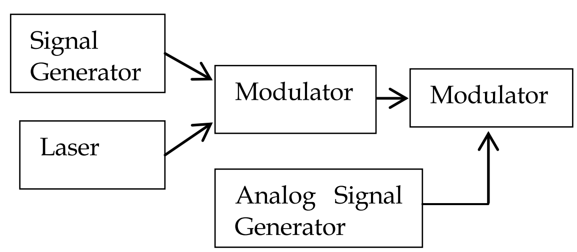

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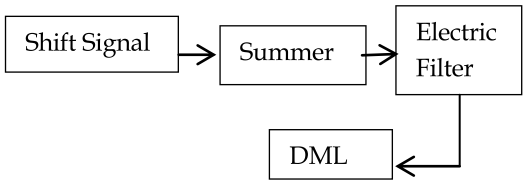
Fig. 3 Transmitter Design for 40Gbps Symmetrical PON for CSRZ Encoded Signal (a) Direct Modulation (b) External Modulation

Fig. 4 shows the transmitter design for 40Gbps symmetrical PON for duobinary modulation for direct and external modulation. For the duobinary generation an ideal NRZ signal is generated which is passed through a delay-and-add circuit followed by a band limiting filter of bandwidth (Bit rate)/2. For the design of 40Gbps system each transmitter bitrate is 10Gbs and hence the bandwidth of band limiting filter is 5GHz.



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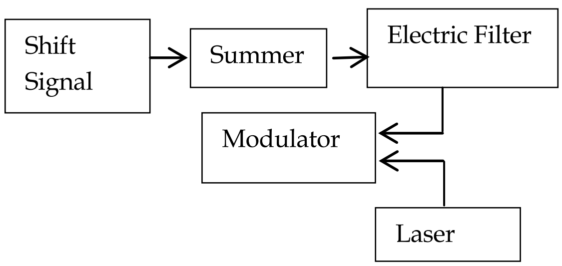
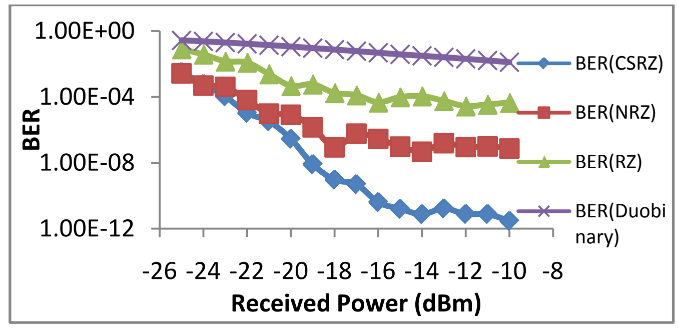


(b)

Fig.4 Transmitter Design for 40Gbps Symmetrical PON for Duobinary Encoded Signal (a) Direct Modulation (b) External Modulation

III. SIMULATION RESULTS

Fig. 5 illustrates the comparison of 40Gbps passive optical network with respect to receive power for a fiber length of 40km. According to the graphs the received power at BER of 10^{-4} for CSRZ is -24dBm, NRZ is -24dBm, RZ is -19dBm. Duobinary has high BER and it needs dispersion compensation to improve its performance. Fig. 6 illustrates the comparison of 40Gbps passive optical network with respect to different fiber length for direct modulation. According to the graphs, BER at 40km for NRZ is 4.31_{e-14}, CSRZ is 2.14_{e-5}, RZ is 2.38_{e-9} and for duobinaryis 3.98_{e-2}. The result for duobinary is out of comparison because of high values of BER. It has high BER and it needs dispersion compensation to improve its performance. Fig. 7 illustrates the comparison of 40Gbps passive optical network with respect to received power for the case of external modulation for the fiber length of 40km. According to the graphs the received power for BER of 10^{-4} for CSRZ is -24dBm, NRZ is -23dBm, RZ is -23dBm and duobinary is -23 dBm. Fig 8 illustrates the comparison of 40Gbps passive optical network with respect to different fiber length for the case of external modulaton. According to the graphs, the BER at 40km for NRZ is 1.94_{e-4}, CSRZ is 8.11_{e-3}, RZ is 1.31_{e-6} and for duobinaryis 3.55_{e-5}.



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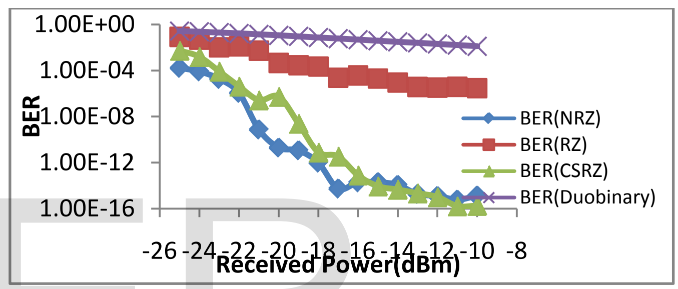


(b)

Fig. 5 BER vs Received Power for Different using Direct Modulation (a) Downstream (b) Upstream

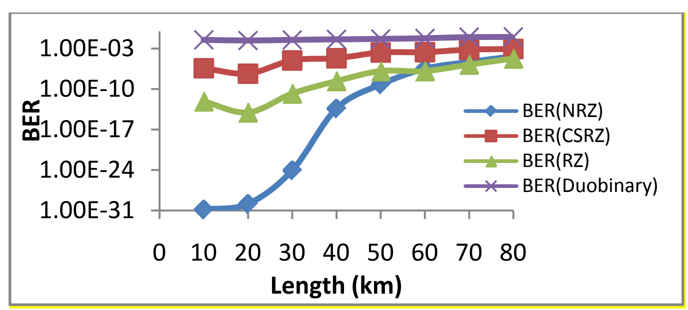
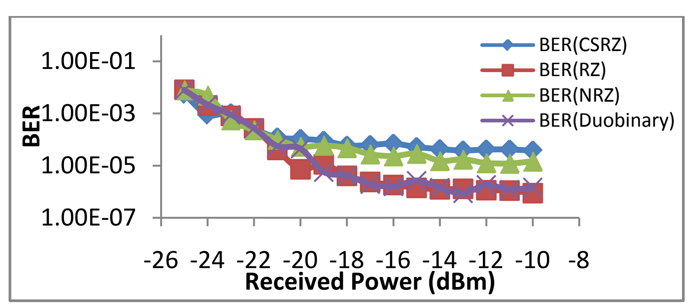


Fig. 6 BER vs Length for Direct Modulation



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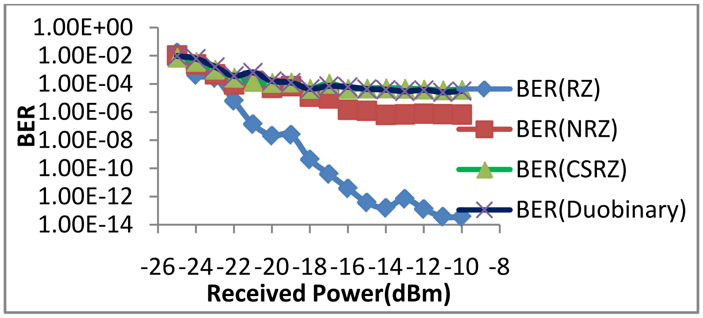

Fig.7 BER vs Received Power for External Modulation (a) Downstream (b) Upstream

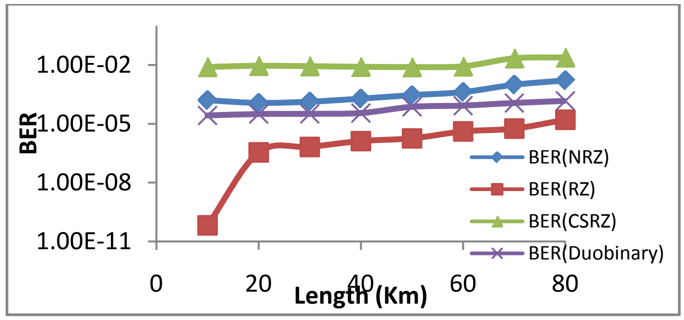

Fig. 8 BER vs Length for External Modulation

Table 1 Sensitivity and Power Budget at BER of 10^{-4} for Directly Modulated System

	Downstream			Upstream		
Modulation scheme	Transmitted Power	Received Power	Power Budget	Transmitted Power	Received Power	Power Budget
NRZ	10dBm	-24dBm	34dBm	5dBm	-24dBm	29dBm
RZ	10dBm	-20dBm	30dBm	5dBm	-20dBm	25dBm
CSRZ	10dBm	-24dBm	34dBm	5dbm	-24dBm	29dBm

Table 2 Sensitivity and Power Budget at BER of 10^{-4} for Externally Modulated System

	Downstream			Upstream		
Modulation scheme	Transmitted Power	Received Power	Power Budget	Transmitted Power	Received Power	Power Budget
NRZ	10dBm	-23dBm	33dBm	5dBm	-23dBm	28dBm
RZ	10dBm	-23dBm	33dBm	5dBm	-24dBm	29dBm
CSRZ	10dBm	-24dBm	34dBm	5dbm	-22dBm	27dBm
Duobinary	10dBm	-23dBm	33dBm	5dBm	-21dBm	26dBm

Table 1 and Table 2 shows the obtained power budget for the two system with different modulation scheme.

IV. Conclusion

At 40Gbps the performance of system with modulated schemes like CSRZ and duobinary support power budget of 34dBm and 33dBm for downstream but for upstream power budget is 27dBm and 27dBm respectively. This is supporting class N1. For NRZ and RZ the power budget is 34dBm, 33dBm, 30dBm for downstream and 29dBm for upstream. NRZ and RZ are the simplest and cost effective forms of modulation;therefore at 40Gbps it is most widely used. CSRZ and duobinary shows equivalent performance and are has costly and complicated transmitter structure so it is not used widely. The performance of duobinary modulation with direct modulation is inferior to external modulation due to the presence of chirp[8] which interferes with chromatic dispersion hence causing distortion, so duobinary technique with direct modulation needs dispersion compensation technique.

V. REFERENCES

[1] K. Asaka, "Consideration of tunable components for next-generation passive optical network stage 2," J. Light. Technol., vol. 33, no. 5, pp. 1072–1076, 2015.

[2] W. Poehlmann, D. Van Veen, R. Farah, T. Pfeiffer, and P. Vetter, "Wavelength Drift of Burst-Mode DML for TWDM-PON [Invited]," vol. 7, no. 1, pp. 44–51, 2015.

[3] D. Dhawan, "High Speed TWDM PON - A Review," no. November, pp. 61–65, 2016.

[4] F. Effenberger and T. S. El-Bawab, "Passive Optical Networks (PONs): Past, present, and future," Opt. Switch. Netw., vol. 6, no. 3, pp. 143–150, 2009.

[5] D. Nesset and S. Member, "NG-PON2 Technology and Standards," vol. 33, no. 5, pp. 1136–1143, 2015.

[6] E. Lach and W. Idler, "Optical Fiber Technology Modulation formats for 100G and beyond," Opt. Fiber Technol., vol. 17, no. 5, pp. 377–386, 2011.

[7] E. Pincemin et al., "Optical Fiber Technology Challenges of 40 / 100 Gbps and higher-rate deployments over long-haul transport networks," Opt. Fiber Technol., vol. 17, no. 5, pp. 335–362, 2011.

[8] Y. Yu and T. Applications, "Chirp-Compensated DBR Lasers for TWDM-PON Applications Chirp-Compensated DBR Lasers for," vol. 7, no. 1, 2015.