PERFORMANCE ANALYSIS OF BIDIRECTIONAL HYBRID ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING-ETHERNET PASSIVE OPTICAL ACCESS NETWORK

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For bottleneck problem of the broadband access networks, Ethernet Passive Optical Network comes out as a striking and promising solution. Even though, Ethernet passive optical network nodes necessitate a cost-effective up-gradation. Accordingly, we propose and demonstrate a hybrid orthogonal frequency division multiplexing-Ethernet passive optical network employing Optical single side band modulation scheme. Case A demonstrates a contrast between symmetric bidirectional single channel orthogonal frequency division multiplexing-Ethernet passive optical network at data rate of 10 and 5 Gbps after a fiber link of 20 km. Case B, targets the transmission of symmetric bidirectional single channel orthogonal frequency division multiplexing-optical single side band-Ethernet passive optical network system and achieves a fiber link of 20 Km with split ratio of 8. Afterwards, eight upstream channels are transmitted simultaneously and successfully obtained at optical linear terminal side to make a bidirectional Ethernet passive optical network system. Further, a contrast between transmission at data rate of 10 and 5 Gbps is carried out that achieves a fiber link of 20 km with split ratio of 8.

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1. Introduction

The bandwidth requirement for multimedia applications such as internet protocol television (IPTV) and high definition (HD) video continue to conflagrate the development in bandwidth-demand in multi-user access networks. The PON (passive optical network) technology proceeds to emerge as the most advance future-proof solution for addressing this need [1, 2]. Also, PON technology has been proved best for transmission of triple-play services such as voice, video and data from OLT (optical linear terminal) to ONU (optical network units) [3]. To get more advantages in terms of range and distortion-free communication, this network using the optical fiber as a feeder throughout the access network. Recently, GPON originate with capability of providing bit rate of 2.5 Gbps in downstream and 1.25 Gbps in upstream channel respectively [1]. Presently, EPON (Ethernet passive optical network) systems deploy two wavelengths: typically 1310 nm for the upstream transmission and 1550 nm for the downstream transmission. In the downstream, Ethernet frames are broadcast by the OLT and are selectively received by each ONU. Alternatively, in the upstream, multiple ONUs share the same transmission channel to send data and control packets to the OLT. Furthermore, EPONs become more influential on emerging with cost-effective up-gradation of WDM (wavelengths division multiplexing) technology. Furthermore, only EPON nodes with privileged traffic can be WDM-upgraded by either deploying fixed-tuned and/or tunable transceivers [4]. WDM-EPON deals with the deployment of multiple wavelengths in the upstream/downstream directions and has potential to combat with the challenges of the metro/access network with the aspect of future developments. Recently, a square root module (SRM) treated WDM-Optical Single Side Band-PON system has been developed for the successful transmission over the distance of 20 km with split ratio of 16 [5]. In addition to WDM technology, OFDM (orthogonal frequency-division multiplexing) comes out as a potential scheme in up-grading the PON networks as well [6]. The OFDM technology not only limits the restrictions on speed and transmission rate but also it offers flexibility, easy and cost-effective deployment of PON networks. OFDM is a multi-carriers scheme which works on the principle of converting high-speed serial data into multiple relatively low-speed parallel data and then different sub-carriers will be modulated. This force OFDM based optical access technology as a next-generation optical-access-research-venture. An OFDM-EPON permits flexible assignment of 4-QAM (quadrature amplitude modulation) at 250 Mbps and 16-QAM LAN traffic at 500 Mbps bandwidth by allocating different number of subcarriers [7]. It is highly flexible in terms of encouraging multiple granularities of bandwidth through high efficient digital modulation and dynamic resource management. All users may share the bandwidth that is allocated to the sub-carriers through TDM mode [8]. Owing to innumerable positives, OFDM has been viewed as assuring system to meet the increased and varied demands of broadband multimedia services for wireless users as well. In this work, we have demonstrated an OFDM based OSSB-EPON (optical single side band-Ethernet passive optical network) system with two different cases which is not elaborated earlier. The proposed system is investigated for successful transmission of bidirectional channel over the SSMF at high data rate with improved split ratio and fiber link between ONU and OLT. The system is optimized at acceptable SNR (signal-to-noise ratio) of 15 dBm. This paper is organized as follows: Section 1 briefly describes need and year to year development in EPON system. Section 2 deals with the portrayal of simulated OFDM based OSSB-EPON model and is followed by section 3 to measure the results. The section 4 puts light on the measured results in section 3.

2. Model Description

Our implementation of the customer access EPON using OFDM and WDM is shown in Fig. 1. In our proposed OFDM-OSSB-EPON system, QAM data signals are generated using 4QAM sequence generator with 2 bit per symbol. This QAM data signals are then OFDM modulated by means of OFDM modulator using 512 subcarriers and FFT size of 1024 to generate OFDM analog data signals. These signals are QAM modulated at 7.5 GHz frequency. This QAM-OFDM treated analog data signals are then modulated by means of DEMZM (dual electrode Mach–Zehnder modulator), phase shifter and an optical source at 1550 nm to generate OSSB signals. These OFDM-OSSB signals are then transmitted over SSMF fiber without using any active device in between OLT and ONU. All design parameters are taken as IEEE 802.3 ah standard [9]. The SMF fiber parameters are chosen as nonlinear reflective index coefficient = 2.6×10^{-20} m^2/W; effective area, A_{eff} = 80 m^2; attenuation = 0.2 dB/km; dispersion = 17 ps/nm/km; and dispersion slope = 0.075 ps/nm^2/km in both the cases. In both cases, PIN photodetector with sample rate of 40 GHz; responsivity of 1 A/W; dark current of 10 nA, OFDM demodulator with 512 sub-carriers, position array 256 and number of FFT (fast Fourier transport) points 1024 are used for electrical transmission. Different spectrum analyzers such as SNR analyzer and BER (bit error rate) analyzers are connected after 3R regenerator at the receiver side to investigate the observations. Both the simulated systems are optimized at acceptable SNR of 15 dBm. The simulation is through Optisys$^{\text{TM}}$ software and is discussed in two cases.

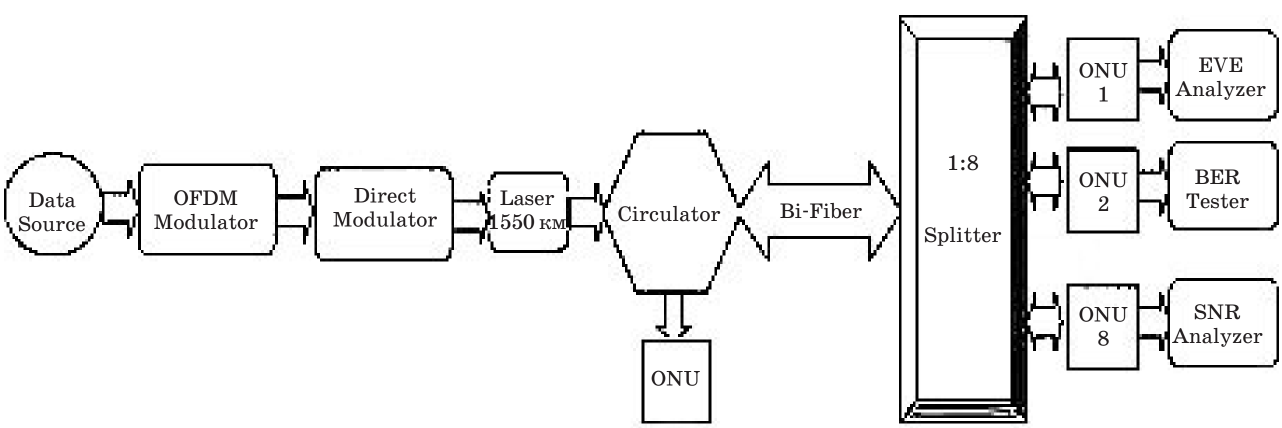

Fig. 1. Bidirectional OFDM-OSSB-EPON based access network.

In case A, for the generation of OFDM treated single side band signals, the input channel is applied to both the electrode of MZM (Mach–Zehnder modulator) in such a way that the input signal is given directly at one electrode and at another electrode with 90° phase shift. This OFDM treated OSSB modulated channel at 1550 nm of data rate 10 and 5 Gbps having power 0 dBm, is transmitted over SSMF simultaneously at distance of 20 km to realize OFDM-based OSSB-EPON access system. Further, a symmetric single upstream channel (i.e at 10 and 5 Gbps) at 1300 nm wavelength is transmitted simultaneously towards the olt side. The performance of the system is evaluated based upon the analyzed SNR, Q-factor, constellation diagram and eye opening. Subsequently, a contrast of SNR and Q-factor at different data rates such as 10 and 5 Gbps is carried out for this single bidirectional channel transmission. In case B, single downstream channel of 1550 nm at data rate of 5 and 10 Gbps, is transmitted at an optical span of 20 km over SMF (single mode fiber) with split ratio of 8 and 0 dBm power simultaneously. Further, eight upstream channels at 1300 nm wavelength and symmetric data rates (i.e 10 and 5 Gbps) are transmitted at an optical span of 20 km towards OLT side through SMF fiber simultaneously to realize OFDM-based bidirectional OSSB-EPON access system. Subsequently, a contrast of SNR and Q-factor for 1*8 bidirectional system at different data rates such as 10 and 5 Gbps is carried to present the bidirectional system performance. Also, various observations like eye diagram and constellation diagram is carried out.

3. Result Discussion

As demonstrated in case A, the results are measured for a OSSB-EPON system with single channel transmission at 10 and 5 Gbps as shown in Fig. 2–5. Consider Fig. 2. On comparing for both data rates of the simulated EPON systems, a noticeable improvement of about 4 and 3.3 dB in SNR of downstream and upstream channel after an optical span of 20 km for OFDM based system is achieved with acceptable BER as shown in Fig. 2. Further, it has also been observed that the quality factor is improved by about 2.8 and 2.7 dB in downstream and upstream channel after an optical span of 20 km is achieved as depicted in Fig. 3.

Further as demonstrated in case B, the measured SNR for realization of 1*8 bidirectional

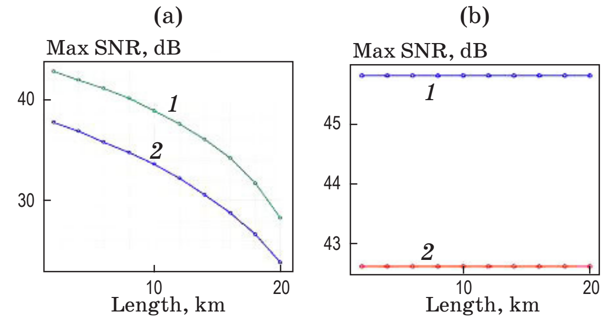

Fig. 2. Measured SNR vs channel length (a) Downstream, (b) Upstream, after an optical span of 20 km at 1500 and 1300 nm for Single channel bidirectional system. Data rate are (*1*) 10, (*2*) 5 Gbps.

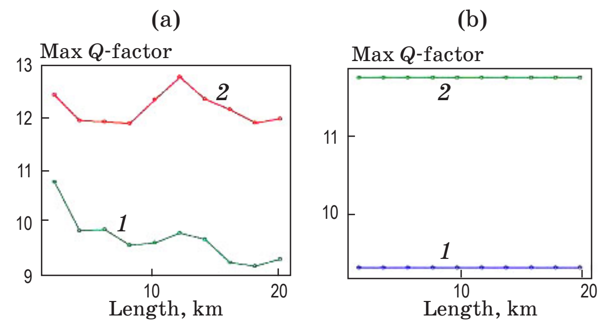

Fig. 3. Measured Q-factor vs channel length (a) Downstream, (b) Upstream, after an optical span of 20 km at 1550 and 1300 nm wavelength for Single channel bidirectional system. Data rate are (*1*) 10, (*2*) 5 Gbps.

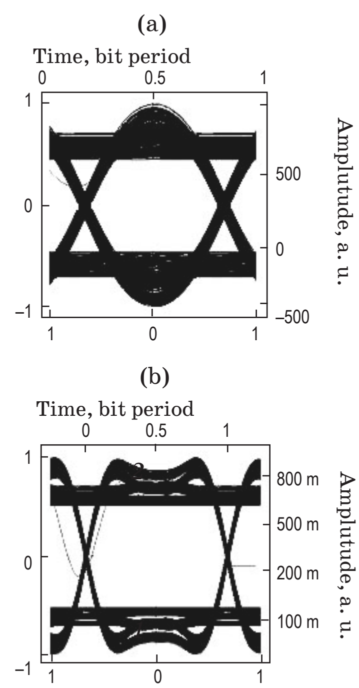

Fig. 4. Eye diagram of upstream channel after an optical span of 20 km at data rate (a) 10, (b) 5 Gbps for Single channel bidirectional system.

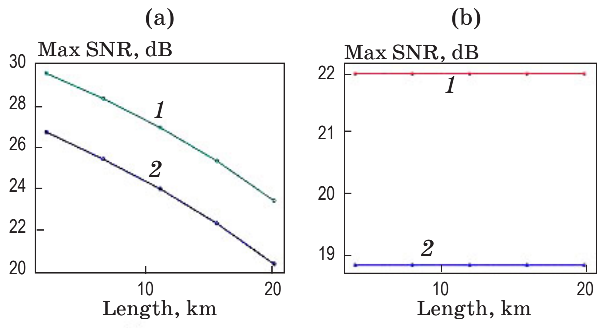

Fig. 5. Measured SNR vs channel length for single bidirectional channel with split ratio of 8 at 1550 and 1300 nm wavelength after optical span of 20 km at 0 dBm at (a) Downstream, (b) Upstream channel. Data rate are (*1*) 10, (*2*) 5 Gbps.

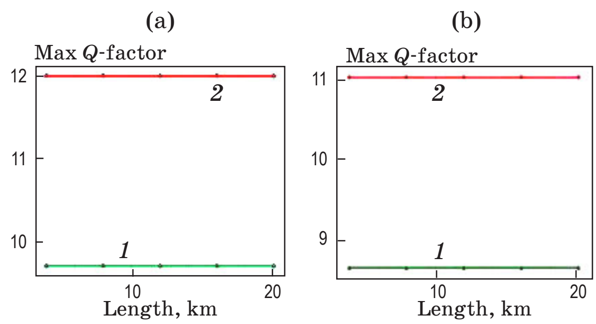

Fig. 6. Measured Q-factorvs channel length for single bidirectional channel with split ratio of 8 at 1550 and 1300 nm wavelength after optical span of 20 km at 0 dBm of (a) Downstream, (b) Upstream channel. Data rate are (*1*) 10, (*2*) 5 Gbps.

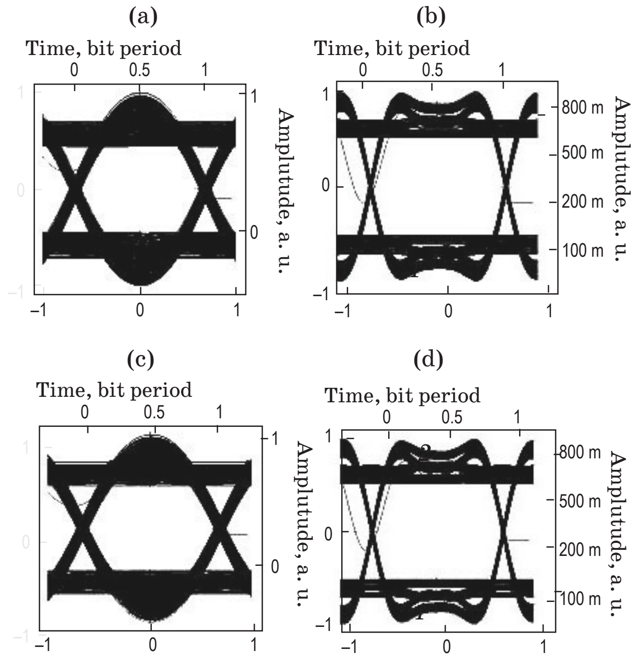

Fig. 7. Eye diagram of upstream channel at data rate (a) 10, (b) 5 Gbps and downstream channel at data rate (c) 10, (d) 5 Gbps after an optical span of 20 km for Single channel bidirectional system with split ratio 8.

channel OFDM-OSSB-EPON system of 10 and 5 Gbps data rate is shown in Fig. 6. The simulated system is capable of achieving optical span of 20 km with split ratio of 8 with acceptable SNR. As seen in Fig. 6, 7, a significant improvement of about 3 and 3.2 dB in SNR and 2.23 dB in Q-factor is achieved at an optical span of 20 km in downstream and upstream direction. The obtained result prevails that OFDM employed OSSB-EPON provides better SNR and Q-factor along with acceptable BER for symmetric single bidirectional channel transmission as demonstrated in case A.

Having a look at Fig. 2, 6, an outsized SNR gap of about 4.6 and 3.6 dB at 10 Gbps data rate in downstream direction and 23.8 and 23.9 dB at 5 Gbps data rate in upstream direction is noticed at fiber link of 20 km respectively. It is also noticed that the rate of SNR decay with increase number of users goes to increase as demonstrated in case B. But this SNR decay is again within the acceptable limits.

4. Conclusion

As per the results obtained from the demonstrated consumer access systems, it is concluded that low BER's with high split ratio were measured for transmission of single bidirectional 10 and 5 Gbps channels over 20 km of standard fiber as demonstrated in case B. It is also observed that, based on our observations, up to 8 ONU's could be well supported by employing OFDM-OSSB technique over such a high data rates. Accordingly, an OFDM based EPON system is recommended to accomplish better optical span with high split ratio at low BER.

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