On WDM RoF–EPON link using OSSB transmission with and without DCF + FBG

Baljeet Kaur a,*, Ajay K. Sharma b, Vinod Kapoor c

a Department of Electronics and Communication Engineering, Guru Nanak Dev Engineering College, Ludhiana, Punjab, India
b Department of Computer Science and Engineering, National Institute of Technology, Jalandhar, Punjab, India
c Department of Electronics and Communication Engineering, National Institute of Technology, Hamirpur, Himachal Pradesh, India

A R T I C L E   I N F O

Article history:
Received 6 May 2013
Accepted 28 September 2013

Keywords:
Optical network unit
Optical line terminal
BER
EPON
RoF
Mach–Zehnder modulator
OSSB

A B S T R A C T

A system is presented which uses optical SSB transmission on WDM RoF–EPON link to compensate dispersion and FWM with DCF and FBG. Performance of the system is improved by 8.91% with the use of DCF and FBG for equal spacing between the channels and it is further increased by 9.51% by keeping unequal spacing between the channels. Results are compared for equal and unequal spacing with and without DCF and FBG. BER, Q factor and eye diagrams have been analyzed for evaluating the performance of the system.

© 2013 Elsevier GmbH. All rights reserved.

1. Introduction

The rapid demand of bandwidth for fast data rate application requires the need of high frequency communication systems. RoF technique is one of the promising solutions for these systems. However chromatic dispersion in fiber creates problem in RoF system, which limits the transmission distance [1]. WDM network with RoF has been researched to make optical network unit (ONU) to support both wired and wireless services [2,3]. When signals carried by optical wave are transmitted by fiber, fiber chromatic dispersion takes place. To overcome chromatic dispersion, several techniques have been implemented [4,5]. Optical single sideband (SSB) transmission is an attractive method to counter the deterioration caused by noise and distortion created by chromatic dispersion [6–9]. SSB technologies are especially advantageous in digital optical fiber communication systems [10], such as high density wavelength multiplexing and long haul fiber transmission. SSB technologies can suppress nonlinear optical effects because of the reduced optical power to adjust the potential of modulators [11,12]. When multiple wavelengths in WDM system carrying different signals propagate in single fiber, dispersion and fiber nonlinearities can lead to crosstalk between carriers, in order to enhance the performance of the system these effects should be minimized. In this paper, DCF and FBG are used on WDM-EPON with RoF system with an OSSB transmission to compensate dispersion and FWM effects. This letter is organized as follows. WDM-EPON with RoF using OSSB transmission model is presented with DCF + FBG in Section 1. Simulation model presented in Section 2 and Results are discussed in Section 3. Finally conclusions are drawn in Section 4.

2. Simulation model

The OSSB transmission using the dual electrode MZM is shown in Fig. 1 [13]. In this model DCF and FBG are used to compensate dispersion and FWM. All parameters for the designing are taken according to IEEE 802.3 ah standard [14]. Design of RF modulation inside the subsystem is shown in Fig. 2. Five channels 1552.5, 1551.72, 1550.91, 1550.11 and 1549.31 nm wavelengths with 0.8 nm equal spacing, 0 dBm power and 15 GHz radio frequency are combined through WDM MUX and then transmitted via bidirectional optical fiber. After passing through fiber DCF is used to compensate dispersion, which reduces power to 1 dBm, then two FBGs are used. First FBG remove the signals, which are greater than fifth channel wavelength 1552.5 nm and second FBG remove the signals less than first channel wavelength 1549.32 nm. Same analysis is done for unequal spacing between channels. Five channels 1552.5, 1552.12, 1551.31, 1550.11 and 1549.31 nm wavelengths are transmitted and then for compensation of dispersion and FWM, DCF and two FBGs are used. DCF reduces the power 1 dBm and first
FBG remove the signals greater than 1552.2 nm and second FBG remove the signals less than 1549.31 nm. The designing inside first subsystem is shown in Fig. 2. OSSB spectrum before and after FBGs for equal and unequal spacing is shown in Figs. 3 and 4, respectively.

At ONU1 the received signal power is again divided through WDM DEMUX into five users as shown in Fig. 5. At the receiver side, we have connected eight ONUs, so total 40 users can receive the signal simultaneously.

From Figs. 3 and 4, it can be seen that with the use of FBGs, the signals before first channel and after fifth channel have been eliminated. The received signal after WDM DEMUX is fed into a PIN photo-detector with 800 GHz sampling rate, responsivity of 0.6 A/W and a dark current of 1 nA. After that, band pass Bessel filter at 15 GHz frequency and 2.5 GHz bandwidth and AM demodulator at 15 GHz frequency and 0.9375 GHz cut-off frequency are selected for the electrical transmission. 3R regenerators and BER analyzers are placed at receiver side to analyze the output shown in Fig. 6.

<table>
<thead>
<tr>
<th>Bit Rate (Gbps)</th>
<th>Q factor (OSSB)</th>
<th>Q factor (OSSB + DCF + FBG for equal spacing)</th>
<th>Q factor (OSSB + DCF + FBG for unequal spacing)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.25</td>
<td>13.23</td>
<td>14.41</td>
<td>15.78</td>
</tr>
<tr>
<td>2.25</td>
<td>12.06</td>
<td>13.52</td>
<td>14.76</td>
</tr>
<tr>
<td>5</td>
<td>8.16</td>
<td>10.44</td>
<td>11.94</td>
</tr>
</tbody>
</table>
3. Results and discussion

The simulation setup of Fig. 1 is employed to transmit OSSB signal for WDM RoF–EPON Link with DCF + FBG. ODSB signal is converted into OSSB with a dual electrode Mach–Zehnder modulator (MZM) having switching bias voltage of 4 V, insertion loss 5 dB and excitation ratio 40 dB. This has resulted in suppression of 5 dB in carrier and 10 dB in the sidebands.

The performance of the system is further enhanced by using DCF and FBG to compensate the dispersion and FWM. Results at Rx3 are shown in Fig. 7.

By comparing the BER patterns of Fig. 7, we found that the eye opening is higher with the use of DCF + FBG for unequal spacing as compared to equal spacing. Analysis has also been done for different input powers and different lengths of fiber as shown in Figs. 8 and 9, respectively.

Q factor is also calculated at different bit rates for equal and unequal channel spacing as shown in Table 1.

From Table 1, we have observed that OSSB transmission with DCF and FBG for unequal channel spacing is also acceptable at 5 Gbps and gives better result as compared to equal channel spacing.

In Fig. 9, results revealed that in order to obtain Q factor greater than 6, the performance of WDM RoF–EPON link with DCF + FBG is quite good even if input power is in the range of −40 to 36 dBm with unequal channel spacing and −35 to 29 dBm in case of equal
channel spacing while this link is usable only at input power of −21 to 27 dBm without DCF + FBG.

4. Conclusion

Five channels, WDM RoF–EPON link using OSSB transmission to compensate dispersion and FWM with DCF and FBG is simulated and analyzed. For the compensation of dispersion and FWM, DCF at −50 ps/nm/km dispersion value and two FBGs have been used. Results have been reported at bit rate of 1.25, 2.25 and 5 Gbps for WDM EPON–RoF link by compensating dispersion and FWM using DCF and FBG. Best results have been obtained at bit rate of 1.25, 2.25 and 5 Gbps for OSSB with DCF + FBG for unequal channel spacing as shown in Table 1. At bit rate of 1.25, 2.25 and 5 Gbps, there is improvement of 8.91%, 12.11% and 27.94% over OSSB and 9.51%, 9.17% and 14.36% over OSSB with DCF + FBG for equal channel spacing, respectively.

References