Optik 124 (2013) 1334–1337

Contents lists available at SciVerse ScienceDirect

Optik

journal homepage: www.elsevier.de/ijleo

On WDM RoF–EPON link using OSSB transmission with and without square root module

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ARTICLE INFO

Article history:
Received 15 November 2011
Accepted 17 March 2012

Keywords:
Optical network unit
Optical line termination
BER
EPON
RoF
Square root module

ABSTRACT

In this paper, we have proposed a technique for the generation of OSSB transmission with carrier for WDM Ethernet Passive Optical Network (EPON) with Radio over Fiber (RoF) optical link. The performance of the system is further enhanced by using a square root module (SRm) at the receiver side. The suppression of 5 dB in carrier and 10 dB in the sidebands has been shown. The improvement in the performance has been reported three times for successful transmission of OSSB as compared to ODSB over the distance of 20 km and it is further enhanced by two times with the use of SQRT module and that has been witnessed by measuring BER and eye opening.

1. Introduction

The increase demand of the capacity of optical transmission systems has led to the development of spectrally efficient optical modulations. WDM–RoF has been regarded as a promising system that can meet the increase and varied demands of broadband multimedia services for wireless users [1]. RoF technique for the WDM–EPON has been researched to make optical network unit (ONU) support both wired and wireless services [2,3]. The WDM–EPON systems using RoF technique can both reduce the cost of BSs and serve as many users as possible. The cell radius will also become relatively small, so that large number of BS's can be accommodated [4]. However, there is one problem in this RoF system, and this is chromatic dispersion in fiber which significantly limits the transmission distance [5]. For a single mode laser, the symmetrical sidebands are created on the optical carrier. Due to fiber chromatic dispersion, a relative phase shift is added to these sidebands which depends on the wavelength, fiber distance and modulation frequency. Each sideband mixes with the optical carrier in the optical receiver. If the relative phase between these two components is 180°, the components destructively interfere and the mm-wave electrical signal disappears. The detected signal power has been considered as reported in [6]. Therefore, it is important to compensate the fiber chromatic dispersion. Optical single sideband (OSSB) transmission is seen an excellent method to overcome this problem [7]. SSB technologies are especially useful in digital optical fiber communication systems [8], such as higher density wavelength multiplexing and long haul fiber transmission. SSB technologies can suppress nonlinear optical effects because of the reduced optical power to demonstrate the potential of modulators [9,10].

In this paper, we have presented a scheme of OSSB transmission in WDM–EPON with RoF system using a commercial simulator optisystem^{TM} to transmit data at 1550 nm wavelength. For downlink, we generated multiple Single Side Band (SSB) optical carriers by using only one dual-electrode MZM modulator. BER of both the downlink and the uplink for two channels after 20 km transmission has been obtained with and without SRm.

This paper is organized as follows: the optical SSB transmission model description has been mentioned in Section 2 and their-after the results are discussed in Section 3. Finally the conclusions are drawn in Section 4.

2. Optical SSB transmission model

An optical SSB transmission for WDM–EPON with RoF was presented to employ a dispersion-compensated system using a dual-electrode MZM modulator as shown in Fig. 1. All the parameters for the designing are taken according to IEEE 802.3 ah standard [11]. We have connected five channels with 0.8 nm spacing. Here eight ONUs are connected with a central office (OLT)

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0030-4026/$ – see front matter © 2012 Published by Elsevier GmbH.
http://dx.doi.org/10.1016/j.ijleo.2012.03.083

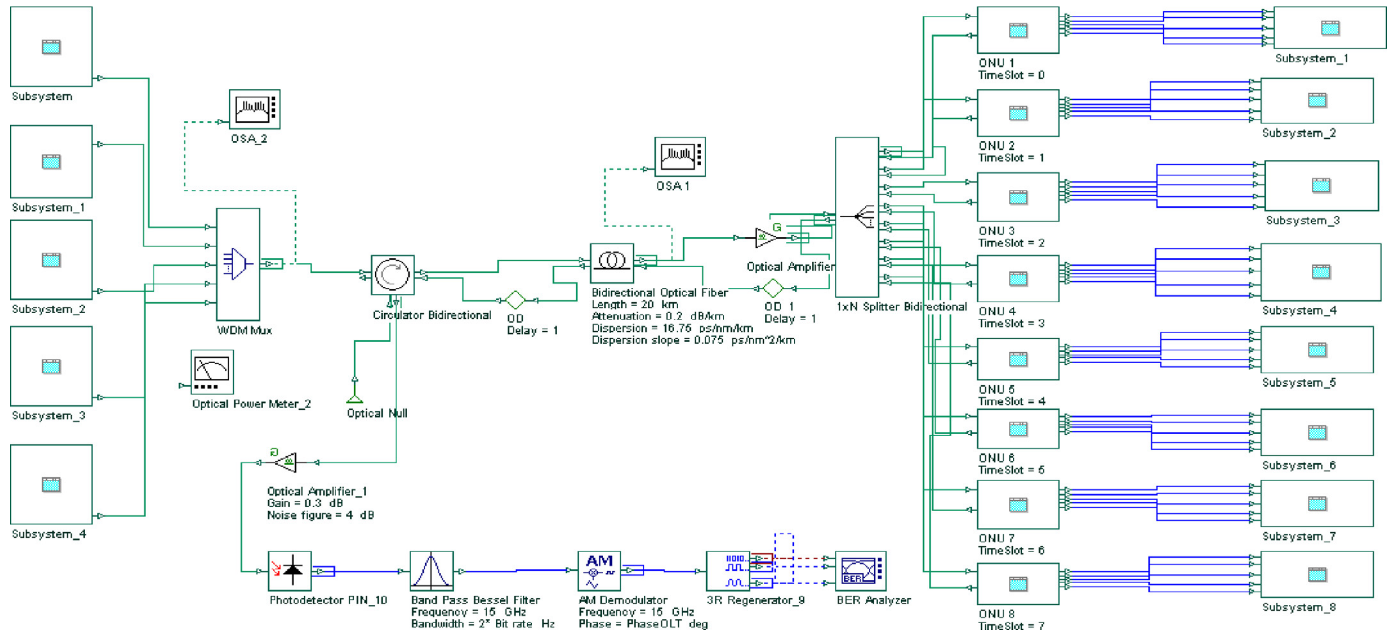

Fig. 1. OSSB model for WDM–EPON with radio frequency using SQRT module.

via an optical fiber access network employing WDM technology. A 20-km of single mode fiber (SMF) was used as the feeder and 2 km of SMF was selected for the distribution fiber. Many parameters have been taken under variation to get the best BER pattern. The parameters of standard single-mode fiber are set to be: effective area $A_{eff} = 80\,\mu m^2$, nonlinear refractive index coefficient $\eta_2 = 2.6 \times 10^{-20}\,m^2/W$, attenuation loss $\alpha = 0.2$ dB/km dispersion, $D = 16.75$ ps/nm/km, dispersion slope = 0.075 ps/nm^2/km and maximum nonlinear phase shift = 5 mrad.

In downstream direction five channels 1552.5, 1551.72, 1550.91, 1550.11 and 1549.31 nm wavelengths with 0.8 nm spacing and 0 dBm power is combined through WDM MUX and then transmitted via bidirectional optical fiber. To generate OSSB signal, input is applied to both the electrodes of Mach–Zehnder modulator, in one electrode directly and another with $\pi/2$ phase shift. In five subsystems 15 GHz RF signal is applied with different carrier frequencies. Design of RF modulation inside the subsystem is shown in Fig. 2.

WDM MUX is launched to combine these carriers for the further transmission. The output of WDM MUX is transmitted through bidirectional optical fiber and then amplified by using an EDFA amplifier further the output is divided by using 1:8 splitters to eight ONUs. Similarly 0 dBm powers is combined from eight ONUs and transmitted to OLT. The OSSB transmission spectrum after WDM–MUX is shown in Fig. 3.

At ONU1 the received signal power is again divided through WDM DEMUX into five users as shown in Fig. 4 and we have connected eight ONUs, so total 40 users can receive the signal simultaneously.

The received signal after WDM DEMUX is fed into a PIN photodetector with 800 GHz sampling rate, responsivity of 0.6 A/W and a dark current of 1 ηA. The photodiode performs a modulus

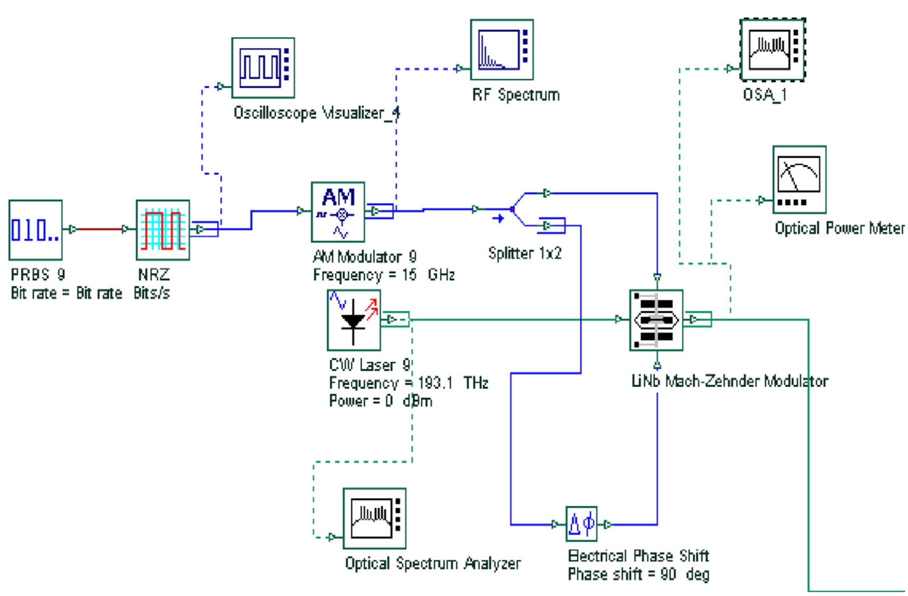

Fig. 2. RF modulation (design inside first subsystem).

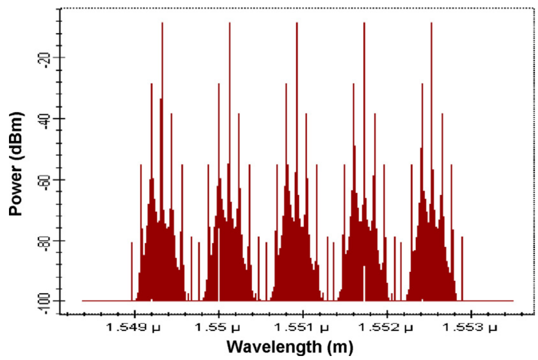

Fig. 3. SSB transmission spectrum for five channels.

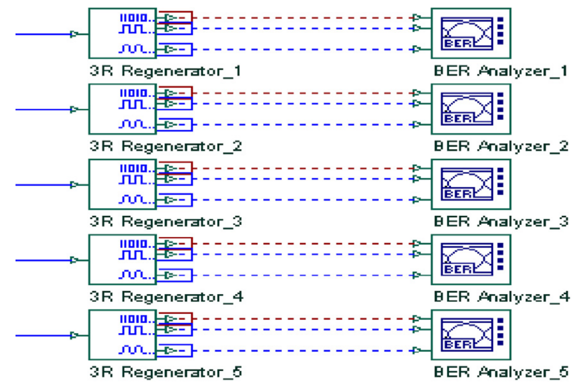

Fig. 6. Measurement blocks after ONU1.

squared operation on the optical field that causes optical linear effects to become nonlinear [12,13]. SRm is designed using MATLAB programming to reduce the nonlinearity and placed after photodiode as shown in Fig. 5. Results are compared with and without SRm.

Different analyzers both at transmitter and receiver side are connected for the analysis.

After ONU1, we have connected five 3R regenerators and BER analyzers as shown in Fig. 6.

3. Results and discussion

The simulation setup of Fig. 1 is employed to transmit OSSB signal for WDM RoF–EPON link. ODSB signal is converted into OSSB

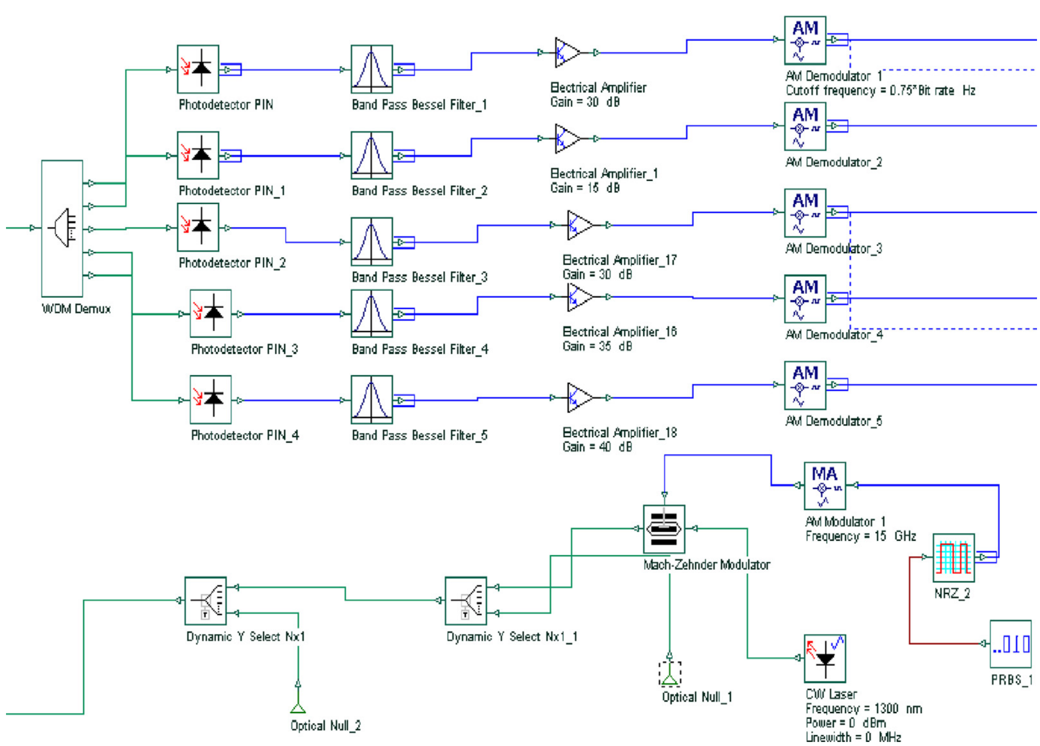

Fig. 4. Designing inside ONU1.

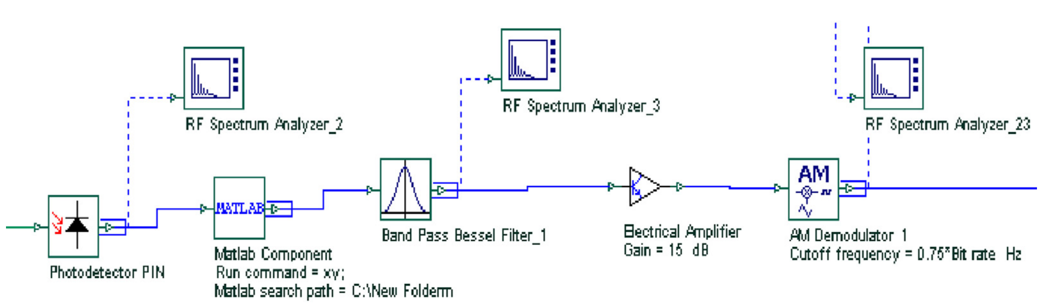

Fig. 5. Photodiode with SRm.

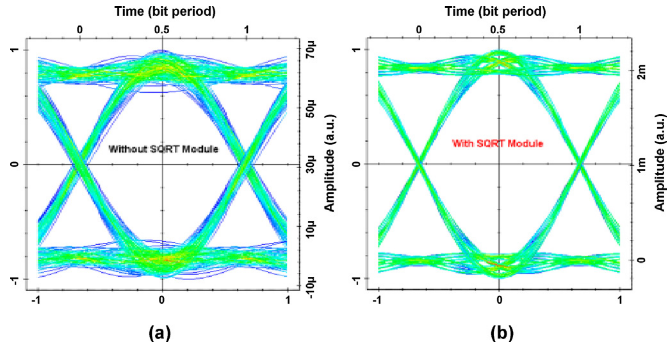

Fig. 7. Output at Rx1: (a) SSB without SRm, (b) SSB with SRm.

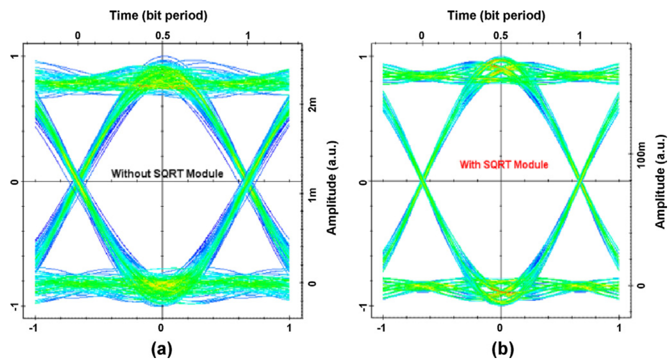

Fig. 8. Output at Rx5: (a) SSB without SRm, (b) SSB with SRm.

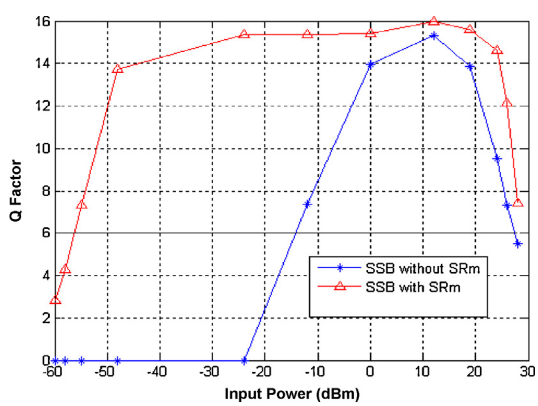

Fig. 9. *Q* factor versus input power for SSB without SRm and SSB with SRm transmission.

with a dual electrode Mach–Zehnder modulator (MZM) having switching bias voltage 4 V, Insertion loss 5 dB and excitation ratio 40 dB showed in Fig. 2. The suppression of 5 dB in carrier and 10 dB in the sidebands were obtained.

The performance of the system is further enhanced by using a SRm at the receiver side to compensate the square-law characteristics of photodiode. BER analyzer is placed at receiver side to analyze the output shown in Figs. 7 and 8 at Rx1 and Rx2.

By comparing the BER patterns of Figs. 7 and 8, we analyzed that the eye opening is higher with the use of SRm as compared to without SRm. For successful transmission of OSSB the improvement in the performance has been reported three times higher than the ODSB and it is further enhanced by two times with the use of SRm.

The *Q* factor has been obtained for OSSB transmission link with and without SRm as shown in Fig. 9. The results revealed that there is significant improvement if SRm is used in the transmission link. To obtain *Q* factor greater than 6, the performance in the OSSB transmission link is quite good even if input power is in the range of −55 to 28 dBm with the use of SRm while the link is usable at input power of −12 to 26 dBm in case of without SRm.

4. Conclusion

Optical SSB transmission with the suppression of 5 dB in the main carrier and 10 dB in the subcarrier is obtained. The improvement in the performance has been calculated three times for successful transmission of optical SSB and it is further enhanced by two times with the use of SRm over a distance of 20 km. The value of *Q* factor has been obtained at different input power with and without SRm. The result revealed that the *Q* value is highest for WDM RoF–EPON link in case of SRm.

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