Optik 121 (2010) 2012–2016

Contents lists available at ScienceDirect

Optik

journal homepage: www.elsevier.de/ijleo

Performance analysis of optical wavelength switching network using multiple output light source

Lan-Chih Yang [a], Chien-Chang Huang [a,*], Hsin-Hung Lin [b], Shyh-Lin Tsao [b]

[a] Department of Communication Engineering, Yuan Ze University, 135, Yuan-Tung Road, Chung-Li, Taoyuan 320, Taiwan
[b] Institute of Electro-Optical Science and Technology, National Taiwan Normal University, Taipei, Taiwan

ARTICLE INFO

Article history:
Received 2 February 2009
Accepted 28 June 2009

Keywords:
Wavelength division multiplex
Passive optical network
Multi-wavelength
Optical switch
Bit-error rate

ABSTRACT

In this paper a 32×32 optical wavelength switching network using the multi-channel and multi-wavelength spectrum-sliced light source is presented where the 2×2 optical-switching elements are utilized in dilated Benes and modified dilated Benes configurations, respectively. The system performances in bit-error rate, especially for the effects of intraband crosstalk, are analyzed in details for the two type networks. Through the simulation studies, the dilated Benes shows better performances than the modified dilated Benes configuration.

1. Introduction

Wavelength division multiplexed (WDM) passive optical networks (PONs) is a promising solution for future high-speed access networks such as fiber-to-the-home or fiber-to-the-building owing to reasons of large capacity, network security, protocol transparency and upgradability [1]. The WDM networks that use a multi-wavelength optical source or set of sources, located remotely from network nodes and shared by nodes, have been proposed for local area network (LAN) applications [2–4].

These sources include semiconductor lasers [5–7], fiber ring lasers [8,9], soliton sources [10] and supercontinuum sources [11,12]. Several sources have also been specifically utilized for practical networks. However, these networks require more cost-effective light sources for commercial implementations. To overcome this problem, there are some substantial efforts to develop WDM PONs using a spectrum-sliced light source [13,14]. It has been reported primarily that the intraband crosstalk, originated from inputs of neighboring fibers carrying the same wavelength signals, may cause severe degradation in system performance for a WDM cross-connect network [15–17]. More studies on intraband crosstalk are required for system performance evaluations.

For WDM PONs with conventional laser sources, this crosstalk has been considered not so important since each laser should operate at the distinct wavelength. Nonetheless, the intraband crosstalk could be generated in WDM PONs by four-wave mixing (FWM) and multiple reflections at connectors and splices [18]. When the spectrum-sliced light source is used, the nonideal shape of WDM filters could contribute to the intraband crosstalk as well. However, to our knowledge, the effects of intraband crosstalk have not been analyzed in details for the system using spectrum-sliced light sources. Previous reports considered the power leakage only in WDM devices used for spectrum-slicing [19,20].

In this paper, we analyze the bit-error-rate (BER) performance of a 32×32 optical wavelength switching network with the spectrum-sliced light source, including the intraband crosstalk effects, for dilated Benes and modified dilated Benes [21] configurations. The remainder of this paper is organized as follows: Section 2 introduces the BER formulation for the networks. In Section 3 the system performances of the 32×32 optical wavelength switching networks are shown. Finally, some concluding remarks are given in Section 4.

2. Formulation of BER performance

The impairment factors for BER performance of optical-communication systems can be categorized into thermal noise, shot noise, timing jitter, multi-channel crosstalk and amplified stimulated emission (ASE). The thermal noise generated by agitation of electrons in a resistor is function of temperature as kT for its power spectral density, where k is the Boltzmann's constant in 1.38×10^{-23} J/K and T is the temperature in Kelvin scale. Then the noise power for the resistor of the receiver is

$$\sigma_{th}=\frac{4kTF_NB}{R} \tag{1}$$

* Corresponding author. Tel.: +886 3 4638800x7315; fax: +886 3 4554264.
E-mail address: cch@saturn.yzu.edu.tw (C.-C. Huang).

0030-4026/$ - see front matter © 2009 Elsevier GmbH. All rights reserved.
doi:10.1016/j.ijleo.2009.06.005

where R is the resistance, F_N is the receiver noise figure and B is the receiver bandwidth in Hz.

The spontaneous emission comes together with optical amplifiers so that noise is added when a light signal passes through an amplifier. The spontaneous emission spectral density is

$$S_{ASE} = (G-1)n_{sp}\chi hf \tag{2}$$

where G is the amplifier gain, n_{sp} is the population-inversion parameter, χ is used to account for the non-uniform carrier density distribution due to gain saturation, hf is the photon energy.

If the incident power to the amplifier is P_{in} and the amplifier has a gain of G, the powers for shot noise, ASE–ASE beat noise and signal–ASE beat noise of the photo-diode are given as the following equations:

$$\sigma_{shot}^2 = 2eR_r(GP_{in} + S_{ASE}B_{opt})B \tag{3}$$

$$\sigma_{sig-ASE}^2 = 4R_r^2 P_{in} G S_{ASE} B \tag{4}$$

$$\sigma_{ASE-ASE}^2 = 4R_r^2 S_{ASE}^2 B_{opt} B \tag{5}$$

where $R_r = (e\eta/hf)$ is the receiver responsitivity, e is the electron charge, η is the quantum efficiency of the photo-diode and B_{opt} is the optical filter bandwidth. Note that if the dark current I_d of receiver is considered, the shot noise power in (3) should be modified as

$$\sigma_{shot}^2 = 2e[R_r(GP_{in} + S_{ASE}B_{opt}) + I_d]B \tag{6}$$

For the BER performance evaluations, the basic expression can be described as

$$\mathrm{BER} = \frac{1}{\sqrt{2\pi}}\int_{\rho}^{\infty}\exp\left(-\frac{\alpha^2}{2}\right)d\alpha = \frac{1}{2}erfc\left(\frac{\rho}{\sqrt{2}}\right) \tag{7}$$

with

$$\rho = \frac{2S}{\sqrt{\sigma_{th} + \sigma_{shot} + \sigma_{sig-ASE} + \sigma_{ASE-ASE}}} = \frac{2S}{\sigma_{total}} \tag{8}$$

Note that (8) does not include the interchannel interference due to crosstalk. This effect, however, is quite important for multi-channel WDM communications. To treat the crosstalk interference simply for BER evaluation, the equivalent noise for the crosstalk effects is conducted with the power expressed as

$$\sigma_{ct}^2 = \left(D\frac{P_r}{X}\right)^2 \tag{9}$$

where P_r is the receiver power and $X = (P_s/P_c)$ is the ratio of the signal power P_s to the intrinsic crosstalk P_c. The signal-to-noise expression in (8) thus is modified as

$$\rho = \frac{2S}{\sqrt{\sigma_{th}^2 + \sigma_{shot}^2 + \sigma_{sig-ASE}^2 + \sigma_{ASE-ASE}^2 + \sigma_{ct}^2}} \tag{10}$$

Although the system has 32 input sources, we consider only the filter-associated crosstalk from the adjacent wavelength channels. Therefore, the BER expression can be written for 3-channel transmission as

$$\mathrm{BER} = \frac{1}{8}\left\{erfc\left(\frac{\rho_-}{\sqrt{2}}\right) + erfc\left(\frac{\rho_+}{\sqrt{2}}\right) + 2erfc\left(\frac{\rho_0}{\sqrt{2}}\right)\right\} \tag{11}$$

with

$$\rho_- = \frac{S-2a}{\sigma_{total}} \tag{12}$$

$$\rho_+ = \frac{S+2a}{\sigma_{total}} \tag{13}$$

$$\rho_0 = \frac{S}{\sigma_{total}} \tag{14}$$

where a is the amplitude of interference per channel.

3. Performance analysis of 32×32 optical wavelength switching network

In this section, we apply the multi-channel/multi-wavelength spectrum-sliced light source to a 32×32 optical wavelength switching network and then evaluate BER performances. The system consists of four 8×1 multiplexers (MUX), four 1×8 demultiplexers (DeMUX), four erbium-doped fiber amplifiers

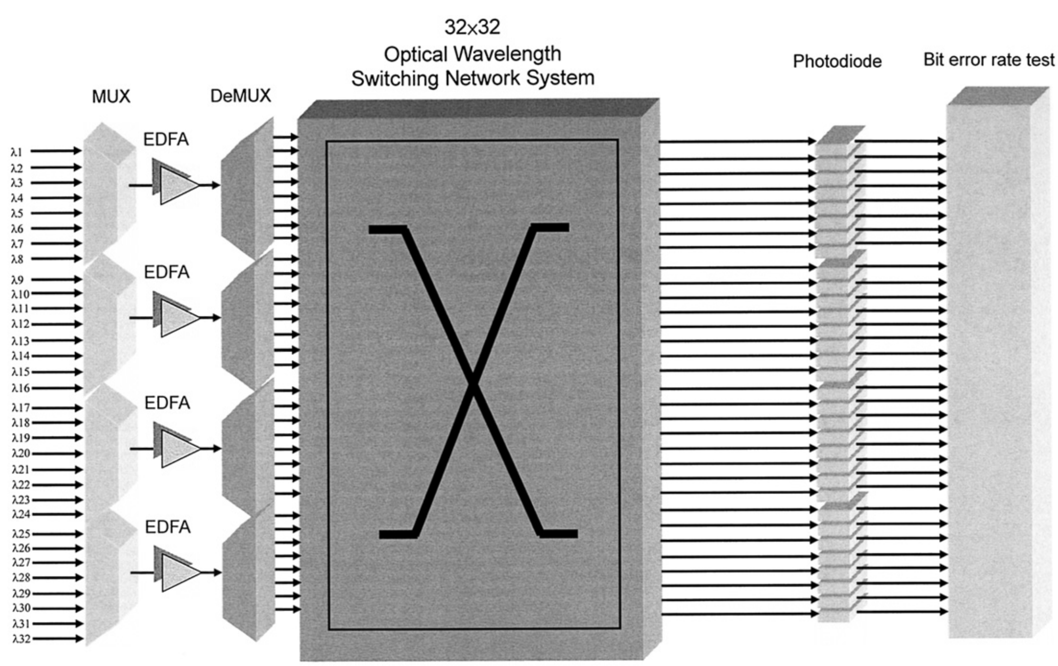

Fig. 1. The schematic diagram of 32×32 optical wavelength switching network system.