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Calculation of crosstalk in the 8 × 10 Gbit/s OTDM system using SMZ switch

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Abstract

Optical time division multiplexing is an emerging and promising alternative for future high-speed photonic networks because of its ability to accommodate higher bit rate and flexible bandwidth. Symmetric Mach–Zehnder (SMZ) have been found to be the most suitable switching element than all the available de-multiplexing switches because of compact size, thermal stability, and low-power operation. In this paper, we simulate eight-channel OTDM systems (all-channel multiplexer and de-multiplexer (DEMUX)) with a Mach–Zehnder modulator and SMZ de-multiplexer to investigate the impact of control signal power and to calculate the crosstalk.

Keywords: OTDM; P_{control}; Crosstalk and SMZ

1. Introduction

Extensive research has been carried out over the years in developing practical OTDM systems, considering its vast potential in future high-speed photonic networks [1–5]. These research have used the Periodically Poled Lithium Niobate hybrid integrated with the Planer Light Wave Circuit for multiplexing of different channels and studied all-channel multiplexer (MUX) and de-multiplexer (DEMUX) systems. Murari et al. [6] presented a new technique: the electro absorption modulator as MUX and DEMUX with phase-locked loop clock recovery. Over the years, it was understood that the performance of an OTDM system largely depends upon the switching characteristics of a DEMUX, and therefore extensive study has been conducted on the performance of various de-multiplexing switches [7–9,13–17]. Important characteristics of optical switches include extinction ratio, insertion loss, crosstalk, and switching time. Investigations revealed that among all the switches, symmetric Mach–Zehnder (SMZ) was found to be most suitable because of compact size, thermal stability, and low-power operation analysis [10]. It was also investigated that SMZ has symmetric switching window and hence it is less vulnerable to jitter. The main advantage of the SMZ structure over other interferometric switches like Terahertz Optical Asymmetric De-multiplexer is that SMZ can be easily integrated on to a single photonic chip [11,12]. Presently, crosstalk suppression in all optical SMZ has gained importance. A study in this regard was presented in the year 2005 [18], in which crosstalk suppression was achieved using two unequal control

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pulses. This study has been accomplished using the virtual photonic simulation package, and it involves a MUX and a DEMUX. But the fiber length over which the signal has to be propagated is missing. This in itself is a serious drawback, since without an optical fiber, the system fails to be a practical OTDM system.

This paper presents eight-channel OTDM systems, which is simple, involving low power, and one that has the superiority of de-multiplexing with an SMZ switch and investigated the impact of control signal power and calculate the crosstalk due to neighboring channels.

2. System descriptions

The transmitter for OTDM comprises a pseudo random binary sequence or PRBS generator, a mode-locked laser diode or MLLD, an electrical generator, an array of time-shifting blocks, an optical multiplexer and an optical normalizer. Multiple channels from an MLLD are RZ modulated with different PRBS patterns. The PRBS block generates eight patterns of binary data, each different from the other and at a bit rate of 10 Gb/s. All the channels from MLLD are at the same wavelength of 1550 nm and of the same power. The pulse width of these channels can be modified in this block. The data patterns from PRBS generator modulate the carrier of same wavelength and before multiplexing each modulated signal is delayed in time.

There are eight time-shifting blocks at the transmitter and eight SMZ DEMUXs at the receiver. The value of time shift between successive channels in case of the eight-channel system is reduced to 1/8 of the time window. This was done to accommodate more number of channels. The total power of all the channels is controlled by an optical normalizer, which determines the average output power of OTDM signal before propagation over the fiber length and is referred to as P_{signal}. Control signal splits in two parts before being coupled with data signal in two arms of an SMZ. The second time delay signal sets the switching window duration and is set to data pulse duration. Pulse width of the control signal is set to the same value as the transmitted channel. The power of the control signal is controlled by an optical normalizer block in this leg. The receiver section shows values of time delay in the first time delay block in each SMZ DEMUX. These values ensure proper synchronization between the receiver and the transmitter. Thus the value of time delay for the first channel is 2.0e-10 s, for the second channel it is 2.125e-10 and so on. Other necessary connections were made to carry out the simulation process. The various parameters of the system are shown in Table 1.

Table 1. System parameters

Parameter	Value
Channel window	2.5e-11 s
Delay Dt	5.0e-12 s
Pcontrol	22 dBm
Psignal	9 dBm
Bit rate	1.0e10
Pattern L	7.0
Pulse width	5.0e-12
Sample rate	6.0
Shift	16.0
Length of the fiber	75 km

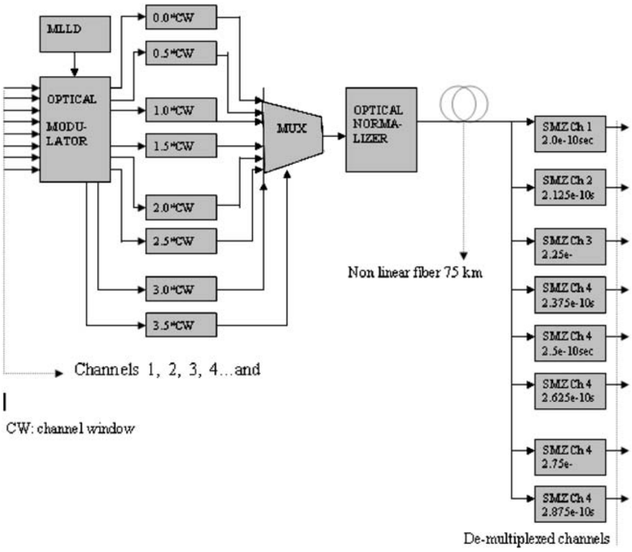

Fig. 1. System description.

When a number of channels are multiplexed together and are transmitted over a common medium, the adjacent channel interference may degrade the system performance. As is often the case, a portion of adjacent channel energy interferes in the desired channel. This interference is termed as crosstalk. Thus the amount of crosstalk involved in various channels is an important parameter that has to be ascertained in order to evaluate the system performance. In addition to this, the variation in crosstalk with a change in different factors is also a study of interest. Crosstalk may be negative or positive depending on the type of interference, and can be defined as the ratio of desired channel power to undesired channel power after switching. Mathematically it can be expressed as

$$\text{Crosstalk} = 10\log_{10} \times \frac{P_{\text{desired channel}}}{P_{\text{undesired channels}}}$$

In this paper, we calculate the amount of crosstalk and its variation with change in P_{control} for an eight-channel OTDM system (Fig. 1).

3. Results and discussion

It is to be observed that for channels 1 and 3, crosstalk varies between −0.0397 to −0.221 and +0.00362 to −0.0159, respectively (Fig. 2). It can be observed that for channels 2 and 4, crosstalk varies between +0.0385 to +0.0273 and +0.00427 to +0.0269, respectively (Fig. 3).

It can be observed that for channels 3 and 5, crosstalk varies between +0.0037 to +0.0368 and +0.0367 to −0.0795, respectively (Fig. 4). It can be observed that for channels 4 and 6, crosstalk varies between +0.0426 to +0.0349 and −0.0474 to −0.0504, respectively (Fig. 5).

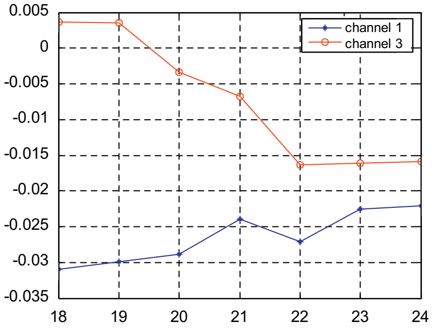

Fig. 2. Crosstalk for channels 1 and 3 when channel 2 is off.

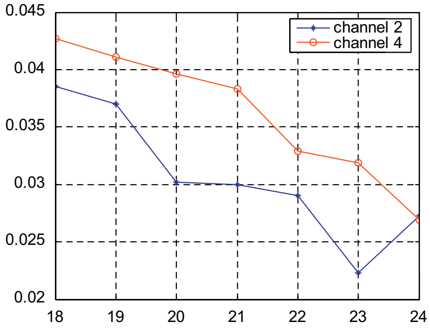

Fig. 3. Crosstalk for channels 2 and 4 when channel 3 is off.

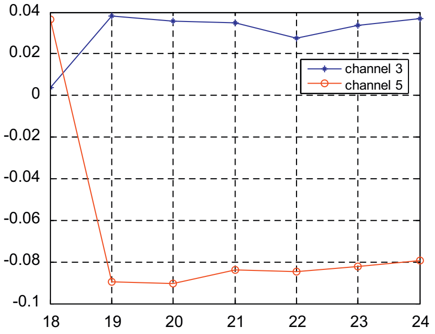

Fig. 4. Crosstalk for channels 3 and 5 when channel 4 is off.

It can be observed that for channels 5 and 7, crosstalk varies between +0.3197 to +0.2211 and +0.6705 to +0.4778, respectively, (Fig. 6). It can be observed that for channels 6 and 8, crosstalk varies between +0.0361 to +0.0426 and −0.0555 to −0.605, respectively (Fig. 7).

It is investigated that crosstalk for channels 1 and 3, 2 and 4, and 5 and 7 decreases with increase in P_{control}. This decrease in crosstalk can be attributed to reduction in decision offset of eye for channels enclosed by this set of channels. For the remaining set of channels, the crosstalk is more or less constant.

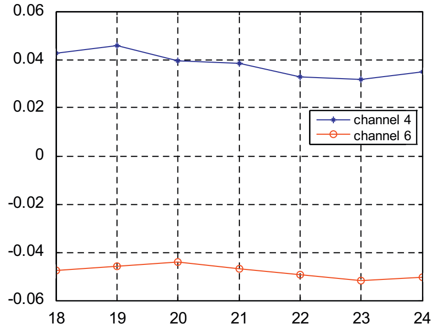

Fig. 5. Crosstalk for channels 4 and 6 when channel 5 is off.

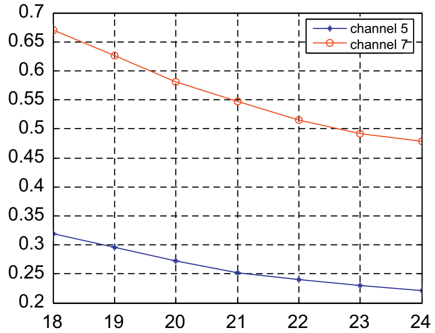

Fig. 6. Crosstalk for channels 5 and 7 when channel 6 is off.

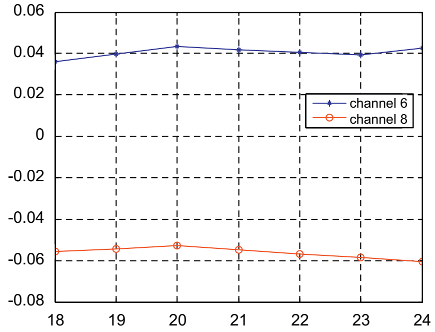

Fig. 7. Crosstalk for channels 6 and 8 when channel 7 is off.

4. Conclusion

An eight-channel 8×10 Gbs OTDM system (all channel multiplexer and DEMUX), with a Mach-Zehnder modulator, SMZ DEMUX, and with a fiber length of 75 km, has been successfully demonstrated and the crosstalk due to neighboring channels has been calculated. It is observed that crosstalk for channels 1 and 3, 2 and 4, and 5 and 7 decreases with the increase in P_{control}. This decrease in crosstalk can be attributed to the reduction in decision offset of eye for channels enclosed by this set of channels. For the remaining set of channels the crosstalk is more or less constant.

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