Analysis of Signal-to-Noise Ratio in Reconfigurable Feed-Forward Optical Delay-lines

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Abstract: We analyze the performance of a feed-forward reconfigurable optical delay line by simulating the signal-to-noise ratio for various optical switch extinction ratios. A method to improve the signal-to-noise ratio is suggested.

OCIS codes: (060.0060) Fiber optics and optical communications; (060.1810) Buffers, couplers, routers, switches, and multiplexer

Reconfigurable feed-forward delay lines are one of the basic optical buffer structures [1, 2]. Because of their straight-forward configuration and easy control, they can be readily applied in telecommunications and all-optical signal processing [3]. Optical delay is realized by switching among different optical routes, as shown in Fig. 1(a). Since practical optical switches (for example, Mach-Zehnder interferometer-based switches) are not perfect, they cannot have infinite extinction ratio (ER) for the two output ports, which inevitably renders the residual signal to interfere with the mainstream one, resulting in inter-symbol crosstalk and thus degrading signal-to-noise ratio (SNR) [4]. Here we analyze the SNR and its dependence on switch ER. A feasible method to improve the SNR is given.

We assume the transmitted optical signal is a random on-off keying (OOK) signal of 40 GHz at 1550 nm wavelength. The delay line structure is composed of seven stages of waveguide pairs connected by MZI switches (see Fig. 1(a)). The structure can be designed to delay 1 to 127 bits, depending on the states of MZI switches. Fig. 1(b) shows the simulated SNR for various switch ERs. The insertion loss of the switches is assumed to be 0.2 dB. As expected, the SNR increases if switches with high ERs are used. In particular, if we would like to have a SNR of >25 dB, the switch ER should be 20 dB, which imposes a great challenge to switch design and fabrication. In order to reduce the crosstalk, variable optical attenuators (VOAs) can be inserted in between adjacent stages [5].

Fig. 1(c) shows the improvement of SNR when VOAs are included. We found that it makes no much difference in which stages the VOAs are inserted. Hence, in our simulations, the VOAs are assumed to be inserted from rear to front. As more VOAs are added, the SNR curves shift upward, indicating the crosstalk can be effectively suppressed by the VOAs. The averaged SNR increases by 3 dB with a pair of VOAs added, 5 dB with 3 pairs, and 10 dB with 5 pairs.

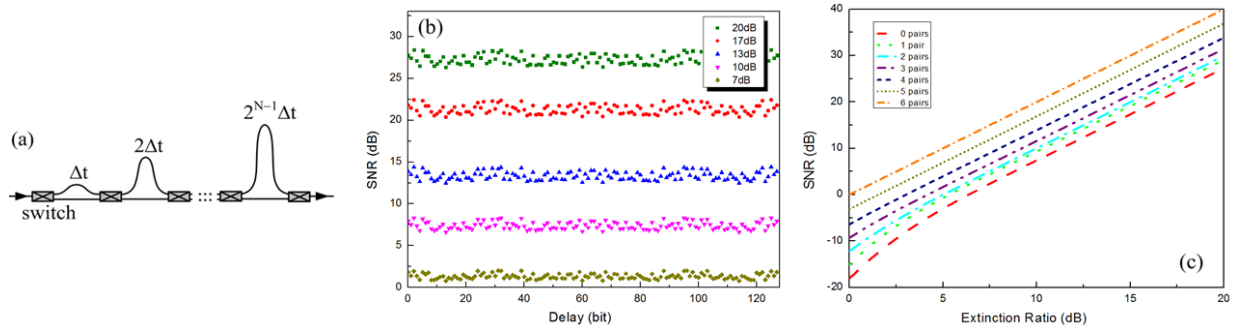

Fig. 1. (a) Schematic of the feed-forward optical delay line. (b) SNR of the output signal for various extinction ratios. (c) Averaged SNR versus switch ER when VOAs are inserted in the delay lines.

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