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Adaptive Steepest-Descent-Feedback Control of Tunable Dispersion Compensators using A Three-Point Sampling Method in Time-Domain Waveforms

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Abstract
We propose a three-point waveform-sampling method for the optimal adaptive control of tunable dispersion compensators in optical dynamic-routing networks. We succeeded in decreasing the residual dispersion drastically in 10 Gb/s transmission simulations.

1 Introduction

Adaptive dispersion compensation using a tunable dispersion compensator (TDC) is essential in optical dynamic routing networks and the ultra high speed transmission over 160 Gb/s per channel. We have proposed and demonstrated a high speed, low cost adaptive TDC control method [1]. The method is based on a feedback control in which the peak eye-opening value is used as a feedback signal and is maximized by the steepest descent method.

We achieved a high speed control by the proposed algorithm based on the steepest descent method. Also, the implementation cost of the method is lower than the dispersion measurement method [2] as we do not need costly measurement instruments.

However, we face the problem of residual dispersion in the previous method; the dispersion is not perfectly compensated for after the maximization of the peak eye-opening value. The reason is that only the peak eye-opening value is used as the feedback signal.

In this paper, we report a new control algorithm based on three-point sampling in time-domain waveforms. We conducted 10 Gb/s transmission simulations and succeeded decreasing the residual dispersion adequately.

2 Adaptive control of TDC using three-point sampling method

Fig.1 shows the optical dynamic routing networks with our proposed steepest-descent-feedback control method. The control algorithm is divided into three steps.

The first step, (i) is a calculation of error value, *Er*, which is the difference between the received and the reference waveforms. The reference waveform which is a received waveform unaffected by the dispersion is measured and registered before transmission. The detailed definition of the *Er* is shown in Fig.2. In the previous method, we obtained the *Er* as the difference of the peak values between the received and reference waveforms as shown in Fig.2 (a). Fig.2 (b) shows the three-point sampling method proposed in this paper. The *Er* is calculated as the summation of the difference of three points between the received and reference waveforms.

$$Er = \frac{1}{2}\sum_{n=-1}^{1}(R_n - P_n)^2 \quad (1)$$

The new definition of *Er* is effective in decreasing the

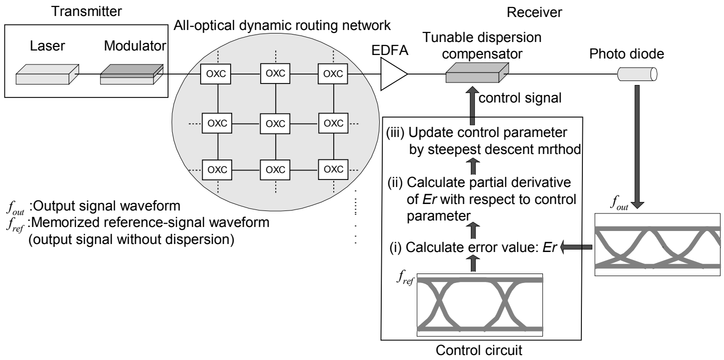


Fig.1 Schematic diagram of optical dynamic-routing networks with proposed adaptive control method

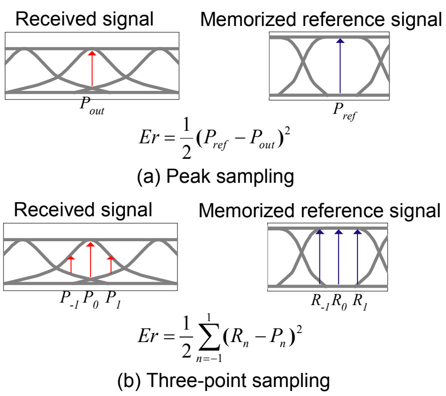


Fig.2 Definition of *Er*

residual dispersion as it represents the effect of the dispersion on the waveform accurately.

Step (ii) is a calculation of the partial derivative of *Er* for the steepest descent approach. In the following simulations, we adapted virtually imaged phased array (VIPA) [3] as a TDC. The partial derivative with respect to the VIPA's control parameter, S ps/nm, is approximated as

$$\frac{\partial Er}{\partial S} = \sum_{n=-1}^{1}\left(P_n - R_n\right)\frac{\partial P_n}{\partial S} \tag{2}$$

$$\frac{\partial P_n}{\partial S} = \pm\frac{P_0^{\,2}}{T_{FWHM}^{\,2}}\sqrt{1-P_0^{\,2}}\left(\frac{n^2 P_0^{\,2}}{8}-1\right)\mathbf{exp}\left(\frac{-n^2 P_0^{\,2}}{16}\right)\cdot\frac{\lambda^2}{2\pi c} \tag{3}$$

where T_{FWHM} is the full width at half maximum of the transmitted signal, λ is the center wavelength and c is the speed of light.

The final step (iii) is an update of S by the steepest descent method.

$$S \Rightarrow S - \varepsilon\frac{\partial Er}{\partial S} \tag{4}$$

where ε is an appropriate constant. We repeat these steps until the *Er* becomes small enough.

3 Transmission simulations at 10Gb/s

We conducted transmission simulations by OptiSystem [4] to confirm the effectiveness of the proposed method. Fig.3 shows the simulation model. The transmission speed was set at 10 Gb/s and the modulation format was nonreturn-to-zero. The transmission fiber was SMF and the dispersion was 18 ps/nm/km. We measured the BERs and eye-diagrams when the transmission route changed from Route1 (where the dispersion had been compensated for perfectly; S = -2700 ps/nm) to Route2.

Fig.4 shows the eye-diagrams after the compensation. The eye-opening after the compensation by using the

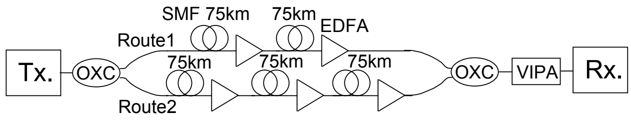
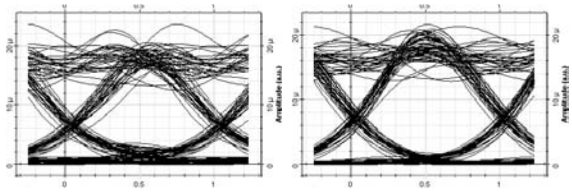


Fig.3 Simulation model



(a) Peak sampling method (b) Three-point sampling method

Fig.4 Eye-diagrams after compensation

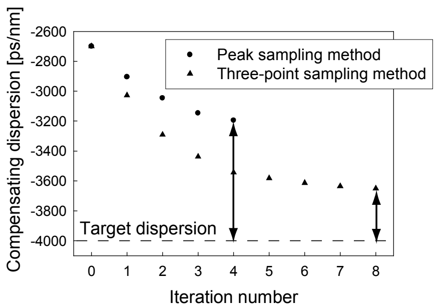


Fig.5 Compensating dispersion

three-point sampling method is wider than the one obtained using the peak sampling method. The BER after compensation was 3.7×10^{-10} for the peak sampling method and $<10^{-12}$ for the three-point sampling method respectively. Fig.5 shows the compensating dispersion for every update of the VIPA. The residual dispersion after the compensation by the three-point sampling method is about half of the residual dispersion when we use the peak sampling method.

4 Conclusion

We have reported an optimal feedback control method of the TDC in this paper. This method is based on the steepest descent method and the three-point sampling in time-domain waveform. Using this method, we can implement high speed and low cost optimal adaptive dispersion compensation.

5 References

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