Optical signal monitoring of DPSK signals using RF power detection

Jian Zhao[1], Chao Lu[1], Zhaohui Li[1], H. Y. Tam[2], P. K. A. Wai[1]
[1]Photonics Research Centre, Department of Electronic and Information Engineering
The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong
Phone: +852 27664094, Fax: +852 23628439, 06900824R@polyu.edu.hk, enluchao@polyu.edu.hk
[2] Photonics Research Centre, Department of Electrical Engineering
The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong

Abstract - We demonstrate DPSK signal dispersion monitoring by measuring low frequency RF power. This scheme can realize dispersion monitoring up to 4320ps/nm with sensitivity to 0.045dBm/ps/nm. OSNR effect on the monitoring system is studied and discussed.

Introduction

In recent years, the data rate of optical transmission system has moved from 10Gbit/s to beyond 40Gbit/s [1]. At such a high speed, dispersion becomes a significant impairment which could affect the detected signal quality and as a result BER of the transmission system. Chromatic dispersion(CD) monitoring thus is essential in order that tunable dispersion compensator can be used to realize optimum system performance. This is especially important in reconfigurable optical networks where dispersion varies with dynamic optical path selected and different components passed. In optical transmission systems, different modulation formats are often employed to achieve optimum transmission performance. Among them, differential phase shift keying (DPSK) format has been widely studied and used for its better nonlinear tolerance than NRZ format in long haul system and 3dB OSNR advantage when balanced detection is used. Dispersion monitoring in DPSK modulated optical transmission system is thus an important issue that need to be addressed in high speed optical network design. Several optical performance monitoring (OPM) methods have been proposed in recent years including asynchronous amplitude sampling histogram for OSNR and dispersion monitoring[2], delay tap amplitude sampling[3], RF spectrum analysis for noise monitoring[4] and dispersion monitoring using RF pilot tone[5, 6]. Due to the need for large amount of data collection, asynchronous amplitude histogram is a slow process and may not be suitable for some applications. Since additional signal on the transmission data is needed for pilot tone method, data transmission quality will be affected. RF spectrum analysis has been used for noise monitoring[7]. However, using the method for effective dispersion monitoring was not demonstrated. Here, we show that the total amount of RF power in detected signal is related to the dispersion accumulation in the DPSK signals. Simulation results indicate that up to 4320ps/nm dispersion can be monitored and sensitivity up to 0.045dbm/ps/nm can be obtained. The effect of OSNR on the performance of the dispersion monitoring system is studied and results presented.

Theory analysis

In phase shift keying (PSK) system, the PM-AM conversion causes amplitude ripple that increases linearly with total accumulated fiber dispersion. When the optical carrier is phase modulated by a sinusoidal signal with angular frequency Ω , the AM power fluctuation could be described as [2]

$$\Delta P \cong 2P_0 J_0(A) J_1(A)\Omega^2 \beta_2 \Delta L \qquad (1)$$

Where P_0 is the average signal power, A is the depth of phase modulation, J_0 and J_1 are the Bessel functions of the first kind of order 0 and 1, β_2 is the second derivative of the propagation constant and ΔL is fiber length. The data signal could be considered as summation of many different frequencies and different amplitudes components as:

$$E_{signal} = \sum_m A_m \sin(\Omega_m + \varphi_m) \qquad (2)$$

When the modulation signal is NRZ data signal instead of the sinusoidal signal, the power generated by PM-AM process can be described as:

$$\Delta P \cong 2\beta_2 \Delta L P_0 \iint J_0(A_m) J_1(A_m)\Omega_m{}^2 d\Omega_m dA_m \qquad (3)$$

Considering the filter is fixed, the integration could be a constant as T_B.

$$T_B = \iint J_0(A_m) J_1(A_m)\Omega_m{}^2 d\Omega_m dA_m \qquad (4)$$

So the equation (3) could be described as

$$\Delta P \cong 2\beta_2 \Delta L P_0 T_B \qquad (5)$$

Similar result can be obtained for MZM modulated DPSK signals. From equation (5), we could see clearly the total power of the ripples increases linearly with the total amount of dispersion $\beta_2 \Delta L$. So we can simply realize dispersion monitoring by measuring the RF power of the detected signal. The dispersion monitoring sensitivity S is defined as the power change over the fiber length changes. So S could be described as

$$S \cong \frac{\Delta P}{\Delta L} = 2\beta_2 P_0 T_B \qquad (6)$$

S is related to the lowpass filter bandwidth and launch power. Another attractive feature is that the dispersion monitoring can be independent of other impairments such as OSNR. We can realize this monitoring of dispersion simply by using two bandpass filters B1 and B2 at different portion of the signal RF spectrum. So the detected power of the two filters are

$$\Delta P_1 \cong 2\beta_2 \Delta L P_0 T_{B1} \qquad (7)$$

$$\Delta P_2 \cong 2\beta_2 \Delta L P_0 T_{B2} \qquad (8)$$

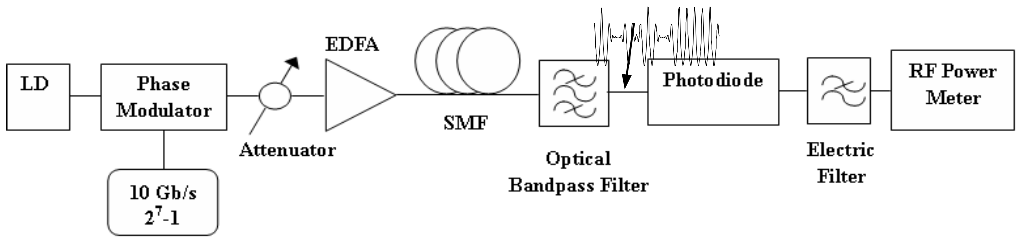

Fig.1 Schematic of dispersion monitoring simulation

$$r' = \frac{\Delta P_1}{\Delta P_2} = \frac{T_{B1}}{T_{B2}} \qquad (9)$$

From equation (9), it is shown clearly the power ratio of the outputd of the two bandpass filter is independent of the OSNR. In practice, the measured power contains the noise floor and PM-AM conversion generation, so the equation (9) should change to

$$r = \frac{I_1 + \Delta P_1}{I_2 + \Delta P_2} \approx \frac{\Delta P_1}{\Delta P_2} = \frac{T_{B1}}{T_{B2}} \qquad (10)$$

I_1 and I_2 are the initial noise powers correspond to B1 and B2. When the narrow bandwidth filter used for monitoring, the I_1 and I_2 are relatively small comparing with the PM-AM conversion generation and the initial noise can be ignored in equation (10). The OSNR independent dispersion monitoring can be accomplished only if the bandwidth and center frequency are chosen carefully.

Simulation setup

The configuration of the proposed DPSK signal monitoring system is shown in Fig.1. The CW laser source was externally modulated by a 10 Gbit/s pseudo-random bit sequence (PRBS) with length 2^7-1. SMF with dispersion coefficient of 16ps/nm/km was used to introduce variable amount of dispersion. The attenuator and EDFA were used to adjust the OSNR of the input signal. The DPSK signal was filtered by an optical bandpass filter with 0.32nm bandwidth and converted to electric signal through a photodiode. Digital signal pass through the electrical filter which is a lowpass filter or a bandpass filter and then be detected by the RF power meter. The monitoring sensitivity and maximum amount of dispersion(corresponding to certain length of SMF fibre) that can be monitored depend on the bandwidth and center frequency of the filter employed. The inset shows the DPSK signal with ripples after transmission. A commercial available simulation software VPI transmission maker was used for the simulation study.

Results and discussions

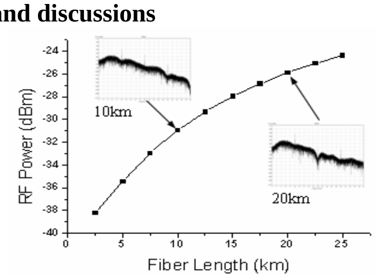

Fig. 2 RF detected Power against fiber length

Fig. 2 shows the RF detected power related the fiber length from 0km to 25km. The detected power is obtained by a lowpass filter with 3dB bandwidth of 7 GHz. From Fig. 2, we can find the power integration of the RF low frequency components increase with the increase of CD. The corresponding RF spectrum at 160ps/nm and 320 ps/nm are shown in the inset.

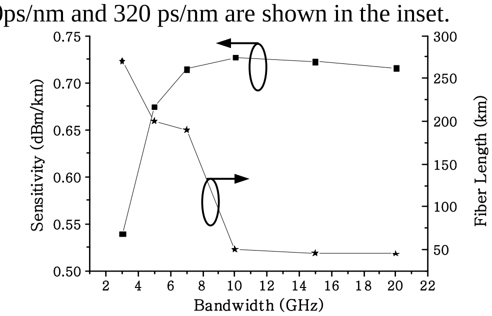

Fig. 3 CD monitoring range and S depend on the filter bandwidth

Fig. 3 shows that S is related to filter bandwidth corresponding to equation (6). The S increases to 0.727dBm/km which corresponds to 0.045dBm/ps/nm for a lowpass filter with bandwidth of 10GHz. The maximum CD can be monitored reach 270km which corresponds to 4320ps/nm.

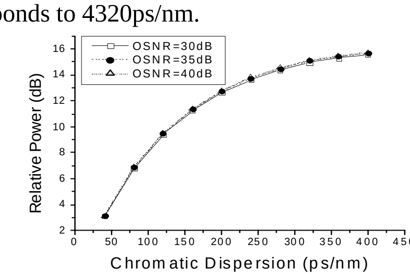

Fig. 4 CD monitoring curves under different OSNR

Fig. 4 shows the OSNR independent dispersion monitoring result which verifies equation (10). The curves correspond to OSNR equal to 30dB, 35dB, 40dB respectively. The monitoring result is obtained by two bandpass filters whose center frequencies are 1GHz and 7GHz with the same 3dB bandwidth of 50MHz.

Acknowledgment

The authors would like to acknowledge the support of project G-YX91 of Hong Kong Polytechnic University.

Reference

[1] Z. H. Li, et al., PTL, vol. 16, pp. 1760-1762, 2004.
[2] Z. H. Li, et al., PTL, vol. 17, pp. 1998-2000, 2005.
[3] S. D. Dods, et al., OFC'2006, paper OThP5.
[4] C. Dorrer, et al., PTL, vol. 16, pp. 1781-1783, 2004.
[5] Z. Pan, et al., OFC'2003, pp. 402-403.
[6] C. Youn, et al., OFC'2003, pp. 403-404.
[7] R.S. Luís, et al., 6th Conf. on Telecommu., 2007, paper 7