A novel optical signal monitoring method of DPSK signal based on delay tap sampling and Hausdorff distance measure

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Abstract: We demonstrate an optical signal monitoring method for NRZ-DPSK signals using asynchronous delay tap sampling and Hausdorff distance measure. The application of the technique for residual dispersion monitoring is demonstrated and high tolerance to other impairments and pulse shape is shown.

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1. Introduction

In recent years, constant amplitude differential phase-shift keying (NRZ-DPSK) signals have attracted so much attention for its OSNR advantage in long haul transmission systems at 40Gbits and beyond [1]. As a result it is essential to find an effective monitoring technique for optical networks employing such modulation format. Several monitoring methods have been proposed including amplified spontaneous emission (ASE) and nonlinear phase noise monitoring using RF spectral analysis [2], OSNR and dispersion monitoring using asynchronous amplitude histogram [3] and signal monitoring using pilot tone. The techniques offer various degree of trade off between performance and system complexity. However, in all the studies, the effect of other transmission impairments on the performance of the parameter to be monitored was not considered. Delay tap sampling monitoring technique was introduced as an effective technique for signal monitoring [4]. It has been used successfully for OSNR monitoring of RZ-DPSK signals [5]. However, its effectiveness for chromatic dispersion (CD) monitoring was not fully demonstrated. In this paper, we study the use of the technique for CD monitoring of NRZ-DPSK signal. A new parameter for CD estimation using Hausdorff Distance (H.D.) measure was introduced. Our results have demonstrated successfully chromatic dispersion monitoring in the range of 0-400 ps/nm with high accuracy. Tolerance to other transmission impairments and pulse shape was studied to evaluate the robustness of the scheme.

2. Principle

Delay tap asynchronous sampling technique combines the original asynchronous sampling and a tap delay line so a pair of data could be obtained during one sampling process as showed in Fig.1. $\Delta t$ is the fixed delay time and $T$ is the repetition rate. Because the data pair obtained are from the same pulse or the adjacent pulses, they can reflect the pulse shape information which has a strong relationship with the impairments. To extract information about parameters to be monitored from the sampled data, various methods have to be used.

Hausdorff Distance measure is one of the shape comparison methods [6]. This method is based on a distance measure of the edge maps of two figures. The Hausdorff distance is defined as follows:

$$H(A, B) = \max(h(A, B), h(B, A))$$

$$h(A, B) = \max_{a \in A} \min_{b \in B} \| a - b \|$$

The function $h(A, B)$ is called directed Hausdorff distance from point set A to B. Hence Hausdorff distance measures the mismatch between the two points set and can be used as measure for shape comparison. In this paper, the two point sets generated from delay tap sampling process were used as the point set A, B for the Hausdorff distance measure.
distance measure to estimate the dispersion in a NRZ-DPSK based transmission link.

The configuration of the DPSK signal monitoring system is shown in Fig.2. At the transmitter site, 10GHz DPSK signal is generated by a dual drive MZM with 2 dB insertion loss and zero chirp. The modulation data is a pseudo-random binary sequence (PRBS) with length $2^{7-1}$. The laser output power is launched into the single mode fibre at 0dBm. An attenuator and an EDFA are used to adjust the OSNR of the system. The EDFA’s noise figure (NF) is 4dB and the fibre dispersion is 16ps/nm/km at 193.1THz with an effective core area of $80*10^{-12}$ m$^2$. At signal monitoring module a 3-order Bessel optical band pass filter with 0.32nm bandwidth is used before the photodiode (PD). The asynchronous sampling processes occur after the optical-electrical conversion and the data are collected.

3. Simulation Results and Discussion

Chromatic dispersion (CD) monitoring and the tolerance of the scheme to variation of other system parameters are studied through software simulation using VPI. Fig.3 (a) obtained with 1 bit period delay shows the variation of the delay tap sampled diagrams for different amount of uncompensated transmission fibre which corresponding to different amount of residual dispersion. The diagram is constructed through the use of amplitude of one sample of the two adjacent samples as the x axis and the other one as the y axis. The cross points correspond to the average power value which decreases with the increase of fibre length considering the fibre loss. Finding the diagram’s shape change and the location of the cross points in this diagram can enable the monitoring of the DPSK signal easily. Hausdorff Distance measure could extract the feature difference between the diagrams and the accuracy is much better than direct observation from Fig.3 (a).

Fig.3 (b) shows the Hausdorff distance measure result obtained from the 1 bit delay tap sampling data. From the diagram, we can see that the Hausdorff distance is a monotonic function with the increase of dispersion. Other impairments may affect the accurate estimation of the dispersion as shown for different OSNR, nonlinearity, PMD and pulse shape. The results show that for OSNR up to 22 dB and PMD up to 10 ps/km$^{1/2}$ the effects are limited. The effect of fibre nonlinearity on the result is very limited as shown in Fig.3 (b). No noticeable difference can be observed with nonlinear index coefficient $n_2$ reaching up to $50*10^{-20}$m$^2$/w. This is also a result of good nonlinear tolerance of NRZ-DPSK to fibre nonlinearities. Fig.3 (b) shows that Hausdorff Distance measure is also independent of pulse shape.

4. Conclusion

We study the use of delay tap sampling method with Hausdorff Distance measure to monitor the dispersion in a DPSK signal based optical transmission system. This method can be used for monitoring of wide range of residual dispersion up to 400ps/nm. Measurement results show the scheme is insensitive to OSNR, PMD, nonlinearity and pulse shape variations.

5. Reference