Research on PMD Mitigation by Using Distributed Fast Polarization Scrambling and FEC

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Abstract: Polarization mode dispersion (PMD) is one of the major obstacles in high-speed (above 100Gbits rate) and long-haul optical communication system. The principle and performance of scrambling is introduced in this paper and the fundamental idea of improving PMD mitigation by using distributed fast polarization scrambling (D-FPS) combined with FEC is proposed, which would be a promising approach for performance improvement in ultra-high-speed optical communication system.

OCIS codes: (060.0060) Fiber optics and optical communications; (060.4254) Networks, combinatorial network design

1. Introduction

In modern optical communication systems, forward-error correction (FEC) is commonly used to increase system margin. While FEC is effective in correcting random errors such as those resulted from amplified spontaneous emission (ASE) noise, in is ineffective for correction the PMD-induced burst errors that tend to last much longer than the burst-error correction period (BECP) of the FEC. By using distributed fast polarization scramblers (D-FPSs) in systems with FEC can improve their PMD tolerance. This paper will introduce the basic theory of PMD mitigation using D-FSPs and FEC. Finally, proposing an assumption that the impact for system performance caused by the style of FSPs is distributed along the fiber link.

2. The performance analysis of PMD mitigation with D-FPS

Some experiments for PMD mitigation using D-FPS's and FEC has been done by Dr. Xiang Liu [1]. And Fig.1 display mean DGD tolerance versus OSNR penalty for two different scrambler frequencies of 5MHz (black squares) and 50MHz (gray triangles) for NRZ-DPSK at the post-EFC BER of 10^{-9} .In order to confirm that no error burst which cannot be handle by the FEC are present and to determine the addition improvement which might be attributed to the FEC's burst error correction capability at high scrambling speed of 5MHz or 50MHz, the DGD tolerance was measured by observing the post FEC BER and keeping it at 10^{-9} .Scrambling at 5MHz leads to an improvement in DGD tolerance at a 1dB OSNR penalty of 250percent to 7.6ps. A further improvement of 13percent is observed by the use of a higher scrambling frequency, e.g., 50MHz, leading to a mean DGD tolerance of 9.2ps (NRZ-DPSK), which corresponds to 40 percent of the bit period.

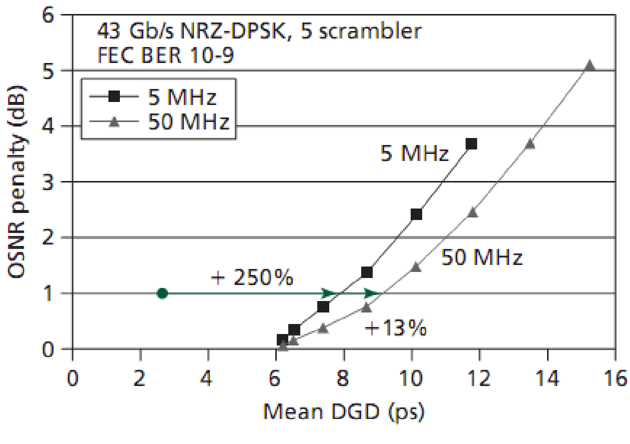

Fig.1. Mean DGD tolerance versus OSNR penalty

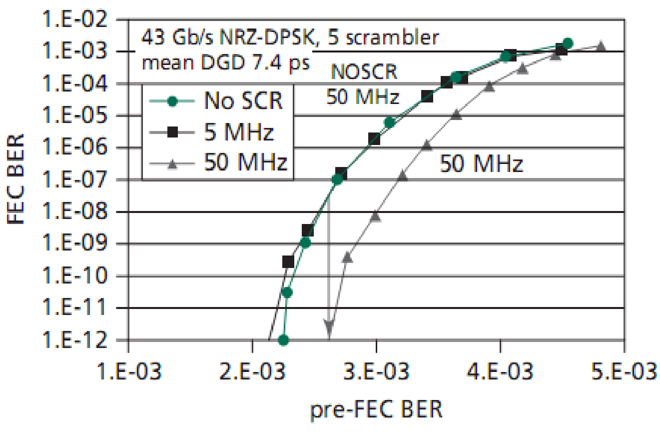

Fig.2. The FEC output BER versus input BER

In order to investigate whether or not the FEC burst-error correction capability enhances the mean DGD tolerance, Fig.2 plots the FEC output BER versus input BER at different scrambling frequencies of 5MHz and 50MHz and without scramblers (corresponding to a mean DGD of 0ps.. The Set of 5 DGDs had a mean DGD of 7.4ps when scramblers were present. At scrambling frequencies of 50MHz (gray triangles), an improvement is observed as compared to the 5MHz curve (black boxes), which is nearly identical with the FEC-performance without scrambling (mean DGD 0ps, green dots). At 50 MHz scrambling frequencies, a higher pre-FEC error rate can be corrected by the FEC than for a 5MHz scrambling frequency.

3. Promising approach to improving PMD mitigation with D-FPS

In present experiments and research, the impact of FPS's frequency for the PMD tolerance, and the impact of the number of FPS for the Q-factor penalties and outage probability have corresponding study [2, 3]. As DGD of each section between adjacent PS's was fixed in those experiments, the results obtained there may not be directly applied to practical systems where the DGD of each section is varying with time and wavelength. So the style of FSPs are distributed (not only uniform distribution) [4] along the fiber link should take consider.

Fig. 3 had shown the distribution style model of FSP along the fiber link. Assuming that the total number of the FSP is n, the length between adjacent FSPs is l_i (i =1, 2, …, n). $\Delta\tau$ denotes the instantaneous DGD of each infinitesimal in the link. Using following equation to calculate $\Delta\tau$, $\Delta\tau = \frac{dl}{\Delta v_g} = \frac{d}{dw}\Delta\beta \cdot dl = (\frac{\Delta n}{c} + \frac{\omega}{c} \cdot \frac{d\Delta n}{d\omega})dl$.

Between two fast polarization scrambler, the instantaneous differential group delay,

$$DGD_i = \iint_{l_{i-1}<l<l_i} \Delta\tau dl = \iint_{l_{i-1}<l<l_i} \left[(\frac{\Delta n}{c} + \frac{\omega}{c} \cdot \frac{d\Delta n}{d\omega})dl) \right] dl$$

The lengths between each adjacent link are not fixed. Denotes DGD of each section is <DGDi>. For describing the improvement of the new link, outage probability (OP) as for describing the improvement of the new link, outage probability (OP) as the measured parameter. Then calculate the average BER, $ER_{ave} = \iint BER(\Delta\tau, \tau) p(\Delta\tau) p(\gamma) d\gamma d\Delta\tau$

Where $\Delta\tau$ the total instantaneous DGD of the link is, γ is the splitting factor, $p(\gamma)$ is the probability function of γ, and $p(\Delta\tau)$ is the probability function of total DGD. Using the first order PMD approximation, BER is only determined by $\Delta\tau$ and γ. At the end, the OP is obtained by a multidimensional integration $\int\limits_{BER_{ave}>BER_{target}} \dots \int p(\Delta\tau_1 \Delta\tau_2 \dots \Delta\tau_N) \times d\Delta\tau_1 d\Delta\tau_2 \dots d\Delta\tau_N$.

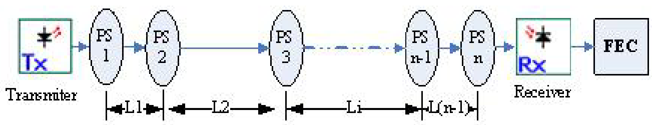

Fig.3. The distribution module of FPSs in the link

As above analysis, we can know that using FPSs in the fiber link, the distribution which can improve system's performance of FPSs is determined by total PMD tolerance of the system and also need accurately simulation and a lager number of experiment.

4. Conclusion

In optical communication systems, we can use distributed fast polarization scramblers (D-FPSs) combined with FEC to improve the system PMD tolerance. Modulation code and the scrambling frequency are of key factor for FEC. Besides which, the distributed style of FSPs that along with the fiber link will also have great impact on the system performance. The research on the distribution is another important way for improving the PMD tolerance.

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