Effects of Signal Spectrum Bandwidth on Different PMD Compensation Feedback Methods

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Abstract

We compared efficiencies of different PMD compensation feedback methods against transmission signal bandwidth, including NRZ, RZ, CRZ format under various duty cycles. We found that the critical factor determining the efficiency of PMD compensation is not the modulation format, but the spectral bandwidth of the transmission signal.

1 Introduction

Polarization mode dispersion (PMD) became one of the most troublesome problems in the expansion of transmission capacity and channel rate \cite{1}. Exhaustive number of reports on its mitigation techniques for the PMD effects thus has been published \cite{3-4}. Recent efforts have been focused to the studies on novel, robust modulation formats against to PMD effects, and various types of PMD compensators (PMDC). Still, for the successful deployment of transmission lines with novel transmission format possibly with efficient PMDC, there exist a need of integrated study on the combined effects of different modulation format, under various PMD compensation schematics.

In this study, we analyze the efficiencies of different PMDC, especially focusing on different types of feedback signal – first DOP, which is known to have high correlations with BER and all orders of PMD component\cite{3}, and secondly filtered RF power\cite{4} – under different modulation formats at different duty cycles. It is found that the fundamental factor determining the efficiency of PMDC (or its monitoring method) is the spectral bandwidth of transmission signals – not the modulation format or duty cycles as much have been explored in former studies \cite{5}. Suggestions for the proper choice of the feedback signal for the PMD compensation, along with the modulation format or duty cycles will be provided at the end with supporting arguments and data.

2 System model and results

40 Gbps transmission system with different modulation formats including NRZ, RZ and CRZ, under various duty cycles have been assumed. RZ signal was applied to the PMD emulator by either assuming a pulse carved NRZ signal from the second external modulator driven at a 40GHz sine wave (for 50% duty cycle), or a raised cosine pulse shape (for 50% or smaller duty cycles). For the CRZ signal, phase modulation has been applied after the generation of RZ pulses. Optical power spectra for some of the tested signal pulses are shown in fig. 1.

Different lengths of DGD sections (20) and polarization controllers have been used for the PMD emulation. The averaged value of DGD, and normalized rotational rate of PSPs from the emulator was 8.0 psec, and 5.5 psec respectively. A commonly employed 3-DOF (degree of freedom) PMDC system being composed of a polarization controller and a variable DGD line has been assumed. For the feedback signal of the compensator, we first compared the DOP and filtered RF power detected
at 1/2, 1/4, and 1/8 of bitrate frequencies.

Fig. 2 illustrates some examples of probability density functions (PDF) of BER, before and after the PMD compensation. Solid rectangular points represent PDFs of BER after the PMD emulator. For the NRZ format, similar amounts of system performance enhancement have been observed irrespectively of the feedback signal types from the PMDC. In contrast, much larger outage probability has been observed for RZ signal in the case of DOP-monitor compensation, than the case of RF-monitor compensation method (Fig 2b). To analyze this behavior, we first compared those DGD values generated in the PMDC against those corresponding instantaneous DGD values out of the PMD emulator (Fig. 3). As can be seen from the figure, for the case of PMDC using DOP as feedback signal (upper trace), there is a significant reduction in PMDC-generated DGD values after some threshold (for this case, about 15psec). We attribute this phenomena to the DGD folding effect over 2π angle in the Poincare sphere for spectrally rich, reduced duty cycle pulses, which makes DOP monitor to mistakenly generate non-optimal, reduced DGD values out of the PMDC than what is really needed for the compensation of DGD from the PMD emulator. We note here that even indirect, this phenomenon could be also explained from those observations made in terms of the RZ pulse width. To get deeper understanding for this observation, we extended our database by calculating the outage probability exceeding 10^-9 BER at different duty cycles for RZ, as well as CRZ signals. It was found that a unified correlation curve could be made between the outage probability and source spectral bandwidth (only), regardless of the modulation format or pulse width. Fig. 4 illustrates the outage probability after PMDC (solid triangle) and the ratio of BER-deteriorated realizations as the result of PMD compensation (hollow circle), as a function of the FWHM bandwidth of the input signals.

Also shown in the figure (line in fig 4a) is the analytically calculated probability – integrated over the Maxwellian distribution curve, for those realizations generating DGD values exceeding the maximum DGD value which could be monitored for each signal spectrum (\( \Delta \tau = 2\pi / \Delta \omega = 1/\Delta f \)). It is noteworthy that, as the signal spectrum is increased, not only the total outage probability after PMDC was increased but also the ratio of BER-deteriorated realizations as the result of PMD compensation is increased. In the case of RF monitoring, we attribute the observed linear dependence of the outage probability against the increased spectrum bandwidth to the increased higher-order PMD effect.

Conclusion

We investigated the efficiencies of different feedback signals in the PMD compensator, under different signal formats and duty cycles. A unified explanation for the correlation between the DOP and signal spectrum has been obtained. It was also found that RF power monitoring would be more useful for the application of bandwidth-rich transmission formats.

References