Differences in 10.7 Gb/s Duobinary and Non-Return-to-Zero Transmission over 1000 km of SSMF

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Abstract - Transmission performance of duobinary modulation by using a low pass filter format over 1000 km of SSMF is investigated along with that of standard Non Return to Zero. The required OSNR at BER =1x10^-3 for both modulation format is shown to be ~12 dB after 1000 km with the respective optimal residual dispersion conditions. Duobinary also shows a wider dispersion tolerance window than NRZ.

Index Terms - Non return to zero, optical duobinary, dispersion.

I. INTRODUCTION

There is growing interest in the study of optical duobinary modulation format because of its potentially larger dispersion tolerance and higher spectral efficiency [1-8]. Many previous studies are either focused on the higher bandwidth, long haul applications [6-8] or the short distance (~200km or so) transmission without dispersion compensation module (DCM) [3-5]. Recently, there have been studies to prove the viability of using the duobinary format in real systems designed for NRZ [9].

In the letter, we experimentally investigate the transmission performance of optical duobinary, compared side by side with NRZ, and demonstrate the systematic study results on their performance difference in terms of required OSNR and dispersion tolerance after long haul transmission. We show that, though duobinary signals have higher back-to-back sensitivity requirements compared to NRZ and it was indicated by [10] that duobinary transmission distance can be limited by self phase modulation (SPM), under our experimental conditions, duobinary can perform equally well as NRZ, if not better, after long distance transmission.

II. EXPERIMENTAL SETUP

The schematic of the experiment is shown in Fig. 1. Five 50 GHz spaced DWDM channels were passively combined and modulated by a 10G LiNbO3 Mach-Zehnder modulator (MZM) (Sumitomo T.MXH1.5-12). The center wavelength was at 1551.30 nm. Their states of polarization were adjusted to be the same. The X-cut, chirp-free modulator was either driven by a duobinary driver or a NRZ driver. The duobinary driver [5] had a 3-GHz 3-dB bandwidth for differential encoding and included a precoder. The NRZ driver was a 20 GHz-bandwidth amplifier (SHF 100CP). The 2^31-1 pseudorandom bit sequences (PRBS) data pattern was obtained from a pattern generator at a clock rate of 10.7-GHz, assuming forward-error-correction (FEC) with 7% overhead. To generate the duobinary signals, the MZM is biased at null and the peak-to-peak driving voltage is about twice the V of the MZM.

The loop setup used a simple dispersion map that was not specifically optimized to get the best performance. As shown in Fig. 1, two spans of standard single-mode fiber (SSMF) were followed by a span consisting of dispersion
compensating fiber (DCF). The lengths of SSMF in the two spans were initially ~100km and ~75 km, respectively. The DCF in the loop compensated the dispersion of ~160 km of SSMF, and left ~255ps/nm residual dispersion per loop. In this case, the nonlinear effect could be smaller than the conventional dispersion map where per-span dispersion compensation is used. However, as we will shown later in this paper and our further results shown in a separate paper, the nonlinear penalty is small under both dispersion map and launch power conditions. Two of the three EDFA’s used in the loop were home-made, single-stage, 980-pumped ones, and the other was a commercial one. The launch power into the spans were kept at ~ 0dBm.

Out of the loop, the signal was detected by an optically pre-amplified receiver, consisting of a two-stage erbium-doped fiber amplifier (EDFA), a 30-GHz optical filter and a PIN receiver with a built-in clock-data recovery (CDR) circuit. The input power to the receiver was ~ -8 dBm.

III. EXPERIMENTAL RESULTS

Fig. 3 shows the measured BER of the center channel vs. the received OSNR for the duobinary signal after 1050 km of SSMF transmission with no post dispersion compensation, e.g. with ~ 1530 ps/nm residual dispersion. We can see that the required OSNR at BER=6x10^{-3} is ~14.5 dB and at BER=1x10^{-3} (close to the threshold of the enhanced FEC [12]) is ~12.2 dB. We observed that, by turning on and off the adjust channels to the center one, there wasn’t observable BER changes, e.g. the crosstalk between the channels was minimal. Also it was observed that the BER performance for all the 5 channels was very similar.

Fig. 3. Measured BER vs. the received OSNR for a 10.7-Gb/s duobinary transmission over 1050 km of SSMF.

Fig. 4 shows the measured required OSNR at BER=1x10^{-3} vs. the amount of residual dispersion for both Duobinary and NRZ signals, by varying the amount of post compensation. Note that the optimum residual dispersions for NRZ and duobinary are ~500 ps/nm and ~1800 ps/nm, respectively. The shift of the optimal performance point for NRZ from zero dispersion, compared to linear transmission cases, could be contributed to the nonlinear phase shifts in the loop transmission. On the other hand, the situation for duobinary is similar to that was observed in the previous linear transmission results. We also expect that duobinary has another optimal under negative dispersion, though we didn’t attempt to measure that here. Though, compared to the dispersion tolerance window under linear transmission conditions, the window of duobinary is narrowed. Still, duobinary shows a much wider dispersion tolerance window (~1700ps/nm for 1dB additional penalty), in contrast to the ~1000 ps/nm window for NRZ. This may help to...
significantly lower the requirements on the accuracy of DCM in the system. To further study the effect of the distributed residual dispersion on the transmission performance, we measured the required OSNR at BER=$1\times10^{-3}$ under different residual dispersion in the loop, as shown in Fig. 5. The lengths of SSMF and/or DCF were slightly varied to change the residual dispersion in the loop.

IV. CONCLUSION

We show experimentally that both the duobinary and NRZ signal can be transmitted over 1000 km with low required OSNR at the threshold of EFEC. Though duobinary has a higher required OSNR at back-to-back, it performs comparably well to standard NRZ after transmission. Duobinary also shows a wider dispersion tolerance window, which would enable the application of cheaper, non-dispersion-slope-matched DCM’s and save system costs for dispersion compensation.

REFERENCES


