Duobinary Transmission beyond 11000ps/nm Fiber Link by a 10Gb/s Transponder

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Abstract: We have demonstrated < 2dB OSNR penalty over 9000ps/nm uncompensated fiber links at 10.71Gb/s data rate from a 300-pin MSA duobinary transponder in conjunction with a tunable optical dispersion compensator APD receiver.

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1. Introduction

Optical duobinary coding has been proved as an effective way to improve fiber chromatic dispersion tolerance at high-speed data rate[1, 2]. Even though the implementation of duobinary code is relatively easy with a 2×Vπ modulation at transmitter's Mach-Zehnder modulator (MZM), the technique has not been deployed at large commercial scale yet. There were several reasons hindered the acceptance of duobinary transmission in today's uncompensated metro optical network: First the back-to-back (BtB) performance from duobinary coding suffers ~2dB penalty comparing to its NRZ counterpart because of the ISI generation from the duobinary coding. For a data rate R, the effective bandwidth of the duobinary code is ~R/4, which clearly violates the minimum Nyquist's bandwidth requirement for ISI-free transmission. In addition, the link budget for a 2dB path-penalty from optical duobinary coding is limited to ~ ±3200ps/nm at 10Gb/s, which falls short comparing to an extended-metro link at 2.5Gb/s data rate over 300km single mode fiber (SMF). Recent developments of MLPE and MLSE receivers have demonstrated an improved link budget of duobinary transmission to ~4000ps/nm[3-4]. However, the complexity of implementation versus performance gain, power consumption and cost do not lend themselves as an optimal solution for transponder–type subsystem package. Recent result demonstrated the link extension of duobinary transmission to 300km single mode fiber at raw BER = 1E-3 level by optical dispersion compensator (ODC)[5]. In this paper, we report a commercial duobinary transmitter based on Intel's tunable transponder incorporated with a tunable ODC receiver from Civcom[6-7] to reach a link beyond 11000ps/nm and restores OSNR performance to a level similar to that from a high performance NRZ transponder.

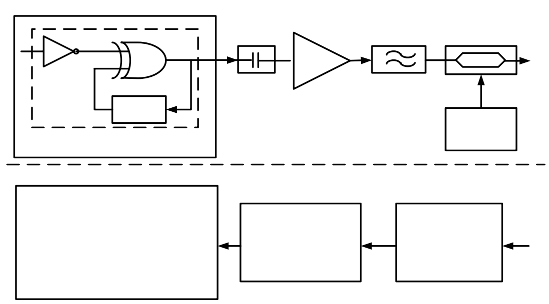

Fig. 1. The schematic block diagram of a full C-band tunable transponder for the extended link: duobinary transmitter and ODC APD receiver.

2 Transponder Implementation and Test Results

Figure 1 shows the block diagram of the duobinary transponder with an integrated ODC APD receiver. For the experiment performed here, the transmitter is a full C-band tunable duobinary transponder under 300-pin MSA platform. The duobinary precoder is integrated within the 16-bit MUX. A 10Vpp swing from RF driver is more sufficient to drive a single-ended MZM. With a proper control of the MZM's DC bias, the duobinary output shows a typical optical eye with extinction ratio of 10.8dB and RMS jitter < 4.0ps. The receiver chain consists of an ODC, APD and DMUX/CDR. The ODC has four independent etalons with a 50GHz free spectrum range. The maximum insertion loss of the ODC is < 1.5dB, which is hermetically sealed into a butterfly package (22mmx12.7mmx9.5mm). Thermal tuning over ±3000ps/nm is achieved with embedded heaters at ITU grid over the full C-band. The maximum power consumption for ODC is 1.8W[7]. The ODC can be preset at a fixed value for point-to-point link, or dynamically adjusted using FEC's corrected blocks as feedback input. It takes about a few seconds for ODC to locate the optimal value from an arbitrary condition. The APD has an integrated TIA for wide dynamical ranges. With offset control at the input of DMUX, the optimal decision threshold of Rx can be achieved.

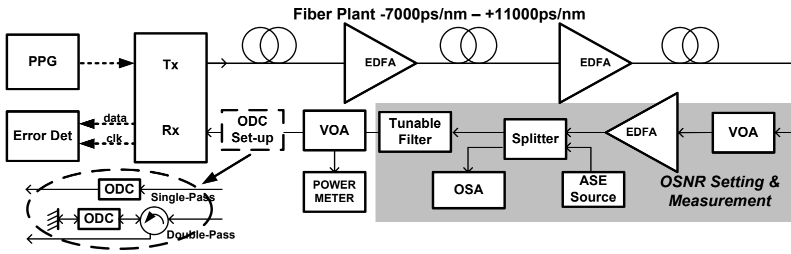

Fig. 2. The test set-up for testing duobinary transmission performance.

To test the duobinary transmission performance with ODC receiver, a duobinary transponder (without ODC) and stand-alone ODC are used. The ODC can be configured under nominal condition (single pass) or high dispersion condition (double pass). The double-pass condition is achieved with a circulator and retro-reflector with an overall insertion loss ~5dB. Figure 2 shows the amplified fiber plant for test. Both SMF and dispersion compensation fibers are used to provide a dispersive link up to +11000ps/nm and -7000ps/nm respectively. The optical launch power into fiber is limited to less than 0dBm so that fiber nonlinear effects can be neglected. A typical optical signal to noise ratio (OSNR) > 30dB is achieved over the fiber links. By attenuating the input into preamplifier and combining the broadband noise source, the OSNR can be adjusted over the dynamical ranges of the receiver.

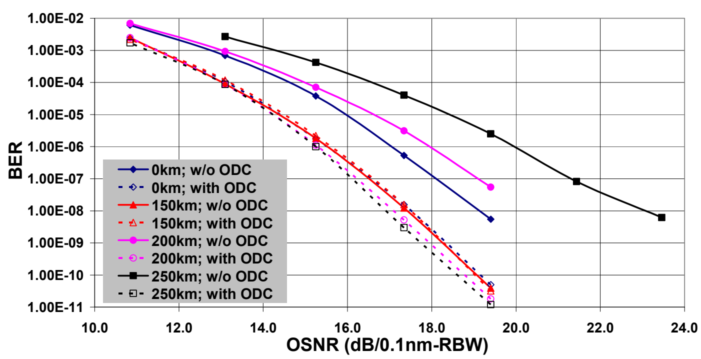

Fig. 3. The typical transmission performance of the duobinary transponder with and without tunable ODC over SMF. The test is performed with pattern PRBS 2^31 – 1 at data rate = 10.71Gb/s. Transmitter is operated at wavelength at 1545nm. The input power at APD receiver is set at -20dBm. Tunable filter's (see Fig. 2) bandwidth = 0.55nm. The solid and dotted lines correspond to duobinary transmission without or with ODC respectively.

For a duobinary transmitter, its transmission performance over the fiber link is well understood: the optimal performance happens at a fiber link ±2400ps/nm, whereas the required OSNR at BtB is actually higher. The 2dB path penalty happens at fiber link = ±3200ps/nm. Figure 3 shows the typical BER curves vs. OSNR over different fiber links with and without ODC at receiver. With ODC receiver, the transponder shows superior performance without any degradation over 0 – 250km SMF. The underlying reason for such a uniform performance is derived from the tunable feature of ODC, which is capable to set the aggregated chromatic dispersion (both fiber and ODC) to the sweet spot (±2400ps/nm) for a duobinary code. Thus the optimal performance is always achieved over the wide ranges of optical fibers.

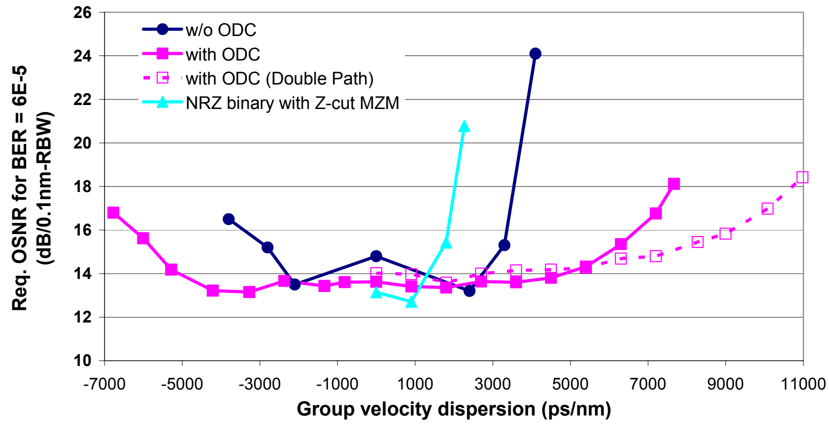

Fig. 4. The required OSNR for duobinary transmission at raw BER = 6E-5 over the fiber links at data rate = 10.71Gb/s with different ODC conditions. The receiver input power is set at -20dBm. The NRZ binary transmission has a Z-cut MZM and extinction ratio is set at 12.5dB.

It is also worth mentioning that there is no obvious BER floor shown in Fig. 3. Thus the transponder can be equally applied to a system with or without FEC in design. In Fig. 4, we have plotted the required OSNR to achieve BER at 6E-5 level over the fiber links. This corresponds to error-free transmission with the use of an ITU G.709 FEC. When ODC is configured under nominal condition, the required OSNR at BtB is 13.5dB (improved by 1.3dB). This is comparable to a high quality NRZ binary transponder which bears a higher extinction ratio[6]. Thus the ISI penalty due to duobinary coding is nearly removed. Comparing to the previous record of ODC[5], this shows more than 5dB OSNR improvement over 300km. We would point out that this technique works over wide dynamical range of receiver input and is insensitive to receiver linearity and noise, which clearly differentiates itself from EDC technologies[4]. Since a zero-chirp modulator is used for transmitter design, the OSNR performance is symmetric with respect to the positive and the negative dispersive links. Near-zero path penalty is observed up to ±5400ps/nm and the 2dB path penalty happens at ±6200ps/nm. With ODC under double-pass condition, the improvement of OSNR at BtB is slightly smaller. However the dispersion tolerance has improved beyond 11000ps/nm, which corresponds to 610km at the longest wavelength of C-band. The ODC has extended the duobinary transmission link over additional 6000ps/nm (max ODC tuning range).

4 Summaries

We have demonstrated a novel duobinary transponder design with tunable ODC receiver. With a clever use of ODC's tunability, the ISI penalty introduced by duobinary coding is nearly removed, which leads to an OSNR performance similar to that from a high performance NRZ transponder. The dispersion tolerance at 2dB OSNR penalty has been extended to ±6300ps/nm. With ODC under double-pass condition, the dispersion tolerance has been improved to more than 11000ps/nm. This technique is suitable for a wide range of applications in extended-metro, ROADM as well as future long-haul networks.

References

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