Flexible 10.7 Gb/s DWDM Transmission over up to 1200 km without Optical In-Line or Post-Compensation of Dispersion using MLSE-EDC

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Abstract *50 GHz DWDM transmission at 10.7 Gb/s over up to 1200 km on NZ-DSF without optical in-line or post-compensation is demonstrated with duobinary signals and receiver-based EDC with system flexibility suitable for add/drop optical networking.*

Introduction

System simplicity leading to low first-installed cost is a key motivation in next generation optical transmission systems for long-haul and ultra long-haul networks. This is evidenced by recent research emphasizing system designs that eliminate in-line dispersion compensation and allowing simpler and cheaper single-stage optical amplifiers. For example, transmitter-based electronic dispersion compensation (EDC) has been shown in a single-channel configuration to facilitate a simpler optical system over standard single-mode fibre in experiment and simulation [1-3]. Similarly, submarine transmission without in-line compensation over 6000 km of a negative dispersion non-zero dispersion shifted fibre (NZ-DSF) using RZ-DPSK modulation format has been shown [4]. However, the Tx-based EDC approach requires a significantly more complex transmitter and the submarine system required per-channel post-compensation at the receiver as well as complex Tx and Rx configurations. Here, we demonstrate a long-haul DWDM transmission system without in-line or post-compensation that is simple in concept and implementation. We combine receiver-based EDC technology with the increased dispersion tolerance of duobinary signals and the lower dispersion of an NZ-DSF to demonstrate 10.7 Gb/s transmission with 50 GHz channel spacing over up to 1200 km of fibre without in-line or post-compensation. We also demonstrate the flexibility to drop traffic anywhere in the link without receiver changes.

Experimental configuration

The basic experimental DWDM system set-up is shown in Figure 1. A re-circulating loop configuration was used with 38 optical channels spaced by 50 GHz ranging from 1547 nm to 1562 nm. The long wavelength end of the C-band was chosen for the channel plan to demonstrate system transmission results for the worst-case channels with the most accumulated dispersion. As shown in the figure, 3x100 km spans of Corning® LEAF® optical fibre comprised the transmission medium of the loop. The fibre dispersion is about 4.25 ps/(nm*km) at 1550 nm and about 5.25 ps/(nm*km) at 1562 nm. The 38 channels were divided into odd and even channels and modulated by two different duobinary modulators driven by the complementary outputs of a pattern generator. The pseudorandom bit sequence (PRBS) used was of length 2^{31} -1. All amplifiers in the loop were single stage EDFAs. The average channel launch power into each span was about -1 dBm.

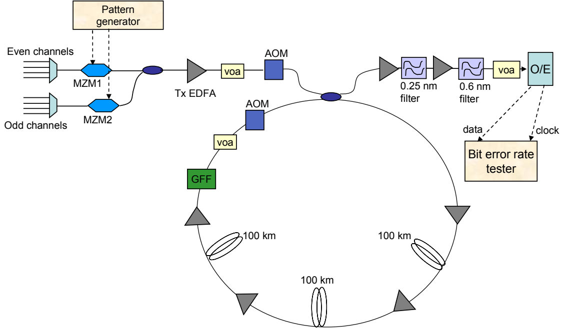

Fig. 1: Experimental re-circulating loop set-up.

The Mach-Zehnder modulators (MZMs) used in the transmitter are commercially available duobinary modulators designed for operation at up to 10.7 Gb/s. The modulators have a low-pass filter (LPF) integrated into the MZM package that produces the three-level electrical signal. The devices are biased at null output and driven with a 2Vpi voltage swing to produce the three-level optical duobinary signal which is well known to possess significantly increased dispersion tolerance in comparison to non-return to zero (NRZ) signals [5,6]. Two different receiver (Rx) set-ups were used in the system experiments. One Rx was a standard photoreceiver with a PIN photodetector and associated clock and data recovery circuitry. The second Rx was from the same manufacturer, but had a Maximum Likelihood Sequence Estimator (MLSE) EDC circuit in the back-end electronics. The MLSE Rx comprises a 3 bit A/D converter and four-state (memory m=2) Viterbi decoder. The two receivers allowed comparison of the maximum uncompensated distance achievable with the DWDM duobinary system.

Experimental results

The first experiment conducted with the system was with the standard receiver without MLSE-EDC. The channels were launched into the system as generated and detected after transmission over 600 km of the LEAF fibre. The results for OSNR and Q values of each channel at this distance are shown in Figure 2.

The Q values were derived from bit error rate (BER) measurements. The minimum Q value was over 13 dB, which has ~1.5 dB margin over the threshold for standard RS (255,239) forward error correction (FEC), and more than 4 dB margin over the threshold for enhanced FEC (eFEC). A 900 km distance was not attainable with the standard Rx due to dispersion limitations at the long wavelengths. For comparison, we would expect comparable performance to that shown in Figure 2 at distances <200 km over standard single-mode fibre with duobinary signals.

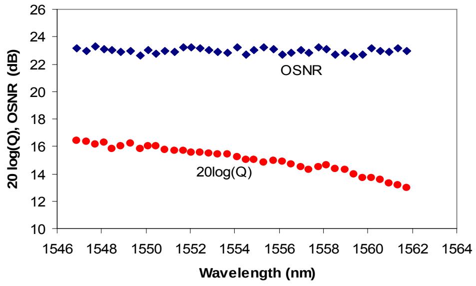

Fig. 2: Transmission results for duobinary signals over 600 km of LEAF® fibre with standard receiver.

We next studied the performance of the system using the receiver with MLSE-EDC. Results are shown in Figure 3 for transmission over 900 km, a distance which became possible with the EDC Rx. The average OSNR value at 900 km was 21.3 dB. The results show that 900 km is just achieved with the minimum Q value meeting the threshold for eFEC with nominal dispersion >4700 ps/nm. However, we note that some degradation of the performance of the MLSE-EDC Rx may be suffered by operation in the burst mode environment of a re-circulating loop. While not well quantified yet, this effect may artificially degrade the loop results found here to some extent.

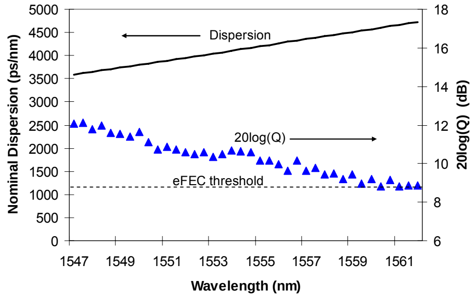

Fig. 3: Q results and dispersion for duobinary signals over 900 km of LEAF® fibre with the MLSE-EDC Rx.

Lastly, we performed experiments with a fixed amount of lumped optical dispersion pre-compensation in the transmitter, but still without in-line or post-compensation. The only change to the system as shown in Figure 1 is the inclusion of dispersion compensation fibre (DCF) in the Tx EDFA. The amount of pre-compensation used was equivalent to that for 125 km of standard single mode fibre (~ -2100 ps/nm at 1550 nm). As the results show, 1000 km transmission with a standard Rx (obtained with a 200 km loop) and 1200 km with the MLSE-EDC Rx are both achievable with significant margin over the eFEC threshold. For comparison, 1200 km was not achievable for all channels without EDC. Finally, the flexibility and simplicity of the system is evident by the data in Figure 5, which shows Q as a function of distance with the EDC Rx. The channels may be dropped at any distance ≤1200 km and be easily detected with the same Rx configuration. We expect that longer reach lengths can be achieved with larger amounts of pre-compensation, and preliminary measurements show 1500 km as feasible.

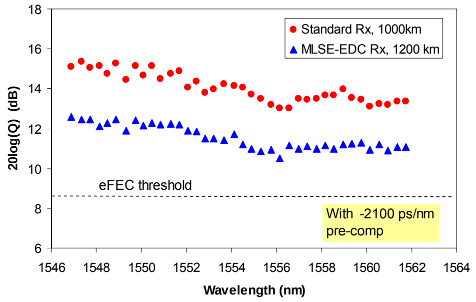

Fig. 4: Transmission results after 1000 km with standard Rx and 1200 km with MLSE-EDC Rx.

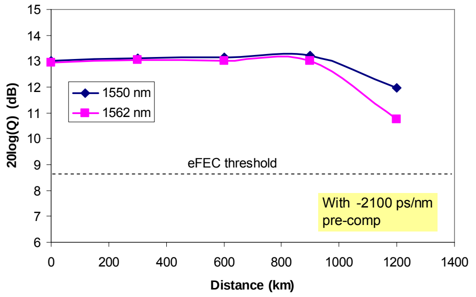

Fig. 5: Transmission as function of distance with fixed optical pre-compensation and MLSE-EDC Rx.

Conclusions

We have demonstrated a 10.7 Gb/s DWDM system with 50 GHz channel spacing over distances up to 1200 km without in-line or post- compensation. The combination of duobinary, MLSE-EDC, and NZ-DSF allows dispersion limited reach lengths of up to 900 km without optical pre-compensation and 1200 km with a fixed pre-compensation of -2100 ps/nm at 1550 nm. The results demonstrate a system for practical long-haul distances with flexibility to add/drop traffic anywhere in the link without receiver modifications.

References

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