Performance of 2.5 Gb/s and 10 Gb/s transient and adiabatic chirped directly modulated lasers using electronic dispersion compensation

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Abstract *For the first time to our knowledge we study the efficiency of electronic dispersion compensation when transient and adiabatic chirped directly modulated lasers operating at 2.5 Gbps and 10 Gbps are used.*

Introduction

In metro/access networks, the cost of transmission systems is a very critical factor and it is closely related with the cost of terminal equipment. Therefore, effective low cost transmitters such as directly modulated lasers (DMLs) could be used. Comparing DMLs with the external modulated lasers (EMLs), they have the advantage of small size, low driving voltage, low cost and high output power and therefore are attractive for use in metro and access network applications.

However, the frequency chirp characteristics of DMLs significantly limit the uncompensated transmission distance over standard single mode fiber (SSMF) to less than 10 Km at 10 Gb/s [1]. At 2.5 Gb/s, DMLs exhibit acceptable performance of about 100 Km. One of the proposed solutions for the mitigation of the chirp problem was the use of special fiber with negative characteristics [1]. However when SSMF is already deployed, other means of improving the transmission performance of DMLs should be used. A proposed approach focuses on the use of electrical processing in the receiver [2], [3], [4].

The majority of studies focus on the use of electronic dispersion compensation (EDC) for EML based systems [2], [3[, [4]. There are some studies [5], [6] that focus on chirped DMLs. However, no detailed studies have been reported to evaluate the performance improvement when EDC is considered for DMLs having different chirp characteristics. In this paper, we demonstrate for the first time to our knowledge the impact from the use of Feed Forward Equalizer (FFE) and Decision Feedback Equalizer (DFE) in the performance of transient and adiabatic chirped DMLs at 2.5 Gb/s and 10Gb/s.

Simulation set up and parameters

The performance of DMLs strongly depends on the characteristics of the laser frequency chirp. The chirp Δv(t) of a DML is related to the laser output power P(t) through the expression

$$\Delta \nu (t) = \frac{\alpha}{4\pi}\left(\frac{d}{dt}[\ln(P(t))] + \kappa P(t)\right) \qquad (1)$$

where α is the linewidth enhancement factor and κ is the adiabatic chirp coefficient [6]. In (1) the first term is related with transient chirp and the second term with adiabatic chirp [6]. Some DMLs exhibit strong adiabatic chirp while some others strong transient chirp. Therefore, the DMLs can be classified into adiabatic and transient chirp dominated DMLs [8]. The laser rate equation parameters for transient and adiabatic chirp dominated DMLs were reported in [8] where they have been also verified by both simulations and experiments and used in this work in order to perform system studies. Assumptions have been made only about the 10 Gb/s adiabatic dominated DML parameters.

For our simulations, we assumed a 10 Gb/s and 2.5 Gb/s non-return to zero (NRZ), PRBS of length 2^{23} -1. An extinction ratio of 15 dB was assumed when using EMLs (as a benchmarking case) and 8.2 dB when using DMLs. The signals were transmitted over SSMF with D = 16ps/km/nm. The interaction of the laser chirp with chromatic dispersion was the dominant source of distortion in the simulations. The performance criterion used in all cases to evaluate the performance of the received signals was the eye opening penalty (EOP).

EDC based on the techniques of FFE and DFE were considered [7]. The algorithm that was used in order to calculate the optimum taps coefficients for each case was the least mean square (LMS). The goal of that algorithm is to minimize the mean squared error (MSE) between the desired equalizer output and the actual equalizer output. The equalizers that were used were fractionally spaced equalizers (T/2). The DFE(5,1) (with five means the number of coefficients in the FFE and one is the coefficient at the DFE) has been identified as the best equalizer after extensive simulations studying the performance of all possible combinations of equalizer's. Results for the simpler FFE based EDC are also reported.

Simulation results

Figures 1, 3 show the eye opening penalty versus the transmission length for DMLs and EMLs at 2.5 Gb/s (Fig.1) and 10 Gb/s (Fig.3) respectively with and without equalizer. The received eye diagrams for the distances corresponding to 1 dB – penalty are presented in figure 2,4 respectively, without and with equalizer (the back to back eye is also shown). The solid symbols in figures 1,3 represent the cases of without equalizer, whereas the open symbols represent the cases with equalizer. The distances achieved for EMLs and DMLs corresponding to 1-dB penalty and the percentage improvement for each case are summarized in table 1 for FFE (5) and DFE (5,1) equalizers.

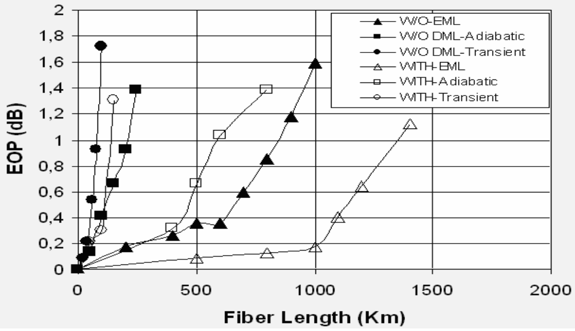

Fig. 1: EOP versus Fiber Length for 2.5 Gb/s without and with equalizer DFE(5,1). The trendlines in figures are drawn as a guide for the eye.

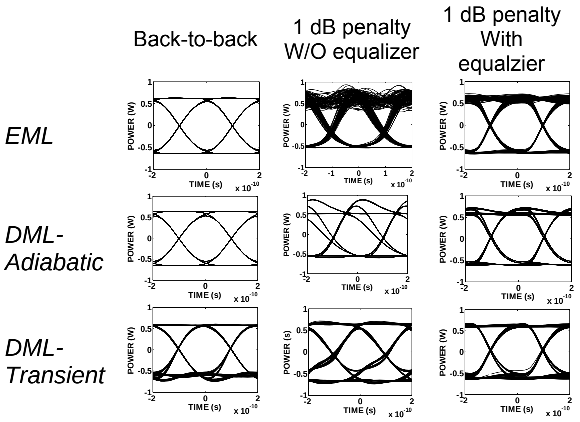

Fig. 2: Eye diagrams for 2.5 Gb/s.

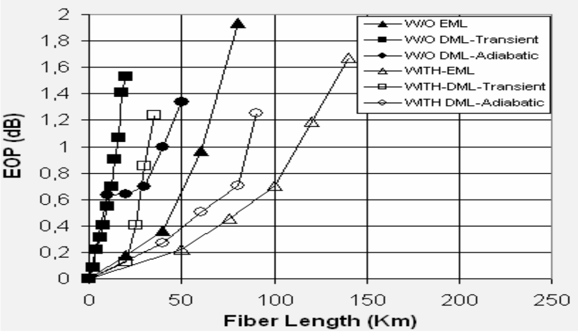

Fig. 3: EOP versus Fiber Length for 10 Gb/s without and with equalizer DFE(5,1). The trendlines in figures are drawn as a guide for the eye.

The transmission distance that can be obtained by using adiabatic dominated DMLs is better than transient dominated DMLs. Furthermore, by using EDC on these DMLs, the improvement on the performance of the system is more pronounced than transient chirp dominated DMLs (212%-300% over 100%-68%). As expected, the DFE has better performance than FFE and both exhibit better performance for the case of adiabatic chirp DMLs, whereas for the case of transient chirp dominated DMLs the performance improvement is close to what observed with EMLs. For adiabatic chirp case, it is worthy to note that the performance improvement of DFE over FFE is not so pronounced. It is also interesting to note that adiabatic chirp dominated DMLs exhibit a performance improvement much better than EMLs.

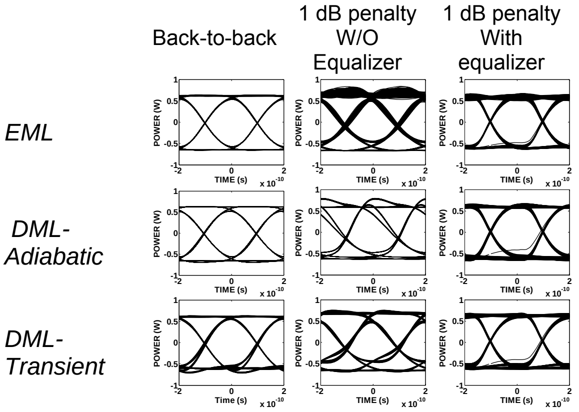

Fig. 4: Eye diagrams for 10 Gb/s.

Type	***Transmission distance(Km) W/O equalizer (1 dB penalty)***	***Improvement (FFE)-Km-(%)***	***Improvement (DFE)-Km-(%)***
EML (10G)	60	100-(67%)	110-(83%)
EML (2.5G)	870	1320-(52%)	1350-(55%)
DML - 10G (Adiabatic)	40	80-(200%)	85-(212%)
DML - 10G (Transient)	16	28-(75%)	32-(100%)
DML– 2.5G (Transient)	80	120-(50%)	135-(68%)
DML– 2.5G (Adiabatic)	200	600-(300%)	600-(300%)

Table 1: The improvement of FFE(5) and DFE(5,1) at 2.5Gb/s and 10Gb/s respectively with 1 dB penalty.

Conclusions

We have demonstrated the effectiveness of FFE, DFE equalizers in conjunction with DMLs. The transmission distance limits of 2.5 Gb/s and 10 Gb/s DMLs using SSMF fiber and EDC are reported. EDC equalized DMLs based systems show great potential to applications in metro/access networks with high data rates.

Acknowledgement

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