System level simulations for 300 m OM3 eSR4 link

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***Abstract*—We use a system level simulation to study the transmission penalty for extended SR4 systems with 300 m OM3 MMF under two types of launch conditions and we show an impact of the fiber bandwidth on the equalized 25.78 Gbps VCSEL-based NRZ link at 850 nm.**

Keywords*—*VCSEL, MMF, selective modal launch

I. Introduction

New short-reach communication standards dictate a transition in the transceivers' speeds from 10 Gbd/lane to 25 Gbd/lane due to constantly growing data traffic [1]. This transition puts a limitation on an achievable transmission distance and, in turn, on an existing implemented fiber infrastructure. An example is 100GBASE-SR4, a physical layer (PHY) standard developed by IEEE 802.3bm task group, which assumes four parallel 25.78 Gbaud 850 nm lanes [2]. The maximum transmission distance is specified as 70 m OM3 or 100 m OM4 multimode fiber (MMF). This definition excludes a transceiver upgrade in already implemented 300 m fiber links that were previously used with 40GBASE-SR4. A 25 Gbaud transmission over 300 m was demonstrated using OM4 wideband fiber, forward error correction (FEC) and equalization [3,4]. In this paper, we explore the possibility of combined selective modal launch (SML) technique and equalization on the receiver side to enable extended SR4 (eSR4) transmission over OM3 MMF. We specifically analyze transmission penalty for 300 m OM3 MMF transmission at 25.78 Gbps. In addition, we consider two types of launch conditions into the fiber, including a centra vertical cavity surface emitting laser (VCSEL) launch and a selective modal launch (SML). We previously demonstrated that SML improves fiber bandwidth as compared to the standard VCSEL launch. Bandwidth distribution for both types of launches was presented in [5] for 2300 OM3 fiber spools. In this work, we focus on the system performance analysis for 300 m OM3 transmission. We use three 300 m OM3 spools with bandwidths ranging from 5.3 GHz to 9.3 GHz. The system performance is compared in terms of receiver (RX) sensitivity at BER of 5e-5 after the fiber transmission. We use the fiber bandwidth measurements combined with a system level simulation of bit error ratio (BER) to quantify the RX sensitivity after the transmission. This approach allows us to evaluate the performance without time-consuming BER measurements. It also enables us to verify whether the eSR4 link budget can be closed with a specific fiber spool. The proposed study can be further extended to various types of signal launches, transmitted wavelengths (e.g. short-wave wavelength division multiplexing) and fiber types.

II. System Level Simulation

The system simulation is performed in a MATLAB environment. Table I summarizes the parameters used in our model of a single 850 nm optical link.

A. TX

The transmitter includes a rate equations based behavioral laser model with 3 dB BW of 19.7 GHz. The total laser bandwidth consists of a combined intrinsic and parasitics response and is presented in Fig.1. The TX eye diagram shown in Fig.1 depicts the output of the laser with a relative intensity noise (RIN) of -133 dB_c/Hz and modulated with a 25.78 Gbps NRZ signal. Extinction ratio (ER) is 4 dB.

TABLE I. eSR4 model Parameters

Parameter	***Value***	***Unit***
	Transmitter	
TX λ_c	850	nm
Laser BW	19.7	GHz
Spectral width	0.41	nm
RIN	-133	dB_c/Hz
Tx ER	4	dB
	300 m OM3 Fiber Link	
BW	5.3 – 9.6	GHz
	Receiver	
RX BW	19	GHz
PD Responsivity	0.5	A/W
Input referred noise	16	pA/sqrt(Hz)
CDR EQ	5 tap FFE + 2 tap DFE	

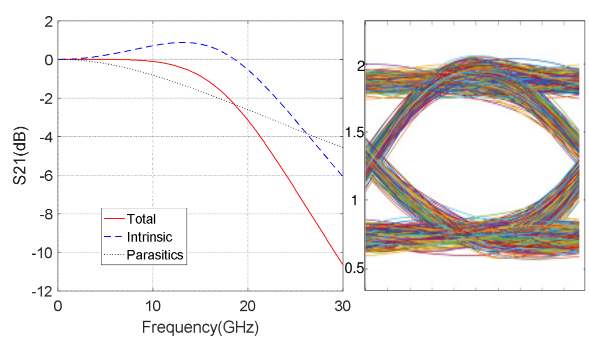

Fig. 1. S21 of the laser model and a TX eye diagram at 25.78 Gbps.

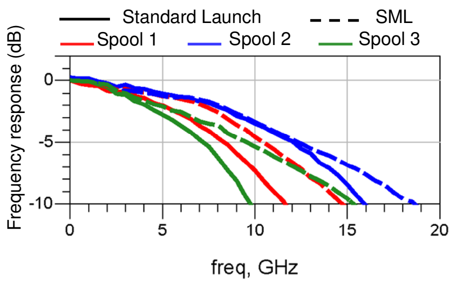

Fig. 2. Frequency response measured for three OM3 300 m fibers (spools 1, 2, 3) with standard VCSEL launch and with SML.

B. Link

We measure frequency responses of the three 300 m OM3 fiber spools for both the standard VCSEL launch and for the SML using vector network analyzer (VNA). To obtain the fiber response for both launch conditions we subtract a measured back-to-back (B2B) frequency response from a full system frequency response. The B2B includes a VCSEL with 0.41 nm spectral width connected directly to a PD. A full system response includes a fiber spool connected between the VCSEL and the PD. The fiber responses measured for both the standard VCSEL launch and SML are presented in Fig.1. The 3 dB bandwidth for the standard VCSEL launch ranges from 5.3 GHz to 9.3 GHz, and for SML, ranges from 6.6 GHz to 9.6 GHz. We use a Gaussian filter with the BW defined in the measurement to model the fiber link. The optical output signal of the fiber is obtained by filtering the optical input signal with the fiber model.

C. RX

The bandwidth of the modelled receiver is 19 GHz. The model includes a photodiode (PD), a linear trans-impedance amplifier (TIA), and a clock and data recovery (CDR). PD has the responsivity of 0.5 A/W and input referred noise of 16 pA/sqrt(Hz). A five-tap feed forward equalizer (FFE) with T/2 spacing and a two-tap decision feedback equalizer (DFE) are implemented in the CDR. We use a median of the rising edge to define the sampling phase and a DC level as the decision threshold for BER analysis.

III. Results and Discussion

We use receiver sensitivities at the BER level of 5e-5 after the fiber transmission as a metric to compare the tested scenarios, as summarized in Table II. The receiver sensitivity for B2B at BER level of 5e-5 is equal to -12.06 dBm. Hence, the transmission penalties vary from 1.61 dB to 4.37 dB for a standard launch and from 1.18 dB to 2.9 dB for SML. Spool 3 has the lowest BW in the tested set; it's effective modal bandwidth (EMB) of 1590 MHz•km and the SML improves it to 1980 MHz•km. The eye diagrams for spool 3 with standard VCSEL launch and with SLM are shown in Fig. 3. The eye is closed for a standard launch scenario at the linear TIA output, before the equalizer (Fig.3a). SLM enables eye opening (Fig.3b), but it is not sufficient to reach BER level of 5e-5. Equalizer implemented in the CDR allows for further eye opening and reaching BER of 5e-5 for both scenarios (Fig.3 c and d).

TABLE II. RX sensitivities at BER=5e-5

Fiber no.	Standard VCSEL launch	SML
Spool 1	-9.17 dBm	-10.20 dBm
Spool 2	-10.45 dBm	-10.88 dBm
Spool 3	-7.69 dBm	-9.16 dBm

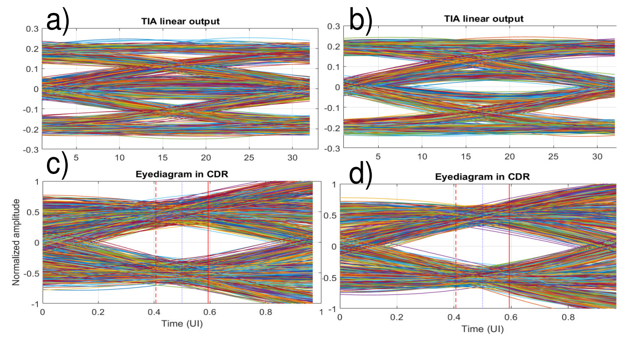

Fig. 3. Simulated eye diagrams for Spool 3 at: a) TIA output with standard launch conditions b) TIA output with SML c) CDR output with standard launch b) CDR output with SML.

IV. Conclusions

The system level simulation presented in this work enables an efficient link performance assessment. We demonstrate that a combination of an equalization and a selective modal launch enables 300 m OM3 transmission for a distribution of OM3 MMF. The 3 dB BW of the tested fibers range from 5.3 GHz to 9.6 GHz. The presented work is based on the eSR4 requirement, but it can also be applied to a different set of requirements, e.g. SWDM, by adjusting the model parameters.

Acknowledgment

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References

[1] Cisco Visual Networking Index: Forecast and Methodology, 2015–2020 (2016). [Online]

[2] IEEE Std 802.3bm(TM)-2015: "Physical Layer Specifications and Management Parameters for 40 Gb/s and 100 Gb/s Operation over Fiber Optic Cables", 2015.

[3] I. Lyubomirsky *et al*., "100G SWDM transmission over 300m wideband MMF," in Optical Communication (ECOC), 2015 European Conference on, Sept 2015, pp. 1–3.

[4] Y. Sun *et al*., "SWDM PAM4 Transmission Over Next Generation Wide-Band Multimode Optical Fiber," in *Journal of Lightwave Technology*, vol. 35, no. 4, pp. 690-697, Feb.15, 15 2017.

[5] A. Tatarczak *et al*., "Reach Extension and Capacity Enhancement of VCSEL based Transmission over Single Lane MMF Links," in *Journal of Lightwave Technology*, vol. 35, no. 4, pp. 565-571, Feb.15, 15 2017.