TRANSMISSION PERFORMANCE OF POF ETHERNET LINKS BUILT WITH COMMERCIAL TRANSCEIVERS

A. López, J. Mateo, M. A. Losada
GTF, i3A, Universidad de Zaragoza, María de Luna 1, 50018 Zaragoza, Spain
aliclope@unizar.es

Abstract: In this work we experimentally characterize commercial Gigabit Ethernet (GbE) POF transceivers in order to assess their influence over link performance. Additionally, these transceivers are used for obtaining, through bit error rate (BER) measurements, the length limits of fibers from several manufacturers when transmitting GbE data without advanced modulation or reception techniques.

1. Introduction

Plastic Optical Fiber (POF) has emerged as low-cost alternative to traditional copper cabling in office and home applications.[1,2] Nowadays, every commercial large-core step-index optical fiber (SI-POF) is able to transmit Fast Ethernet data at relatively long distances, though link length is limited at Gigabit Ethernet (GbE) data rates.[3] On the other hand, graded-index plastic optical fibers (GI-POFs) allow for an increment of the transmission distance at high data rates, representing 1mm-core-diameter GI-POFs a trade-off between the advantages of small-core graded-index[2] and large-core SI-POFs[1,3]. Together with the fiber, commercial transceivers are the key components of the basic transmission link, and thus it is important to characterize their behavior in order to understand the overall link performance.

The main goal of this paper is first the characterization of commercial GbE transceivers determining the influence of their response over the performance of POF links and then the evaluation of the transmission length limits of large-core GI-POFs comparing it with that of conventional SI-POFs by measuring the Bit Error Rate (BER) as a function of the data rate. Results obtained include the maximum fiber length achievable for GbE transmission by each tested POF when using the considered commercial transceivers. These results are assumed to be very valuable both for the deployment of basic in-home networks and for the research of new techniques that allow the extension of these length limits.[4]

The paper is organized as follows: In the first section, we present the experimental setup used for the measurements. The following section contains details and experimental results related to the analysis of commercial GbE transceivers. Then results about the comparative study of several POFs are shown including transmission performance for 50-m length and maximum length for supporting GbE data rate. Finally, the last section summarizes the conclusions derived from the obtained results.

2. Experimental setup

Figure 1 shows the schematic of the experimental setup used in this work. The main module is the transceiver (FOT-FOR), which generates and receives the optical signal and is commercially available from Firecomms™. The BER measurement system is based on the OptoBERT™ OPB3200 from Optellent, which incorporates a PRBS generator that supports continuously variable data rates from 100 to 3150 Mb/s. The optical signal is obtained by feeding the PRBS to the optical transmitter and is propagated through the fiber, while at the other fiber end the receiver circuit regenerates the signal which is injected to the BER tester (BERT). Specifically designed software allows us to measure the BER as a function of data rate by performing a custom scanning of the bit rate. Additionally, the BERT provides the choice of testing link performance when transmitting different data patterns, namely PRBS with pattern lengths of 2^7-1 and 2^{23}-1.

This setup has been used for the characterization of GbE commercial transceivers and their influence over the BER measurements. Moreover, performance of POF links has been evaluated and the fiber length limits for several types of commercial POFs have been determined.

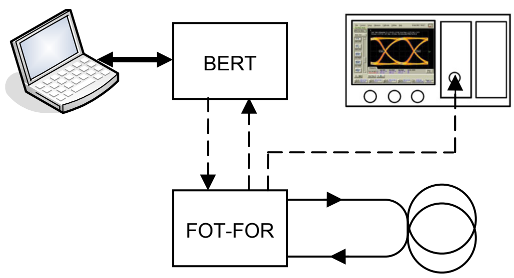

Fig. 1. Experimental setup.

3. Influence of the transceiver response

For the measurements, several commercial Firecomms™ transceivers intended for operation at GbE data rate (1.25 Gb/s) were tested: a pre-commercial prototype (EDL1000G-510) and three samples of the latest release (EDL1000T-EVB). Both models use a Vertical Cavity Surface Emitting Laser (VCSEL) as visible light source (665 nm) and an integrated receiver within a miniature package. The OptoLock® connector acts as interface with the fiber transmitter and receiver ends.

Previous measurements[3] performed with the pre-commercial transceiver EDL1000G-510, revealed deterministic oscillations of the measured BER values, which were improbably related to the fiber response itself. In order to explain the obtained results, we have performed a scan of data bit rate within low and high frequency ranges when transmitting through a short piece of SI-POF and measured the BER. Figure 2 shows the results for the low (left) and high (right) frequency ranges when using a PRBS 2^{23}-1 data pattern.

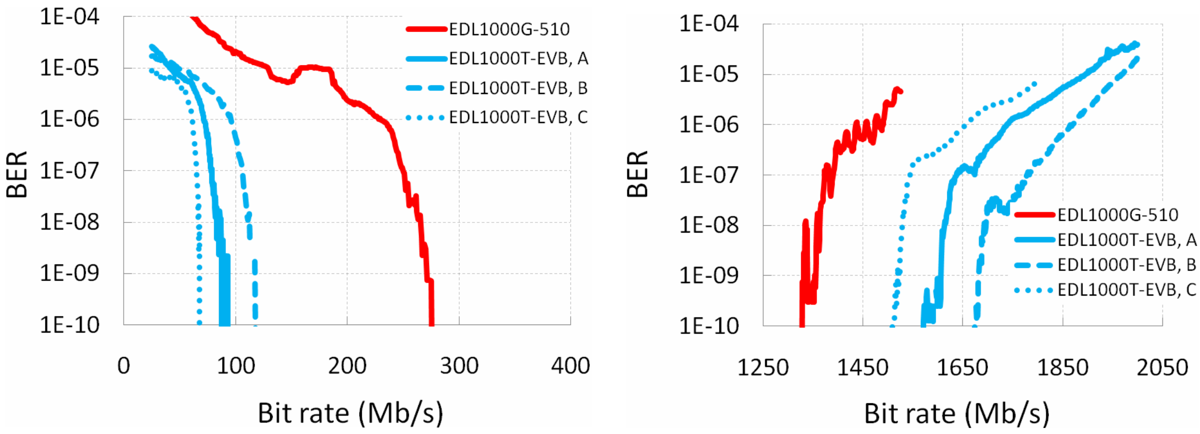

Fig. 2. Error-free limits for lower data rates (left) and upper data rates (right) for the prototype EDL1000G-510 (red) and three different samples of EDL1000T-EVB (blue) using a PRBS 2^{23}-1 data pattern.

As it can be observed, all transceivers considered exhibit a band-pass behavior showing excess of errors both in the lower and higher data rate ranges and error-free performance in the intermediate range. The newer transceivers (model EDL1000T-EVB) present better performance both at low and high frequencies than the previous design (EDL1000G-510). BER measurements obtained when transmitting data according to a PRBS 2^7-1 pattern, show no performance degradation at low data rates, while the behavior at high data rates is shown in Figure 3.

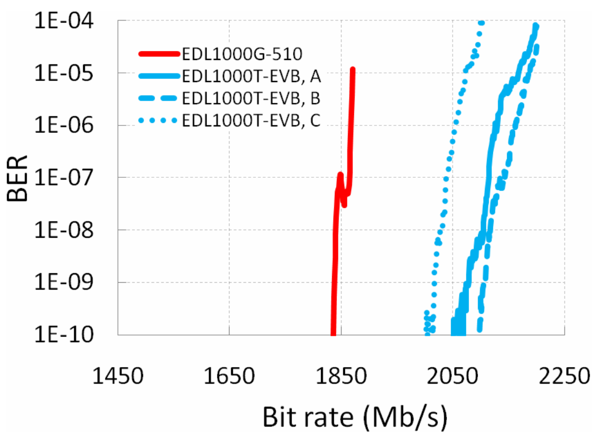

Fig. 3. Error-free limits for upper data rates for the prototype EDL1000G-510 (red) and three different samples of EDL1000T-EVB (blue) using a PRBS 2^7-1 data pattern.

The pattern length affects the error-free range of the data rate, so that shorter pattern lengths allow for wider ranges. When dealing with data rates in the lower frequency range, no high-pass filter effect is observed for the shorter pattern length considered. The reason for both observations is that the length of the runs of marks or spaces is clearly shorter for 2^7-1 than for 2^{23}-1 pattern length and thus, the eye closure induced by the high- and low-pass behavior of the transceiver is more pronounced when transmitting PRBS sequences with longer pattern lengths. BER deterministic oscillations are no longer observable when using the new improved transceivers (EDL1000T-EVB).

4. POF length limits for GbE links

Once the transceiver inherent limits have been obtained and the suitability of the available devices assessed, we analyze the performance offered by several POFs operating in GbE links. The performance is measured in terms of BER and results obtained for the different fibers include the maximum admissible length at 1.25 Gb/s for each of them.

4.1 Tested fibers

In the comparative analysis we have used several 1mm-diameter PMMA-core POFs with step-index profiles from different manufacturers: two Toray broadband fibers, the PMU-CD1002-22-E (PMU) with relatively low NA of 0.33 and the PGU-CD1001-22-E (PGU) with NA of 0.5; the HFBR-RUS500 fiber (HFBR) from Hewlett Packard with NA of 0.47 and the ESKA PREMIER GH4001 (GH) from Mitsubishi with NA of 0.5. Finally, to compare these fibers with large-core GI-POFs, we have tested the OM-Giga, from Optimedia, which also has 1-mm diameter core.

4.2 Data rate limits for 50-m POF length

We have performed a scan of the data rate for 50 m of the tested fibers. The data pattern selected was PRBS 2^7-1, which is adequate to emulate Ethernet 8B/10B encoding. The measured BER was obtained by accumulating errors over a gating time of 5 s. This preliminary comparative analysis is intended to give insight into the suitability of the considered fibers for their use in GbE links covering moderate distances. Results are represented in Figure 4. Received power was in all cases above the sensitivity limit.

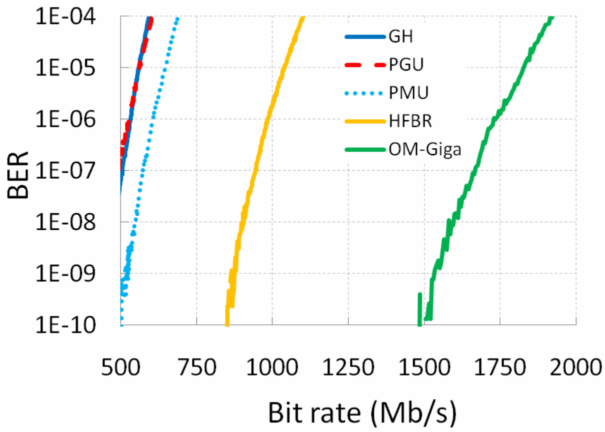

Fig. 4. Bit rate limits for 50 m of the tested fibers, PRBS 2^7-1 data pattern.

As shown in the graph, only the GI-POF considered in the analysis (OM-Giga) is able to transmit GbE data and even exceed the required data rate. Additionally, it has been found that the best of the tested SI-POFs is the HFBR, which has been previously shown to exhibit very strong mode coupling[5,6] and thus presents an improvement of bandwidth performance caused by the averaging of group delays. The observed differential fiber performance with data rate is mainly due to modal dispersion, which in turn depends on the launching conditions, mode coupling and differential mode attenuation. Launching conditions are set by the OptoLock® connector and are assumed to be the same for each of the fibers analyzed. On the other hand, both mode coupling strength and differential mode attenuation are characteristic of each POF and cause the performance differences obtained.

4.3 Length limits at GbE data rate

Finally, our most useful objective was to determine the maximum length for with each of the considered fibers is able to transmit GbE data. For this purpose, we carried out several BER measurements at 1.25 Gb/s 2^7-1 PRBS following a cut-back technique until the BER value was below 10^{-9}. Figure 5 summarizes the results obtained.

As expected from the previous comparative analysis, OM-Giga GI-POF presents the best performance and is able to transmit GbE data through fiber lengths up to 62 m. It must be noted that at this length fiber attenuation is playing a limiting role, since received power was measured to be -20.3 dBm, which is around the receiver sensitivity limit. On the other hand, Hewlett Packard HFBR offers the best performance among the considered SI-POFs and is able to operate in GbE links for distances up to 42 m. The rest of SI-POFs show a similar behavior and can cover distances in the range of 30 m.

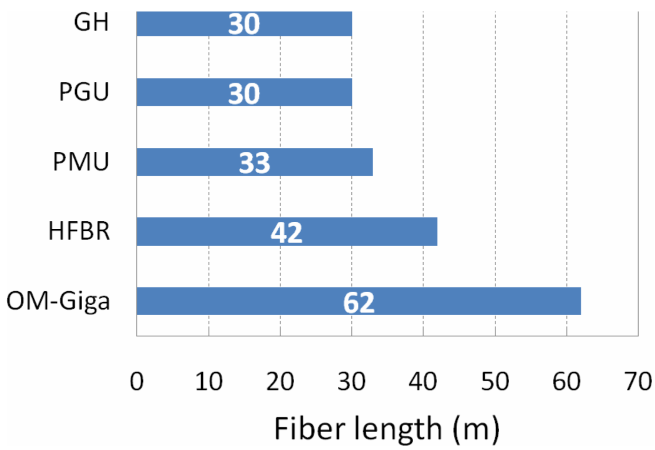

Fig. 5. Length limits for the tested fibers when transmitting GbE data (1.25 Gb/s, PRBS 2^7-1).

5. Conclusions

In this work, we have experimentally assessed the transmission performance of several large-core POFs when operating in GbE links and we have determined their maximum reach. Transmission through a short length of fiber and measurement of BER values has revealed the high- and low-pass behavior of commercial transceivers that is responsible for the data pattern dependency of results.

Through a comparative analysis of the considered SI-POFs, we have demonstrated the technical feasibility of their use without any advanced technique for in-home applications assuming distances shorter than 30 m. Additionally, we have shown the superior performance of large-core GI-POFs, for which the length limits set by attenuation and bandwidth concur in the range of 60 m.

Acknowledgements

This work was supported by the Spanish Ministry for Science and Innovation under grant reference TEC2009-14718-C03-02.

References

1. A. Nespola, S. Abrate, R. Gaudino, C. Zerna, B. Offenbeck, N. Weber, “High-Speed Communications Over Polymer Optical Fibers for In-Building Cabling and Home Networking”, IEEE Photonics Journal 2, 347-358, (2010).
2. Y. Koike, “The Giga House Project”, in Proc. *International Conference on POF, XVIII ed.*, Sydney, Australia, (2009).
3. P. Heredia, J. Mateo, M.A. Losada, “Transmission capabilities of large core GI-POF based on BER measurements”, in Proc. *International Conference on POF, XVI ed.*, Torino, Italy, (2007), pp. 307-310.
4. H. Yang, S. C. J. Lee, C. M. Okonkwo, S. T. Abraha, H. P. A. van den Boom, F. Breyer, S. Randel, A. M. J. Koonen, and E. Tangdiongga, “Record high-speed short-range transmission over 1 mm core diameter POF employing DMT modulation”, Optics Letters 35, pp. 730-732, (2010).
5. M.A. Losada, J. Mateo, L. Serena, “Analysis of propagation properties of step-index plastic optical fibers at non-stationary conditions”, in Proc. *International Conference on POF, XVI ed.*, Torino, Italy, (2007), pp. 299-302.
6. J. Mateo, M.A. Losada, I. Garcés, J. Zubia, “Global characterization of optical power propagation in step-index plastic optical fibers”, *Optics Express* 14, 9028-9035 (2006).