10 Gbit/s Burst-mode Receivers for Next Generation PONs

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I. Introduction

Currently, broadband networks use a combination of optical and electrical networks to provide broadband access to the customers. The core network is an optical fiber network, but for the access network the operators re-use the existing copper infrastructure. However, this copper section to the customer, called the 'last mile', introduces a speed bottleneck between the high speed core network and the high-speed devices and local area networks within the customer's premises. Offering broadband access to the customer over optical fiber would enable the wide-spread use of new applications like HDTV, IPTV, videoconferencing, etc. Next-generation PONs would offer 10 Gbit/s both upstream and downstream which is an enormous increase in bit rate compared to the currently provided broadband services.

The first burst-mode receiver (BM-Rx) presented here was designed for the PIEMAN (Photonic Integrated Extended Metro and Access Network) project [1]. This optical fiber system aims to deliver access bandwidths of up to 10 Gbit/s upstream and downstream to individual customers. At the same time it integrates access and metro networks into one system, thereby greatly simplifying the network architecture and management, and so significantly reducing the cost to deliver future broadband services to residential and SME customers.

Another approach for next generation PON's is to use avalanche photodiodes (APD). This is researched in IST project MARISE [2]. Within this project, INTEC is responsible for the design of a burst-mode transimpedance amplifier (TIA) with very high sensitivity and very large dynamic range.

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II. PIEMAN burst-mode receiver

Figure 1 shows the upstream part of the PIEMAN network. It consists of 32 PONs, each operating at a different wavelength and each connecting up to 512 optical network units (ONUs). At the local exchange, the signals of each PON are amplified by an erbium-doped fiber amplifier to compensate for the splitting losses and the added onto one fiber using wavelength division multiplexing. The burst-mode receiver is located at the service node. To avoid collisions in each PON, time division multiple access (TDMA) is used. This means the BM-Rx receives a quick succession (ns scale) of bursts with different optical power and phase. Special design measures are needed to cope with this kind of traffic.

The designed dc-coupled burst-mode receiver consists of a TIA and a post-amplifier (PA). The total response time required for the TIA is 6 ns, which makes it the the quickest-response burst-mode TIA designed up to today. The PA performs offset compensation within 18 ns using a multistage feedforward approach [3]. It detects both start (activity signal) and end of the burst (reset signal). These signals are respectively used on the clock phase alignment chip that follows the PA, and the TIA, thereby greatly reducing the interface between

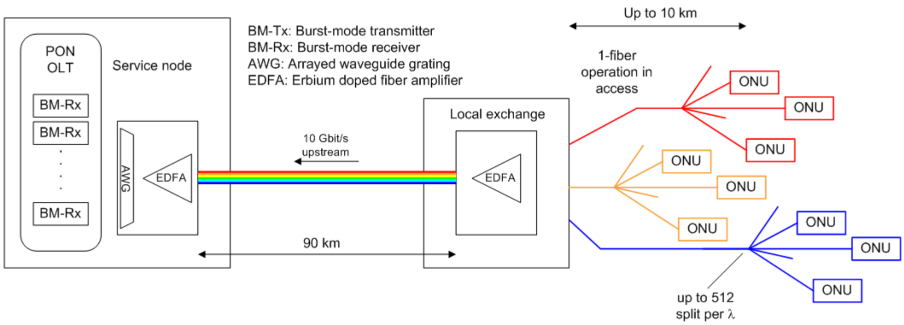

Figure 1. PIEMAN network topology - upstream part only

MAC layer and physical layer.

Test results of a first version TIA were presented in [4] where the measured BM-Rx sensitivity at 10 Gb/s was -12.5 dBm at a loud/soft ratio of 11.5 dB. Based on these measurements, a second version of the TIA was designed. The back-to-back Rx sensitivity of this TIA measured at INTEC was -13.5 dBm at 10 Gb/s, with a dynamic range of 13 dB [5].

III. MARISE APD-TIA

The PIEMAN project focussed on designing burst-mode receivers with a quick response. However, the future standards 10GE-EPON (IEEE 802.3av) and ITU-T XG-PON (ITU-T FSAN) include the possibility for longer guard time and run-in time (order of 500 ns) and therefore, the quick response specified in PIEMAN is no longer required. MARISE aims to deliver an APD-TIA compliant with future standards and therefore the overhead timing specifications of the APD-TIA were increased to 200 ns. To achieve a sensitivity of -27dBm in combination with a 21 dB dynamic range, both the transimpedance gain (as in PIEMAN) and the APD's multiplication gain will be switched (M-control) on a burst-to-burst basis. This will give an extra increase in dynamic range with a factor M_+/M_- (M_+, M_- are respectively maximum and minimum gain of the APD).

Two challenges can be identified related to the M-control. Firstly, changing the APD reverse bias voltage within 200 ns to lower the multiplication gain contradicts the requirement of a well decoupled APD supply. This trade-off will lead to a data dependent multiplication gain and pulse width distortion. Secondly, commercial APD bias voltage sources include temperature compensation and overload protection. The M-control system will have to be compatible with a form of temperature stabilization and overload protection.

IV. Conclusions

The main results from the IST project PIEMAN were presented. The IST project MARISE was introduced and the main challenges related to the APD-TIA design were identified.

References

[1] http://www.ist-pieman.org.

[2] http://www.ict-marise.eu.

[3] T. De Ridder, P. Ossieur, C. Mélange, B. Baekelandt, J. Bauwelinck, X.-Z. Qiu, J. Vandewege, *10 Gbit/s burst-mode post-amplifier with automatic reset*, IET Electronics Letters, vol. 44, no. 23, pp. 1371-+, Nov 2008.

[4] T. De Ridder, P. Ossieur, B. Baekelandt, C. Mélange, J. Bauwelinck, C. Ford, X.-Z. Qiu, J. Vandewege, *A 2.7V 9.8Gb/s Burst-Mode TIA with Fast Automatic Gain Locking and Coarse Threshold Extraction*, Proc. ISSCC'08, 11.1, Feb 2008.

[5] X.-Z. Qiu, C. Mélange, T. De Ridder, B. Baekelandt, J. Bauwelinck, X. Yin and J. Vandewege, *Evolution of Burst Mode Receivers*, Invited paper, ECOC'09, Sept 2009.