A simple 25 and 12.5 Gb/s dual-rate burst-mode receiver compliant with ITU-T G.9804.3 N1-class

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Abstract: Our simple dual-rate burst-mode receiver in a TO-46 package is compliant with the 50G-PON N1-class specifications. Receiver sensitivities of -26.5 dBm and -27.8 dBm were achieved for 25 and 12.5 Gb/s signals with 200 ns preamble length. © 2022 The Author(s)

1. Introduction

Following the wide deployment of 10 Gb/s-class passive optical networks (PON), next-generation 50-Gigabit-Ethernet PON (50G-EPON) and 50-Gigabit-capable PON (50G-PON) have been standardized as IEEE 802.3ca [1] and ITU-T G.9804.3 [2], respectively. 50G-PON is the more remarkable because even at 50 Gb/s, single wavelength transmission can simplify the optical components which represent a major part of an optical transceiver's cost. Therefore, standard low-cost optical packages such as TO-CAN are preferable for 50G-PON systems. In addition, although 50G-PON only supports a single downstream data rate of 50 Gb/s, multiple upstream data rates of 12.5, 25, and 50 Gb/s are specified because asymmetric PON systems such as G-PON are widespread. Recently, a 50 Gb/s burst-mode transimpedance amplifier (TIA) has been reported [3], but there still remains the question of cost-effective burst-mode transmitters and their application to 50 Gb/s upstream. As a result, a 25 Gb/s burst-mode receiver is a key component for early stage 50G-PON systems. Moreover, a 25 and 12.5 Gb/s dual-rate burst-mode receiver is more desirable for smooth migration from 10 to 25 Gb/s-class upstream systems. There have been several studies into 25 Gb/s burst-mode receivers [4 - 6], and several trials of 50G/25G asymmetric 50G-PON systems [7, 8]. Ref. [4] showed a good receiver sensitivity of -27.7 dBm and a fast settling time of 150 ns for 50G-EPON systems. However, the optical package was a butterfly type which is usually much more expensive than TO-CAN. Although the performances of a 25.8 and 10.3 Gb/s dual-rate burst-mode receiver using a TO-CAN package was presented in Ref. [5], it only focused on 50G-EPON, not on 12.5 Gb/s in a 50G-PON system. On the other hand, in Ref. [6], the burst-mode receiver performance at multiple line rates of 25, 12.5, and 10 Gb/s was presented for 50G-PON. The digital signal processing (DSP)-assisted burst-mode receiver achieved a high receiver sensitivity of -26.9 dBm for 25 Gb/s signals and a fast settling time of 92 ns. However, the optical power difference between the burst-mode signals was only 10 dB whereas a maximum of 19.5 dB is required for 25 Gb/s signals in the ITU-T specification. In addition, a DSP-assisted receiver configuration brings with it additional cost and power consumption.

In this paper, we report for the first time a 25 and 12.5 Gb/s dual-rate burst-mode receiver in a simple TO-CAN package without any DSP assistance, which is compliant with the 50G-PON N1-class specifications. It achieves optical modulation amplitude (OMA) receiver sensitivities of -26.5 dBm for 25 Gb/s and -27.8 dBm for 12.5 Gb/s signals at a bit error ratio (BER) of 10^{-2} with a fast settling time of 200 ns by adopting the burst-mode TIA we developed. In our experimental setup, the optical power difference between loud and soft bursts was over 21 dB at the minimum measured receiver sensitivity for both 25 and 12.5 Gb/s signals. A wide dynamic range of more than 20 dB was also achieved for both bit rates because of the overload level of -5 dBm.

2. Configuration of 25 and 12.5-Gb/s dual-rate burst-mode receiver

Figure 1 shows the configuration of a 25 and 12.5-Gb/s dual-rate receiver optical sub-assembly (ROSA) mounted in a commonly-used TO-46 package. It consists of our developed preamplifier IC and a commercially-available 25G avalanche photo diode (APD). The preamplifier IC incorporates a 25G burst-mode TIA with a continuous-mode automatic gain control (AGC) circuit for obtaining a wide dynamic range and a single ended to differential converter (S2D) for which the threshold level is decided by a continuous-mode automatic threshold control (ATC) circuit, where the AGC and ATC circuits do not require external reset signals. To achieve good receiver sensitivity, the transimpedance gain of the TIA was maximized and a capacitive peaking circuit was implemented in the TIA to restore the bandwidth degradation due to the bandwidth limitations of the TO-CAN package and the APD. Dual-rate operation without an external rate-select signal was achieved in our ROSA. As a result, the differential transimpedance gain was 58.1 dB, and the -3 dB and -10 dB bandwidths were 9.5 and 16.5 GHz, respectively, for both 25 and 12.5 Gb/s signals. The IC was fabricated on 0.13 μm SiGe BiCMOS technology.

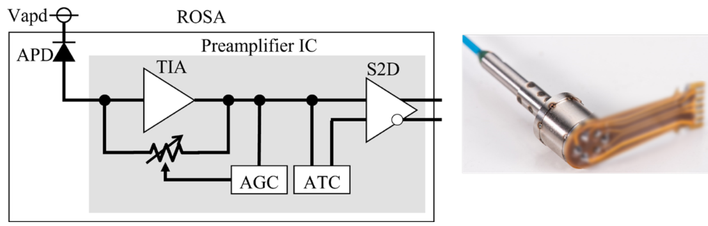

Fig. 1. Configuration and photograph of 25 and 12.5 Gb/s dual-rate burst-mode ROSA

3. Experimental setup and results

Figure 2(a) shows the experimental setup for burst BER evaluation of our dual-rate burst-mode ROSA. A 10G burst-Tx at a wavelength of 1270 nm for the 12.4 Gb/s signal and a 25G burst-Tx at a wavelength of 1310 nm for the 24.9 Gb/s signal were modulated by pulse pattern generator (PPG) slots controlled by a bit error ratio tester (BERT) to generate the respective burst signals. The output eye diagram of the 25G burst-Tx is shown in Figure 2. The extinction ratios of the 24.9 and 12.4 Gb/s signals were 5.0 dB and 6.9 dB, respectively. The optical burst packets were input independently to the ROSA after attenuation, and combined by a coupler. The differential output signals of the ROSA receiving the bursts were connected via 100 pF capacitors to the error detector (ED). The composition of the burst packets is shown in Fig. 2(b), the sequence consisting of a loud burst packet followed by a soft burst packet with guard times of 50 ns between the packets. The soft burst packet consisted of a preamble and a payload. The burst BERs of the soft burst payloads were measured for preamble lengths from 150 ns to 800 ns. The payload patterns for the signals at both bit rates were set to PRBS 2^{31} -1. The payload lengths for both bit rates were the same at 106496 bits. The ROSA input power of the loud burst packet was fixed at -5 dBm for both bit rates.

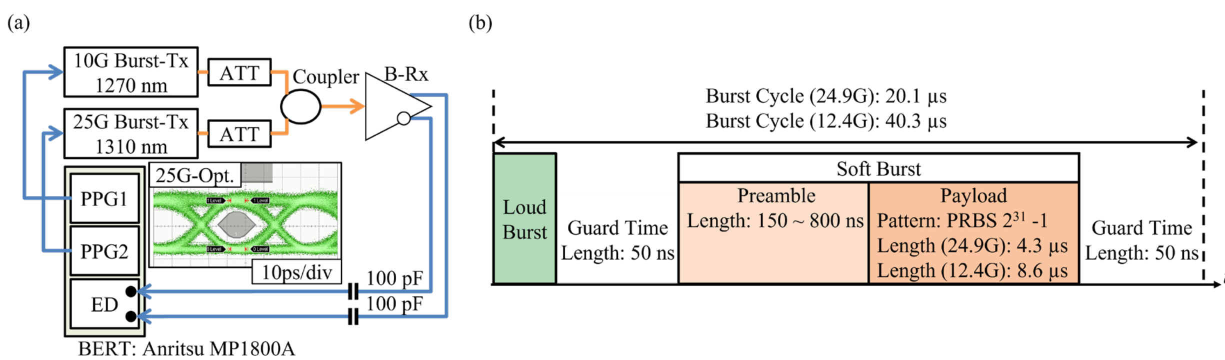

Fig. 2. Measurement setup for burst BER

Figure 3(a) shows the BER performance of the ROSA when receiving 24.9 Gb/s soft burst packets with a 200 ns preamble (solid orange line) and a continuous PRBS 2^{31} -1 signal (solid blue line). As shown by the orange line, the minimum receiver sensitivity expressed as OMA at BER = 10^{-2} was -26.5 dBm. The burst penalty was only 0.3 dB thanks to the rapid AGC and ATC functions in the preamplifier IC. According to the measured minimum receiver sensitivities vs. preamble length, all the sensitivities at preamble lengths from 150 ns to 800 ns met the G.9804.3 N1-class specification of -24.5 dBm. Likewise, Figure 3(b) shows the measured BERs when receiving 12.4 Gb/s signals. From the burst BER result (dotted orange line), the minimum receiver sensitivity expressed as OMA at BER = 10^{-2} was -27.8 dBm, down 0.7 dB from the continuous mode. By relating the sensitivity to preamble length, the ROSA had 1.5 dB margins over the G.9804.3 N1-class specification of -26 dBm. At both line rates, the BER was less than 10^{-12} when the soft burst packet was at -5 dBm, this being equivalent to the highest overload level in the G.9804.3 N1-class specifications. The maximum power differences between the two burst signals were respectively 21.5 dB and 22.8 dB for the 24.9 and 12.4 Gb/s burst BER measurements. These values are also compliant with the G.9804.3 N1-class specifications.

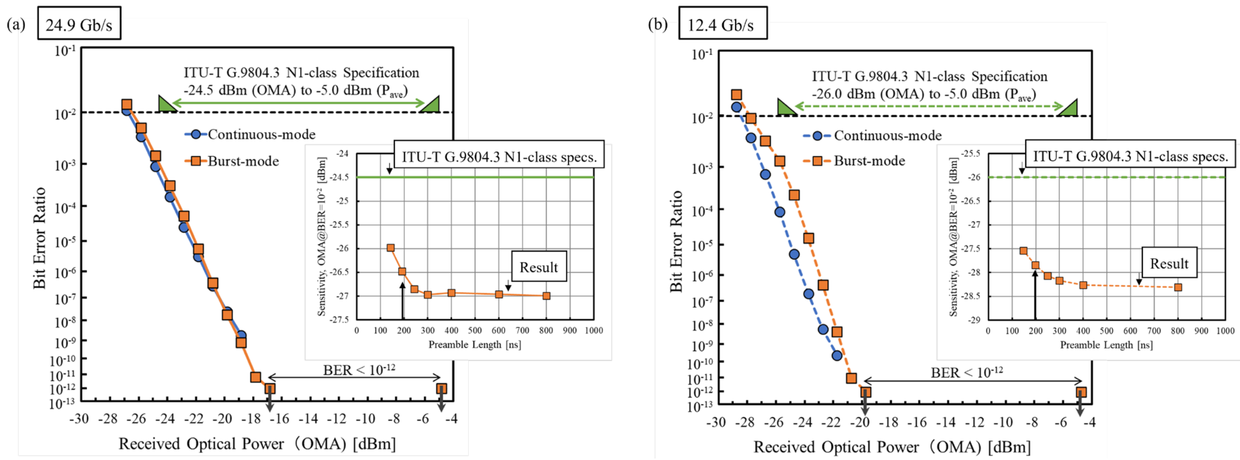

Fig. 3. BER characteristics with minimum sensitivity preamble length for (a) 24.9 Gb/s and (b) 12.4 Gb/s

Table 1 summarizes the receiver performances of our work and of several references and the ITU-T G.9804.3 N1-class specifications. This shows that our results easily met all the G.9804.3 N1-class specifications in terms of lower sensitivities, shorter preamble lengths and greater maximum power difference between the burst signals. These results were obtained even when mounted in a cost-effective TO-CAN package without any DSP assistance.

Table 1. Measured receiver characteristics and the Standard

Parameter	G.9804.3 N1	Ref. [4]	Ref. [5]	Ref. [6] [1]	This work
Line rate [Gb/s]	24.9 / 12.4	25.8 / -	25.8 / 10.3	25 / 12.5	24.9 / 12.4
Minimum receiver sensitivity at BER $=10^{-2}$ (OMA) [dBm]	-24.5 / -26.0	-27.7 / -	-26.0 / -31.2	-26.9 / -31.0	-26.5 / -27.8
Preamble length [ns]	< 611	150 / -	600 / 600	92 / 92	200 / 200
Overload [dBm]	-5.0 / -5.0	-3.0 / -	-3.0 / -6.0	-6.0 / -	-5.0 / -5.0
Maximum power difference between burst signals [dB]	19.5 / 21.0 [2]	21.7 / - [3]	23.0 / 28.2 [3]	10 / 10 [3]	21.5 / 22.8 [3]
DSP assistance	-	Without	Without	With	Without
ROSA package type	-	Butterfly	TO-CAN	TO-CAN	TO-CAN

[1] 10G BER was also measured.
[2] Power difference between overload and minimum receiver sensitivity (OMA)
[3] Power difference between bursts in minimum receiver sensitivity measurement

4. Conclusions

We described the configuration and performance of a 25 and 12.5 Gb/s dual-rate burst-mode receiver compliant with the G.9804.3 N1-class specifications, mounted in a standard TO-CAN package with no DSP assistance using the burst-mode TIA we developed. It achieved minimum receiver sensitivities expressed as OMA of -26.5 dBm for 24.9 Gb/s and -27.8 dBm for 12.4 Gb/s signals, in either case recovered in a short preamble length of 200 ns. We also achieved both a wide dynamic range and a power difference between the burst signals of more than 21 dB.

5. References

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