Optical Transceiver for Optical Access Systems

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In recent years, as a way of economically realizing a high-speed, large-capacity optical subscriber network, the commercial introduction of 1.25-Gbps GE-PON (Gigabit Ethernet-Passive Optical Network) systems has been expanding. In the case of a GE-PON system, individual subscribers (or ONUs: Optical Network Units) are geographically located at varying distances from an optical star coupler, so packets that reach a given station-side OLT (Optical Line Terminal) from such individual ONUs vary in intensity. Therefore, the optical receivers used in the OLT must be able to instantaneously reproduce packets of varying light intensity. On the other hand, the optical transmitter of an ONU must be able to instantaneously emit a light packet at a signal (transmission) rate of 1.25 Gbps. In this paper, we describe an optical transmitter, optical receiver and optical transceiver which we have developed for use in GE-PON OLTs and ONUs, all of which comply with the international standard IEEE 802.3ah and which attain satisfactory performance characteristics.

1. GE-PON System Overview

Figure 1 shows the topology of a GE-PON system in which a single OLT is connected with multiple ONUs by a star coupler. Since this structure enables shared use of most of the optical fibers serving as transmission paths to connect the multiple ONUs and the (single) OLT, the operating cost is expected to be lower.

Regarding downstream traffic from the OLT to ONUs, each ONU extracts data from time slots that are allocated to it by means of a multicasting service method using the 1.49-µm wavelength band. On the other hand, for upstream traffic from the individual ONUs to the OLT, the 1.31-µm wavelength band and a time division multiplex method is used to control transmission timing so as to avoid collisions of data from the individual ONUs.

Since these ONUs are located at geographically varying distances from the optical star coupler and so the optical intensity of individual ONU-launched packets vary from packet to packet received at the OLT, the receiving circuitry of the OLT is required to stably reproduce packets of varying intensity.

2. OLT Optical Transceiver

2.1 Configuration of the OLT Optical Transceiver

Figure 2 shows a simplified block diagram of the OLT optical transceiver.

The optical transmitter consists of a high-output-power DFB-LD (Distributed Feedback-Laser Diode) with a wavelength of 1.49 µm and a driver IC and is equipped with an APC (Automatic Power Control) circuit, a signal degradation alarm-issuing feature and a shutdown capability.

The optical receiver consists of an APD ( Avalanche Photodiode), a preamplifier capable of handling burst signals, a limiting amplifier equipped with an ATC (Automatic Threshold Control) function, and an APD bias voltage supply circuit. It operates on a reset signal-free basis. A preamplifier IC and a limiting amplifier IC have been newly developed using a 0.32-µm SiGe BICMOS process to be compliant with the IEEE802.3ah standard.

Figure 3 shows external views of the optical transmitter and the optical receiver of the OLT. The optical transmitter measures 32.4 mm by 20 mm by 11 mm, operates on a power supply voltage of 3.3V ± 5% and consumes power of less than 0.76 W. The optical receiver measures 46.3 mm by 30.6 mm by 12.7 mm, operates on a power supply voltage of 3.3V ± 5% and...
consumes power of less than 0.87 W.

Fig. 3 Photograph of OLT transmitter and receiver

2.2 OLT Optical Transmitter Characteristic

Figure 4 shows an optical output waveform after the signal has passed through a fourth-order Bessel-Thomson filter with a cutoff frequency of 937 MHz. Favorable waveforms measuring +4.0 dBm or greater in average optical output power, 17 dB or greater in extinction ratio and 65% or greater in mask margin were obtained at ambient temperatures from 0°C to 70°C. The transmission penalty after transmission through 20 km of single-mode fiber (SMF) (total dispersion: 317 ps/nm) was 0.1 dB or smaller.

Fig. 4 Output waveform of OLT with fourth-order Bessel-Thomson filter

2.3 OLT Optical Receiver Performance

Since the OLT optical receiver for the PON system must stably reproduce burst signals of varying levels from each ONU at high speed, the receiver must have wide dynamic-range performance. As a burst-capable preamplifier gain control method, we adopted a continuous AGC scheme.

Figure 5 shows the bit error ratio performance at the time of burst reception. As the measurement method, with the average optical output power of the first packet fixed at –6 dBm, the bit error ratio performance of the second packet’s data region (PN-7) was evaluated by varying the average optical output power of the second packet. At ambient temperatures from –5°C to 75°C, a bit error ratio performance of 1 x 10^-12 or smaller was obtained over a reception optical level range of –30.1 dBm to –5 dBm, comfortably complying with the IEEE802.3ah standard.

Fig. 5 Measured bit error ratio performance of OLT

3. ONU Optical Transceiver

3.1 Configuration of the ONU Optical Transceiver

Since this ONU optical transceiver is an optical interface to be installed in subscriber terminal equipment, it is required to make burst transmissions in order to avoid collisions with packets transmitted by other ONUs.

Figure 6 shows a simplified block diagram of the ONU optical transceiver. It consists of the transmitter block, the receiver block and the interactive wavelength multiplexing optical module which incorporates a light-emitting device (laser diode), a light-receiving device (photodiode), a preamplifier IC and wavelength selective combining and splitting devices in order to reduce size and cost. In addition, it also incorporates a rejection filter that works in the 1.55-µm band in preparation for future triple-play services carrying superimposed video signals.

Fig. 6 Block diagram of ONU optical transceiver

As for the light-emitting device in the transmitter block, an FP-LD (Fabry-Perot laser diode) is used for transmission through 10 km of SMF (single-mode fiber) (PX10) while a DFB-LD is used for transmission through 20 km of single-mode fiber (the PX20). For controlling the optical output power level, a feed-forward-type APC scheme is applied. A shutdown capability is also incorporated.

The receiver block consists of a PD (photodiode), a
preamplifier, and a limiting amplifier and is equipped with a loss-of-signal alarm-issuing feature. Figure 7 shows an external view of the ONU optical transceiver. It measures 46.6 mm by 19.6 mm by 21.0 mm, operates on a power supply voltage of 3.3V ±5% and consumes power of 0.99 W or less.

![Fig. 7 Photograph of ONU transceiver](image)

### 3.2 ONU Optical Transmitter Performance

Favorable waveforms measuring +1.8 dBm or greater in average optical output power, 11.0 dB or greater in extinction ratio and 30% or greater in mask margin were obtained at ambient temperatures from 0°C to 70°C. Figure 8 shows optical output waveforms of the head and tail ends of a packet. During burst operation, the rise time is 43.2 ns or smaller and the fall time is 0 ns, both with adequate margins with respect to the value of 512 ns specified by IEEE802.3ah.

![Fig. 8 Burst-on/burst-off time of packets](image)

### 3.3 ONU Optical Receiver Characteristics

Figure 9 shows ONU bit error ratio performance. At ambient temperatures from 0°C to 70°C, a bit error ratio performance of 1 x 10^{-12} or smaller was obtained at a reception optical level of −28.5 dBm, comfortably complying with the IEEE802.3ah standard. Furthermore, the amount of deterioration caused by crosstalk due to operation on the transmitter side has been reduced to 0.2 dB or less by optimizing the structural and parts-mounting design.

![Fig. 9 Measured bit error ratio performance of ONU](image)

As discussed above, we have developed optical transceivers that satisfy the international IEEE802.3ah standard, for use in GE-PON OLTs and ONUs and demonstrated that they produce satisfactory performance. We will continue with research and development in order to offer faster yet less expensive products.