100-Gbps EML CAN for 5G Mobile Communication System

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1. Introduction

Data traffic is rapidly increasing due to the spread of mobile communication devices and the use of cloud computing systems to exchange information. In response, mobile communication systems are being shifted from 4G to 5G around the world. This requires large-capacity optical communication systems between backbone networks and base stations, driving demand for 100-Gbps products.

In the structure of conventional 25-Gbps electro-absorption modulated laser (EML) CAN, there are many specular points of high-frequency signals due to impedance mismatch, making it difficult to secure the signal passband required for 100-Gbps high-speed operation.(1) Accordingly, we have developed a new structure with a wider signal passband as follows. The band of the EML element was widened, sections related to impedance mismatch in the package structure were reviewed, and a metal plate was introduced between the package and flexible printed circuit (FPC), which has made it possible to reduce signal reflection. In addition, components for 25-Gbps EML CAN were used to reduce the cost and the 4-level pulse amplitude modulation (PAM4) system in which a single pulse signal carries 2-bit data is supported, which has led to 100-Gbps optical signal transmission devices with a communication speed that is four times faster.

2. EML Element Design

In the adopted hybrid structure, a buried-type DFB with excellent high-temperature properties and an EA modulator with a high-mesa waveguide are monolithically integrated.(2) For the high-mesa waveguide, the optical confinement rate is high even when the width of the waveguide is narrow and the trade-off relationship between the band and extinction ratio can be eased. In order to realize high-speed operation of 100 Gbps, the band needs to be expanded by reducing the capacitance of the EA modulator and the extinction ratio needs to be secured at the same time. To achieve this, the length of the modulator was made shorter than the conventional model to reduce the capacitance; the extinction ratio, which is in a trade-off relationship, was reduced compared to the conventional model while the 100G Lambda MSA LR1 specifications(3) were satisfied in the design.

3. Design to Expand the Band of EML CAN

For operation at 100 Gbps, the passband needs to be 35 GHz or higher in general. The output impedance of the circuit for driving the device is 50Ω. Therefore, optimizing the impedance of the EML CAN structure to 50Ω reduces reflection, which makes it possible to expand the band. However, the impedance mismatch in the conventional CAN structure needs to be reduced.

Figure 1 shows the appearance and internal structure of this product. Usually, an FPC is connected to the rear of the stem to install the product into a transceiver. As the internal structure, the FPC is connected to the EML via the glass penetration section and electrical signals are sent. In the conventional structure, the impedance of the glass penetration section is not 50Ω, which limits the band. Consequently, for this product, the diameter of the signal pin and the permittivity of the glass material were reduced, bringing the impedance close to 50Ω. In addition, the material of the reinforcing plate of the FPC was changed to an electrically conducting material and the reinforcing plate was implemented above the GND layer, which enhanced the GND between the stem and FPC.

4. EML CAN Evaluation Results

Table 1 lists the target specifications of this product and evaluation results. Figure 2 shows a comparison of the frequency response characteristics (S21) between this product and 25-Gbps EML CAN. The figure shows that the −3-dB passband width of 25-Gbps EML CAN is up to 19 GHz while that of this product has been extended up to 36 GHz.

Next, to evaluate the optical waveforms, a digital signal processor (DSP) with an internal driver was used. In the established evaluation system, a data pattern in the 53.125-GBd PAM signal transmission mode (short stress pattern random quaternary (SSPRQ)) was created and input to this product; the PAM4 optical waveforms output from this product were evaluated using a special optical oscilloscope. In the evaluation, the intensity levels of the four values were adjusted so as to minimize the transmitter and dispersion eye closure quaternary (TDECQ), which is the standard for evaluating PAM4 optical waveforms.

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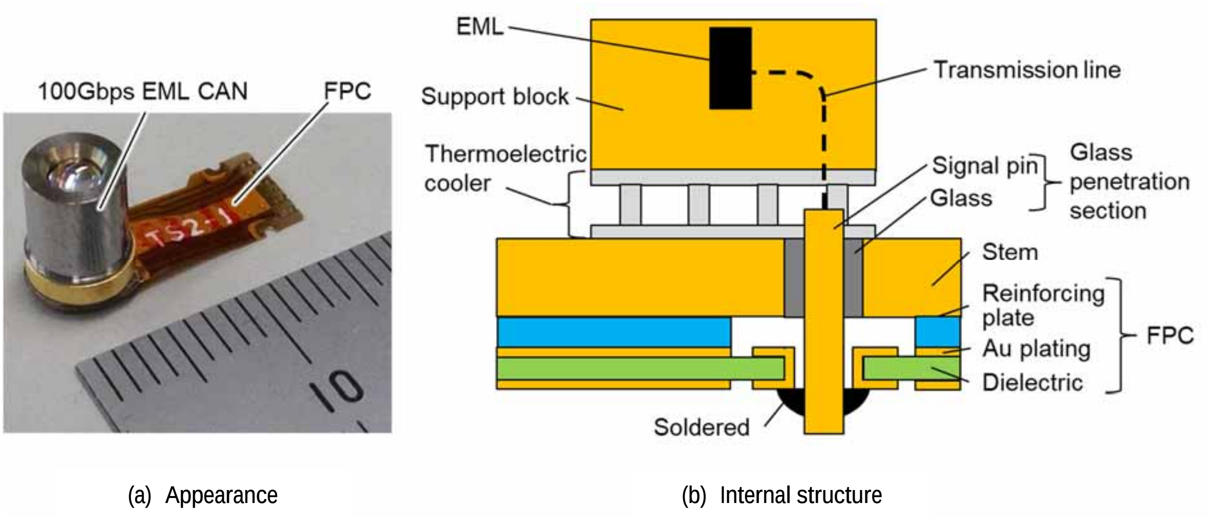

Fig. 1 Appearance and internal structure

Table 1 Product target specifications and evaluation results

Item	Target specification	Evaluation result
Emission wavelength	1304.5~1317.5nm	1312.0nm
Optical output (CW, Iop = 100 mA)	≥10.5dBm	12.8dBm
Optical modulation amplitude at the time of modulation	0.8~4.6dBm	0.8~4.6dBm (Iop=60~80mA)
-3-dB passband	≥35GHz	36GHz
Extinction ratio at the time of modulation	≥5.0dB	5.6dB
TDECQ	≤3.4dB	2.5dB
Power consumption of thermoelectric cooler	≤0.7W@-40℃ ≤0.5W@95℃	0.46W@-40℃ 0.38W@95℃

Figure 3 shows the back-to-back (BTB) PAM4 optical waveforms measured with the oscilloscope. As the evaluation results, the extinction ratio at the time of modulation (outer ER) was 5.6 dB and TDECQ was 2.5 dB; thus, they have margins compared to the LR1 specifications. The evaluation also revealed that the optical modulation amplitude at the time of modulation (outer OMA) also satisfies the LR1 specifications.

Figure 4 shows the power consumption of the thermoelectric cooler when the case temperature (Tc) was changed from −40℃ to +95℃. The consumption of this product is similar to that of 25-Gbps EML CAN and the power consumption per Gbps could be reduced to one quarter that of conventional 25-Gbps EML CAN. Regarding the product specifications, the power consumption is 0.7 W when Tc is −40℃ and 0.5 W when Tc is 95℃.

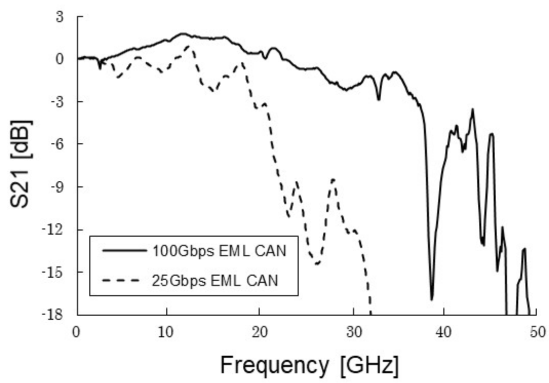

Fig. 2 Frequency response characteristics of this product and 25-Gbps EML CAN (S21)

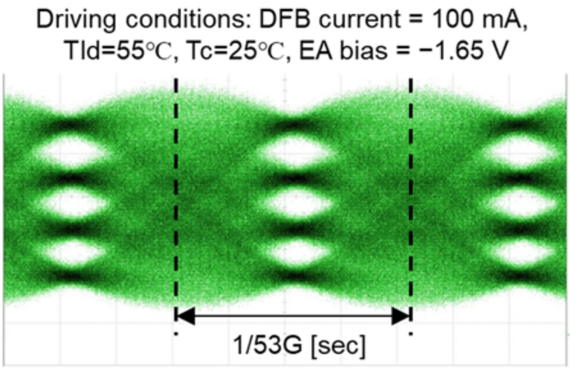

Fig. 3 PAM4 optical waveform

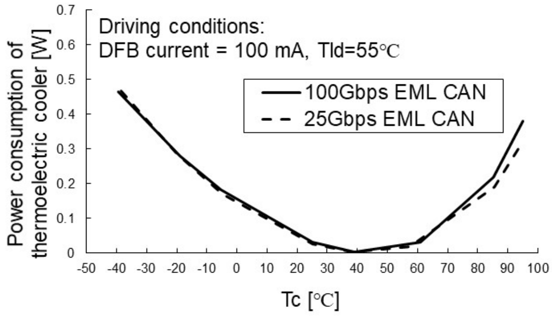

Fig. 4 Evaluation results of power consumption of thermoelectric cooler

5. Conclusion

Mitsubishi Electric has developed 100-Gbps EML CAN for 5G mobile base stations. To expand the band, the length of the EA modulator in the EML element was reduced, the impedance of the stemmed glass penetration section and other sections was matched as the package structure, and an electrically conducting material was used as the reinforcing plate of the FPC. These improvements reduced signal reflection and achieved the passband of 35 GHz or higher. To evaluate the optical waveforms, a DSP with an internal driver was used. The obtained BTB showed that the outer ER was 5.6 dB and TDECQ was 2.5 dB; these values have margins compared to the 100G Lambda MSA LR1 specifications. The power consumption of the thermoelectric cooler was 0.46 W when Tc was −40°C and 0.38 W when it was +95°C. The power consumption per Gbps was reduced to one quarter that of 25-Gbps EML CAN, thus greatly reducing the energy consumption of optical communication systems.

References

(1) Okada, N., et al.: Cost-Effective 10.7Gbit/s Cooled TOSA Employing Rectangular TO-CAN Package Operating up to 90°C, OFC, JWA38 (2010)
(2) Morita, Y., et al.: 1.3 μm 28 Gb/s EMLs with Hybrid Waveguide Structure for Low-Power- Consumption CFP2 Transceivers, OFC, America, paper OTh4H.5 (2013)
(3) 100G LAMBDA MSA, 100G-FR and 100G-LR Technical Specifications Rev 2