Crosstalk reduction between RF input channels of coherent-driver-modulator package by introducing enhanced ground lead structure

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This Letter presents a novel RF ground lead structure for surface-mount-type optical modules that enables RF crosstalk reduction and bandwidth enhancements. Conventional RF lead-pins of a surface-mount-type optical module have a bent shape that affects on RF ground stability and RF crosstalk between channels. The authors introduced an enhanced ground lead with an optimised shape for RF ground scheme enhancement. They prepared two types of high-bandwidth coherent driver modulator packages for demonstrating RF performance difference, one with the conventional bent ground lead and the other with the optimum-shaped ground lead. The measured results of the package with the enhanced ground lead successfully exhibited adjacent far-end crosstalk reduction of about 5 dB at 50 GHz, and the crosstalk of ~30 dB or less up to 58 GHz was confirmed. Moreover, they obtained the improvement in the insertion loss of 1 dB at 54 GHz and the 3-dB electrical bandwidth enhancement of 2 GHz. These RF performances are sufficient for a high-bandwidth coherent driver modulator package that allows 96-GBd class operations.

Introduction: Internet protocol traffic is growing exponentially, and thus the demand for large-capacity digital coherent optical communications systems is increasing. Expanding the capacity of optical communications systems requires optical transmitters and receivers that can operate at higher speed and with higher-order modulation formats. Crosstalk is a critical parameter for ensuring signal integrity as well as for increasing bandwidth. Therefore, it is important to suppress it for higher-speed operation.

Conventional standardised surface-mount-type optical modules have several RF differential signal lead pins and RF ground lead pins. The top surface of a motherboard and the bottom surface of a surface-mount-type optical module package via the RF lead-pins. The RF lead-pins provide RF signal transition path between the two surfaces with 0.3-mm height difference. Along the RF transition path, there is one of the main issues in RF ground scheme that determines RF crosstalk characteristics between different channels. In other words, the ground lead-pin structure is very important for achieving lower crosstalk and higher bandwidth.

For example, a high-bandwidth coherent driver modulator (HB-CDM) [1–3] and a high-bandwidth intradyne coherent receiver [4, 5] have achieved high-speed operation up to 64 GBd with higher-order modulation formats up to 64QAM, and they are key components for constructing large-capacity optical communications systems. These modules employ surface mount lead structures for the RF interface. The crosstalk in them is mainly determined by the lead-pin structure of surface-mount-type RF packages, and reductions in the package crosstalk are needed. Specifically, the crosstalk between adjacent channels should be ~30 dB or less in the frequency band in use (for example, 64 GBd up to 35 GHz; 96 GBd up to 53 GHz); however, this has been difficult to achieve with the conventional bent lead structure for over 64-GBd operations.

In this Letter, we focus on the ground lead structure of surface-mount-type optical modules to enable crosstalk reduction between RF input channels and bandwidth enhancement. We introduced an enhanced ground lead pins with an optimised shape for RF ground scheme enhancements. We examined ground-signal-signal-ground (GSSG)-based RF packages for the HB-CDM and confirmed that the enhanced ground lead structure improved the far-end crosstalk between adjacent channels by about 5 dB at 54 GHz. Moreover, the package shows the roll-off frequency of more than 65 GHz. These RF characteristics are sufficient for the HB-CDM package that enables 96-GBd class operations.

Enhanced ground lead structure: Figs. 1a and b show the RF area of fabricated HB-CDM packages with the enhanced ground lead and the conventional bent ground lead, respectively. To suppress the leakage of the electromagnetic field to other channels at the lead root, we devised an enhanced ground lead structure with a thick root section and flat surface, while a signal lead has a conventional bent lead structure. Four RF transmission lines are integrated in the package. The RF input (lead side) interface has an 0.8-mm pitch GSSG configuration and is connected to a printed circuit board (PCB) with solder. The RF output interface is 625-μm-channel-pitch GSSG-based coplanar transmission lines and is connected with a linear four-channel driver [2, 3]. All RF transmission lines of the package were designed to have a differential-mode impedance of 100 Ω and a common-mode impedance of 25 Ω for impedance matching.

As shown in Fig. 1a, the enhanced ground lead is thicker at its root and has a straight shape, compared with the conventional bent ground lead structure shown in Fig. 1b. Fig. 2a shows a schematic electromagnetic field of the enhanced ground lead. The root of the ground lead is thicker than the signal lead, and the thicker ground reduces an electromagnetic field leakage from the signal lead of a channel to another channel. In addition, to maintain compatibility in the solder mounting process, the enhanced ground lead and the signal lead in contact with the PCB have the same thickness and width. In detail, the lead width in the PCB connection area is 0.2 mm and the lead thickness is 0.15 mm for both the signal lead and enhanced ground lead. On the other hand, the thickness and width of the root of the enhanced ground lead are about 0.3 mm. In general, the root area of the lead pin tends to have a higher impedance, which causes degradation of RF characteristics due to impedance mismatch. With the enhanced ground lead, the impedance increase in the lead root area can be

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suppressed, and impedance matching and RF characteristics can be improved. We conducted RF simulations using a model in which the package was soldered to a PCB with a 2.5-mm RF transmission line from the lead tip [1]. The results showed that the far-end crosstalk to an adjacent channel could be improved by about 3 dB at 50 GHz by employing the enhanced ground lead. Furthermore, far-end crosstalk of less than −30 dB at up to 55 GHz, a roll-off frequency of around 65 GHz, and an electrical 3-dB bandwidth of 58 GHz were observed.

**Measurement results:** Fig. 3 shows a photograph and a cross-sectional image of the package used for the RF measurements. To measure the S-parameters of the fabricated package, we soldered it to a PCB board. The PCB board is equipped with a G3PO connector to facilitate measurement. In the RF measurements, the RF input side (lead side) was connected to the G3PO connector by an RF cable, and the RF output side (driver pad side) was accessed by a GSSG RF probe. Since it is difficult to access the output side from both above and below, S-parameter measurement is difficult without the G3PO connector. The probe access could also be facilitated by moving the RF transmission line from the lower surface to the upper surface of the PCB using an RF via. However, in that configuration, the RF characteristics may be degraded due to the RF via, and accurate RF characteristics may not be obtained. From the above viewpoints, we believe that our measuring method is optimum for RF measurement of this package.

**Conclusion:** An enhanced ground lead structure enhances ground scheme and suppresses the leakage of the electromagnetic field at the lead root. Moreover, the enhanced ground lead reduces impedance mismatch in the connection between the leads and a PCB. Compared with the conventional bent ground lead, the crosstalk was improved by 5 dB at 50 GHz, and the crosstalk of −30 dB or less was achieved up to 58 GHz with the enhanced ground lead. The above results indicate that the leakage of the electromagnetic field at the lead root is suppressed effectively by the enhanced ground lead. In general, crosstalk of less than −30 dB is required at frequencies in the 3-dB electro-optic bandwidth of a transmitter (for example, 64 GBd up to 35 GHz, 96 GBd up to 53 GHz). From that point of view, the package with the enhanced ground lead has enough crosstalk characteristics and electrical 3-dB bandwidth for enabling 96-GBd class operations.

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One or more of the Figures in this Letter are available in colour online.

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