Development of LN modulator drivers for 100G digital coherent communication

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[Summary] We have developed LN modulator drivers for 100G digital coherent communication to increase the capacity of high-speed optical communications. We have installed four driver circuits in a small package of 34.6 × 25.4 mm and achieved an output voltage of more than 7.0 Vp-p at 32 Gbaud with the performance needed to drive LN modulators. The unique implementation with simple internal structure reduces crosstalk between adjacent circuits by up to about –20 dB at 20 GHz.

1 Introduction

The explosive growth of the smartphone market and the resultant increase in network traffic seems likely to continue into the future, requiring faster speeds and larger capacities to handle the traffic increase. To meet these needs, the Optical Internetworking Forum (OIF) established a framework in 2009 for a Dense Wavelength Division Multiplex (DWDM) communications method to support 100G speeds over ultra-long distances. Subsequently, the Dual Polarization-Quadrature Phase Shift Keying (DP-QPSK) method using digital coherence technology was also agreed upon. This method is a superior modulation from the viewpoint of resistance to wavelength dispersion, polarization mode dispersion and noise.[1]

Figure 1 shows the block diagram for a transmitter module using the DP-QPSK method agreed by OIF.

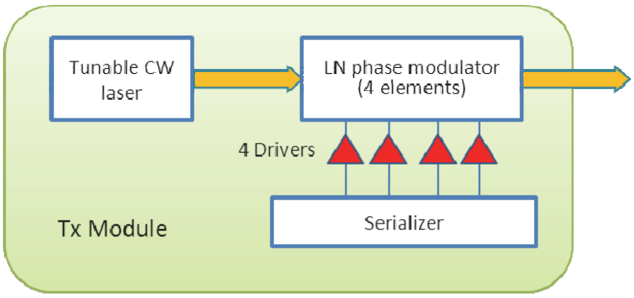

Figure 1 Block Diagram of DP-QPSK Transmitter Module

As shown by this block diagram, the O/E conversion for the DP-QPSK communications method uses a Lithium-Niobate (LN) modulator requiring four drivers to drive the four elements in one modulator.

Anritsu has applied its experience in high-frequency assembly technologies for high-frequency modules used in measuring instruments, as well as its mass-production technology in fabricating communications semiconductors for EDFA pump laser diodes to develop the AH34161A driver module incorporating four LN modulator elements in one module and targeted at digital coherence communications transceivers. Figure 2 shows the external appearance of the driver module.

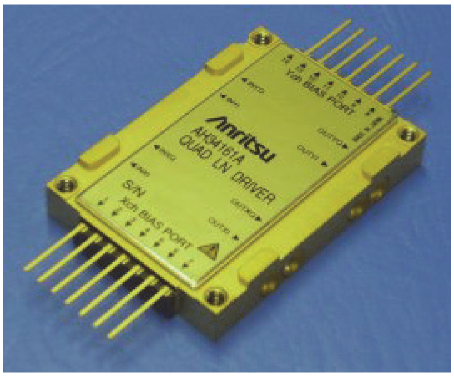

Figure 2 External View of AH34161A LN Driver

2 Development Concept and Themes

The LN modulator agreed by OIF has a Vπ specification is 3.5 V at 32 Gbaud and since the DP-QPSK driver requires a voltage of 2 × Vπ, the output amplitude of the driver for such modulators must be at least 7 Vp-p at 32 Gbaud. In addition, since the modulator Vπ value is individually different, the driver output amplitude must also be tunable within a fixed range.

This work aimed to develop and easy-to-use driver module for the LN modulator for incorporating in communications appliances and offering the basic functions and performance to drive an LN modulator and featuring the following items:

- Small Part Footprint
- Easy Mounting and Adjustment
- Low Cost
- High Quality

2.1 Small Part Footprint

Figure 3 shows the block diagram of the developed AH34161A with four input driver circuits. The size of the DP-QPSK transceiver agreed by OIF is 177.8 mm × 127 mm (7 × 5 inches). Since other parts for the Tx side starting with the LN modulator itself plus parts for the Rx side must all be included within this package size, the driver incorporated in the transceiver must also have the smallest possible area. As mentioned above, four drivers are incorporated in the transceiver but this development incorporated four driver circuits in one package to reduce the mounting area further when using multiple packages.

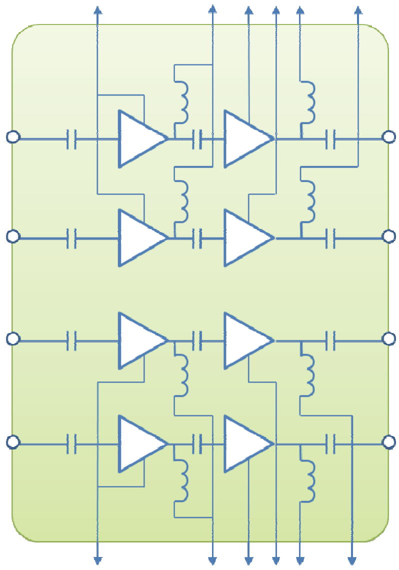

Figure 3 Block Diagram of AH34161A LN Driver

Moreover, to minimize the total area in the transceiver, the DC blocking capacitor and Bias-T were also built into the package. As a result, the smaller DC blocking capacitor and Bias-T parts upstream and downstream of the driver enabled denser package mounting on the PC board and smaller overall size.

2.2 Easy Mounting and Adjustment

The above-described DC blocking capacitor at the driver input section and the Bias-T at the output section not only require some mounting area on the PC board but are also easily affected by the board high-frequency characteristics. Consequently, mounting these parts on a PC board requires careful implementation so as not to degrade the high-frequency characteristics. One aim of this development was to mount parts affected by high-frequeny characteristics in the package so users can implement easy mounting without concern about degraded high-frequency characteristics.

In addition, since the OIF-agreed LN modulator uses four GPPO conversion connectors at the RF input ports, the driver output ports also use these GPPO conversion connector for simple connection with the modulator.

Finally, because the DP-QPSK modulation method performance is affected by differences in the 4-channel delay times, the electrical lengths of the four signal paths must be as similar as possible. To create identical length connectons between the driver and modulator, the pitch of the GPPO conversion conectors at the driver output side is at the same pitch as the LN modulator input connectors. Figure 4 shows the dimensions of the driver output section.

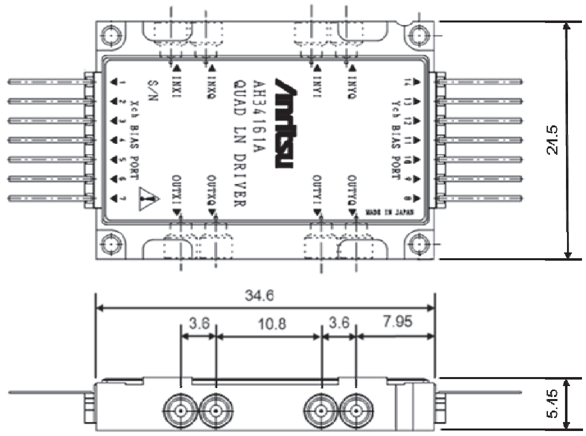

Figure 4 Dimensions of AH34161A LN Driver

2.3 Low Cost and High Quality

Considering the recent price competition for communications equipment, keeping the parts cost as low as possible is important. On the other hand, sufficient reliability must be assured to support continuing operation irrespective of the appliances in the systems communications path.

Generally, since costs tend to rise in direct relationship to the parts count, whereas the reliability drops, this development aimed to minimize the parts count with the simplest possible structure needed to achieve the target performance.

3 Resolving Problems

3.1 Decreased Crosstalk

Inclusion of multiple identical circuits in a small package handling high frequencies can cause problems with generation of crosstalk. In particular, crosstalk is easily generated in transmission circuits of the same lengths, which is especially true of circuits fabricated with a narrow pitch to fit multiple circuits in a package as well as when each circuit includes group delay. In actual usage, this crosstalk can have a negative impact on frequency characteristics because each of the four circuits is carrying a completely different signal. Consequently, it is necessary to take countermeasures to crosstalk when fabricating small-footprint packages.

Generally, in most cases in-package transmission circuits use micro strip line (MSL) technology. This MSL is easy to form with a relatively simple structure but since the transmission mode is close to the TEM mode, unwanted spurious emissions are easily generated due to mismatching of upstream and downstream connection parts.

Emissions from transmission circuits are one of the major causes of crosstalk. A common technology used to attenuate this crosstalk is to attach radiowave-absorbent materials near the MSL, but the adhesive materials for affixing the radiowave-absorbent materials may sometimes produce gases within the sealed package, depending on the adhesive so this technology is not necessarily favored from the long-term reliability viewpoint.

To solve the above problem, this development used grounded coplanar waveguide (G-CPW). The transmission mode of G-CPW is close to the TEM mode like MSL circuits, but introduction of grounding between transmission circuits has a shielding effect that should reduce crosstalk.

Figure 5 shows the crosstalk measurement results for the developed AH34161A using G-CPW technology.

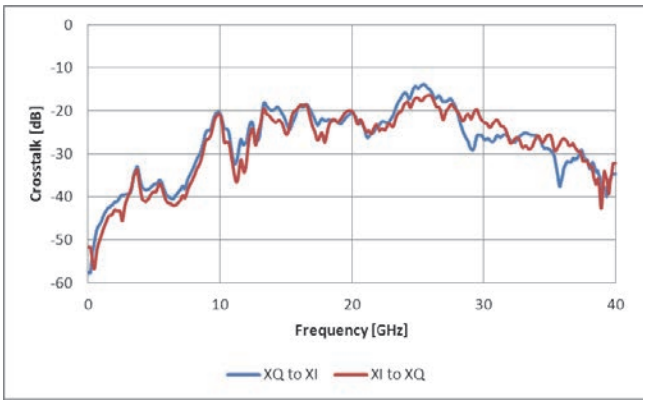

Figure 5 AH34161A Crosstalk Characteristics

Even without affixing radio-absorbent materials around the transmission circuits, it was possible to achieve crosstalk of less than –20 dB at frequencies of 20 GHz or more.

3.2 Increased Pulse Response

As a secondary effect, it was possible to confirm the superiority of the G-CPW group delay characteristics by comparing MSL and G-CPW using electromagnetic field simulation. Figure 6 shows a simulation model for the MSL and G-CPW electromagnetic field analysis and Figure 7 shows the simulation results. The trace lengths in this simulation model were 10 mm.

From the graph in Figure 7, clearly the G-CPW group delay characteristics show a smaller gradient with frequency than the MSL group delay characteristics. These group delay characteristics in the pulse transmission path of the LN driver cannot be ignored. When transmitting pulses including high-frequency components, differences in the transmission speeds between the fundamemental and the harmonic waves cause loss of the pulse wave fidelity and, as shown in Figure 7, the waveform disturbance overshoots more as the gradient increases.

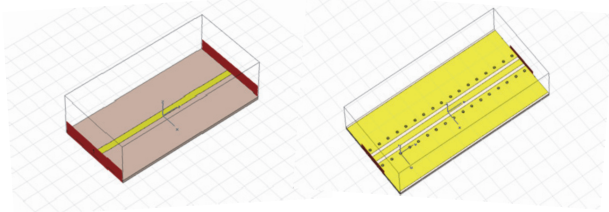

Figure 6 MSL and G-CPW Simulation Model

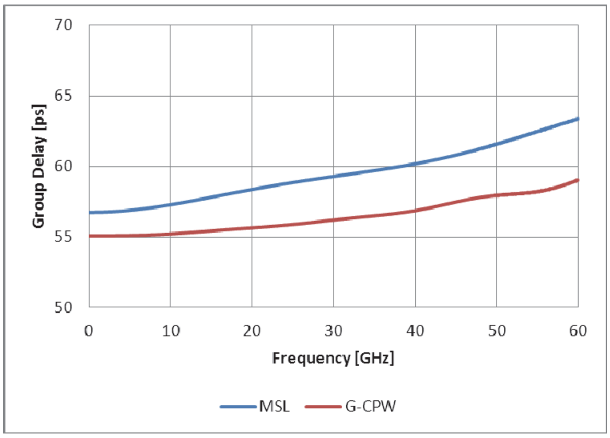

Figure 7 MSL and G-CPW Group Delay Simulation

Figure 8 shows the pulse response characteristics when transmitting a 10 Gbit/s EYE pattern over a circuit with the characteristics shown in Figure 7. The waveform carried over MSL has a much larger overshoot than the waveform carried over G-CPW.

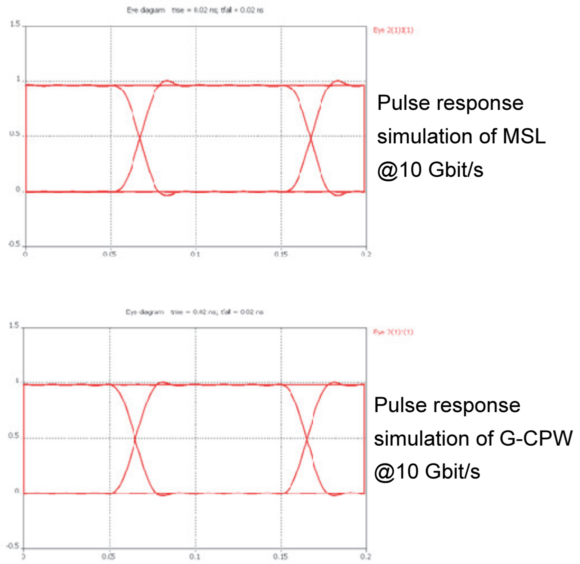

Figure 8 MSL and G-CPW Pulse Response Simulation

Based on these simulation results, we can say that G-CPW is best not only as a countermeasure to crosstalk but also for pulse response characteristics.

Figure 9 shows the output waveform of the AH34161A using the above-described structure.

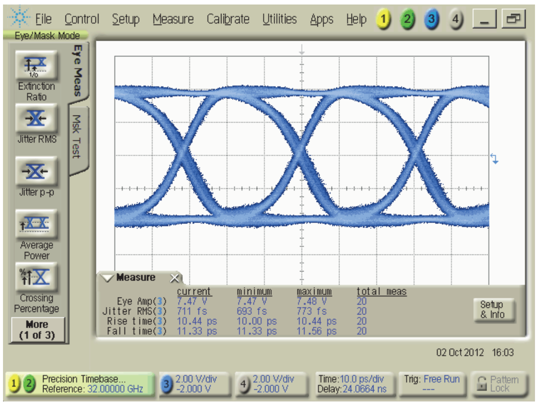

Figure 9 AH34161A Output Waveform (32 Gbit/s)

<<Measurement Conditions and Results>>

- Bit rate: 32 Gbit/s
- Input Amplitude: 500 mVp-p
- Output Amplitude: 7.5 Vp-p
- Jitter: 700 fs rms

Due to this simple structure, the AH34161A outputs a stable, high-grade waveform.

3.3 Reduced Outgassing

The adhesive materials used in packaging release gases that are trapped in the sealed package and can affect reliability. However, this package achieves the required characteristics because it has been developed with fewer parts to help cut costs, and uses G-CPW without radiowave absorbers near the traces. Additionally, the Bias-T is included within the package for better simplicity, eliminating the adhesives used to secure the conically wound choke coils commonly used for the Bias-T. Instead, this development formed a unique choke coil from gold wire without the need for conical coils.

Table 1 lists the internal gas analysis results for the AH34161A using the above-described outgassing countermeasures. The results show the absence of any halogen gases with adverse effects on product quality as well as well-controlled moisture levels.

Table 1 AH34161A Internal Gas Analysis

Method: MIL-STD-833 method 1018, Units: vol%

Water	H_2	He	N_2	O_2	CO_2
0.35	0.03	<0.01	99.61	<0.01	0.01

4 Future Developments

The AH314161A is a compact single-package LN modulator driver with four circuits for 100G digital coherence communications applications. Since many transceivers use surface mount technology (SMT) for the upstream serializer stage, to further reduce mounting space in the transceiver, we are examining methods for achieving SMT-to-coaxial conversion in the driver by using SMT leads for the driver inputs and GPPO conversion connectors for the outputs.

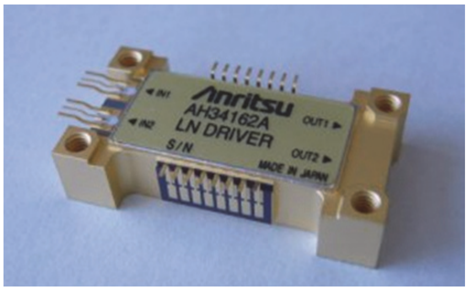

Figure 10 Investigated Compact Driver

5 Conclusions

We have successfully developed a LN modulator driver for 100G digital coherence systems. The required blocking capacitor and Bias-T upstream and downstream of the driver circuit have been incorporated in the small 4-channel package to simplifyhandling and minize the part footprint.

High performance and high reliability have been achieved with a simple structure using G-CPW traces for signal transmission in the package.

References

1) The Mechanical Social Systems Foundation, "Research Report into Coherent Optical Communications System (summary)", Systems Technical Development Report, 21-R-7, pp. 17, March 2010 (In Japanese)

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