A 48 Gbps Communication Link Over D-Band Polymer Microwave Fiber

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***Abstract*—A D-band transmitter and receiver are packaged from bare die MMICs that were designed and fabricated in a 130 nm SiGe BiCMOS technology. The packaged modules are interfaced to a WR-6.5 waveguide at the RF and coaxial connectors at the LO and IF ports. Both transmitter and receiver cover an RF frequency range of around 120-150 GHz while the required LO frequency is 1/4 of the RF frequency. A D-band communication link built with the packaged transmitter and receiver demonstrated up to 48 Gbps 16-QAM over 1-meter polymer microwave fiber (PMF), 40 Gbps 16-QAM over 2 meters PMF, and 16 Gbps QPSK over 4 meters PMF.**

***Index Terms*—D-band, transmitter, receiver, PMF, data rate, communication, 16-QAM, QPSK**

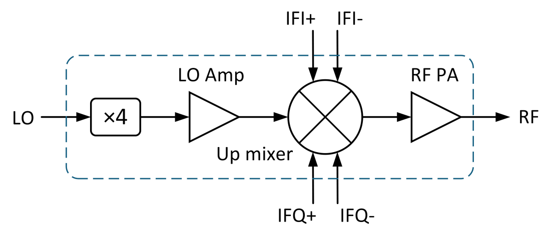
I. Introduction

The ever-growing demand for trustworthy high data rate communication links, driven by applications such as 6G networks, ultra-high-definition video streaming, and industrial automation, has led to a significant interest in millimeter-wave frequency bands. The D-band (110-170 GHz) has emerged as a promising candidate due to its abundant bandwidth. The development of reliable D-band transmitter and receiver is essential for establishing trustworthy communication links capable of supporting high data rate. Benefit from the continuously improved semiconductor technologies, gigabit-per-second data rate has been successfully demonstrated among different technologies [1] [2] [3] [4]. In recent years, PMF has been demonstrated as a promising and cost-efficient solution for short-range data transmission links, particularly for applications requiring high data rates. It offers advantages such as enhanced flexibility and reduced energy consumption compared to the traditional waveguide and optical fibers [5].

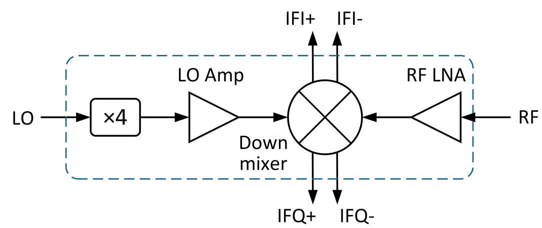
This paper presents a pair of D-band transmitter and receiver front-end modules packaged from the bare die MMICs with a microstrip-to-waveguide E-plane probe transition for the D-band RF signal and wire-bonded on-wafer pads to microstrip line on carrier board for LO, IF and DC. The packaged transmitter and receiver were characterized independently in the frequency domain and a communication link over different lengths of the PMF was demonstrated.

II. Design and Assembly

The MMICs were designed and fabricated in Infineon's 130 nm SiGe BiCMOS process (B11HFC), which featured with f_t/f_{max} of 250/370 GHz. Figure 1 shows the schematic diagram of the designed transmitter and receiver, which integrate a frequency quadrupler, a local oscillator (LO) buffer amplifier, an IQ-balanced Gilbert mixer and a D-band RF amplifier. Figure 2 shows the chip photo and more details can be found in [6].

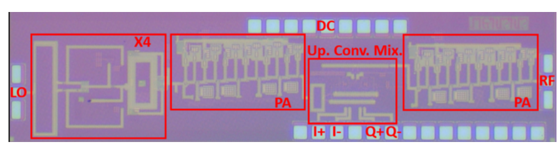


(a) Transmitter

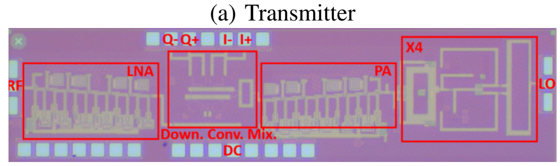


(b) Receiver

Fig. 1: Schematic diagram.



(a) Transmitter



(b) Receiver

Fig. 2: Chip photo.

At the RF port, the MMIC is coupled to the waveguide through a separate transition manufactured on a 50 um thick Alumina. The waveguide is split in the middle of the broad wall and the transition is coupled to the waveguide through an E-plane radial stub as shown in Figure 3. To evaluate the

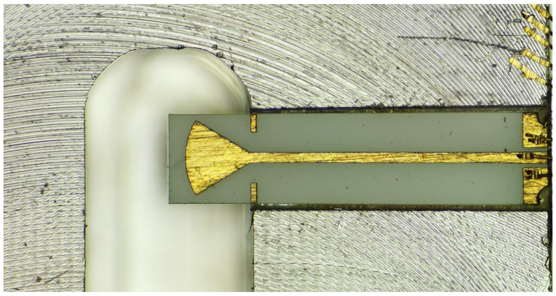


Fig. 3: The waveguide to microstrip transition on 50 um Alumina substrate.

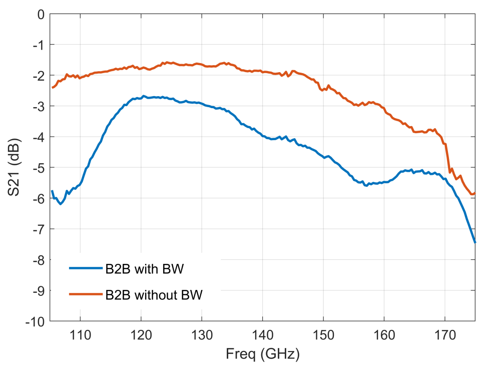


Fig. 4: Masuremed S21 of transitions back-to-back (B2B) with and without bond wire (BW).

insertion loss and additional effect from bond wire, a transition back-to-back (B2B) connected with bond wires (BW) and a transition B2B printed on a single Alumina substrate where no bond wire needed were measured. Figure 4 shows the measured S21. At the frequency of 140 GHz, 1 dB insertion loss is from the transition and an additional 1 dB loss is due to the bond wire interface.

Figure 5 shows a photo of the split-block. All the signal and DC pads are connected out through bond wires. The MMIC is placed as close as possible to the transition considering the parasitics of a bond wire are dominated by its electrical length. Four IF paths on the carrier board are length-matched. DC biases are firstly wire-bonded to surface-mounted chip capacitors for decoupling and then further bonded to feed through capacitors, which enable access to the designed DC supply PCB at the back side of the split block. Figure 6 shows a photo of the packaged transmitter and receiver modules. Both Tx and Rx modules are featured with a WR-6.5 waveguide interface at the RF port, a 2.4 mm coaxial connector at the LO port and four 3.5 mm coaxial connectors at the IQ-balanced IF ports. The size of both modules is 50mm×35mm×20mm excluding the connectors.

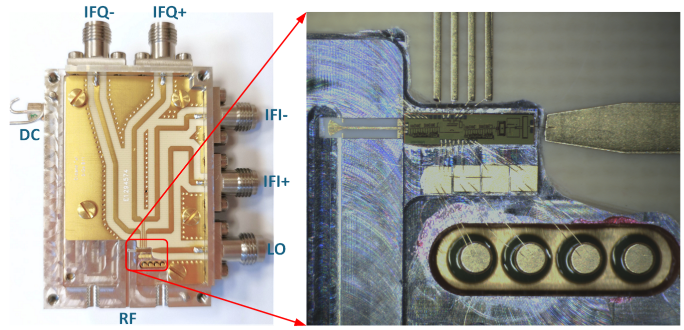


Fig. 5: Photo of the split-block.

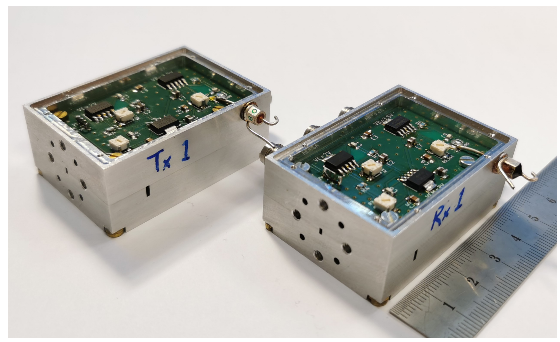


Fig. 6: Photo of the packaged transmitter and receiver modules.

III. Measurement

A. Frequency domain measurement

The transmitter and receiver are characterized separately in frequency domain by a Keysight PNA-X N5247A with the mixer option enabled. The measurement setup is shown in Figure 7. The D-band RF signal is transmitted and received through a VDI WR-6.5 frequency extender. Four quadrature-phased IF ports are combined into a single-ended port through two external baluns and a 90° hybrid. Figure 8 shows the measured conversion gain of the transmitter at an IF frequency of 2 GHz, and Figure 9 shows the measured conversion gain at an LO frequency of 132 GHz. RF bandwidth covers 120 GHz to 150 GHz with a sideband suppression of 10 dB. At an LO frequency of 132 GHz and an IF frequency of 2 GHz, the RF output power is measured versus the IF input power. As can be seen in Figure 10, the transmitter delivers a saturated output power of around 0 dBm.

For the receiver module, the measured conversion gain is shown in Figure 11 and Figure 12. At the IF frequency of 2 GHz, a conversion gain of 10-13 dB is obtained over 123-150 GHz, while more than 10 dB sideband suppression is observed.

B. Link measurement

To verify the performance in a communication link, the modules were connected using PMFs of different lengths. The measurement setup is shown in Figure 13. The link was tested using direct modulated I/Q data input provided

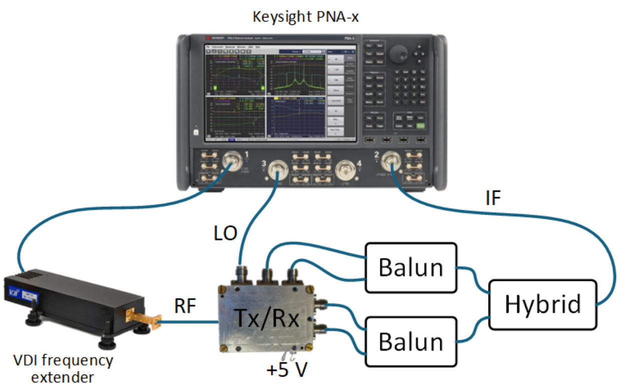


Fig. 7: Frequency domain measurement setup.

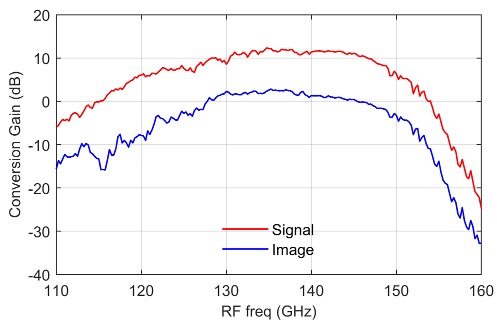


Fig. 8: Measured conversion gain of the transmitter vs RF frequency at fIF=2 GHz.

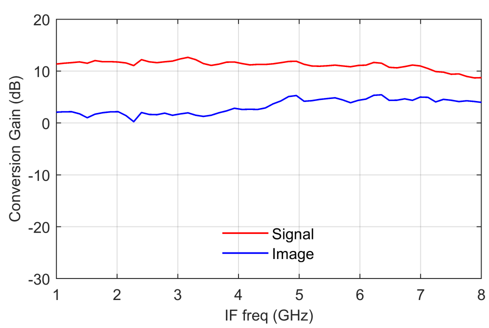


Fig. 9: Measured conversion gain of the transmitter vs IF frequency at fLO=132 GHz.

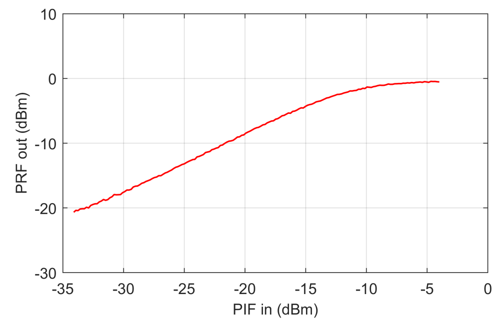


Fig. 10: Measured RF output power of the transmitter vs input IF power at fLO=132 GHz and fIF=2 GHz.

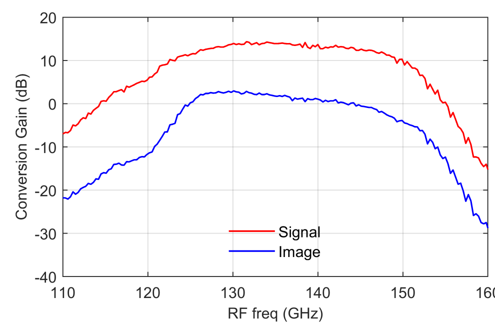


Fig. 11: Measured conversion gain of the receiver vs RF frequency at fIF=2 GHz.

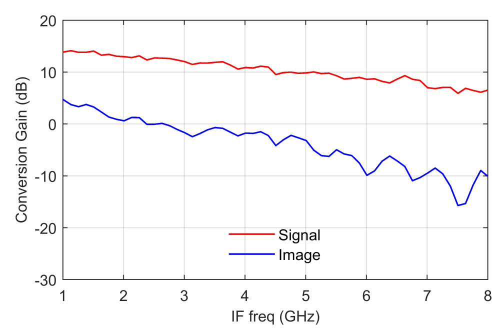


Fig. 12: Measured conversion gain of the receiver vs IF frequency at fLO=135 GHz.

by a Keysight M8195A arbitrary waveform generator (AWG). A pseudorandom binary sequence (PRBS-10) was generated using root-raised cosine pulse shaping with a roll-off of 0.85. The LO signals for both transmitter and receiver were split from a Keysight E8257D PSD signal generator. At the receiver side, a Keysight UXR1104A oscilloscope was used to capture the output signal. The PMF provided by Huber+Suhner has a rectangular polymer core and circular foam cladding. At the LO frequency of 134 GHz and transmission of 16-QAM modulation, Figure 14 to Figure 16 show the measured I/Q constellation through the link with 1m, 2m and 4m PMF, which correspond to data rates of 48 Gbps, 40 Gbps and 12 Gbps, respectively. Transmission of QPSK modulation was also tested over 4 meter PMF. The constellation is shown in Figure 17 and corresponds to 16 Gbps.

IV. Discussion and Conclusion

In this paper, a pair of fully packaged D-band transmitter and receiver modules are presented. Both transmitter and receiver are interfaced with a WR-6.5 rectangular waveguide for the RF and coaxial connectors for the LO and IF. The required LO is 1/4 of the RF frequency, and the four IF ports

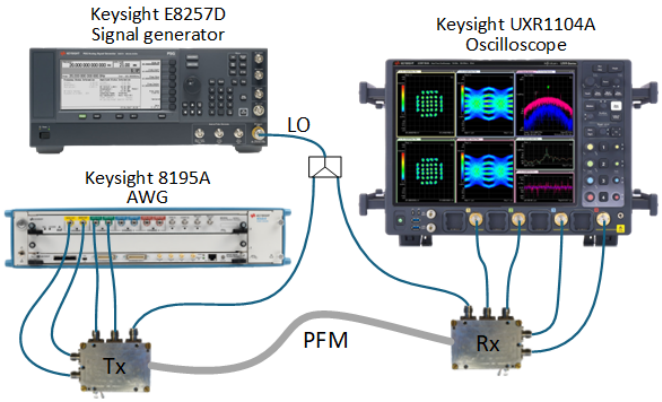


Fig. 13: The measurement setup used during the PMF link measurements.

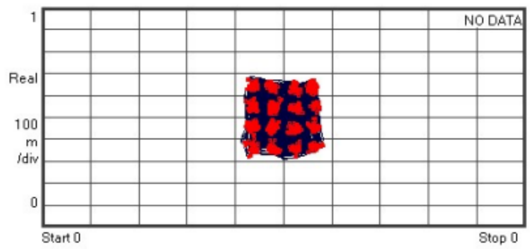


Fig. 14: Received I/Q constellation of a 12 GBd QAM-16 transmission over a 1-meter PMF. The LO is 134 GHz and EVM=10.0%, SNR=17.4 dB.

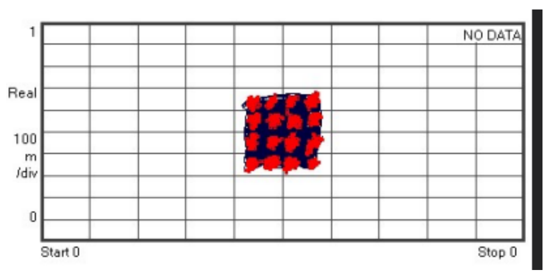


Fig. 15: Received I/Q constellation of a 10 GBd QAM-16 transmission over a 2-meter PMF. The LO is 134 GHz and EVM=10.5%, SNR=17.0 dB.

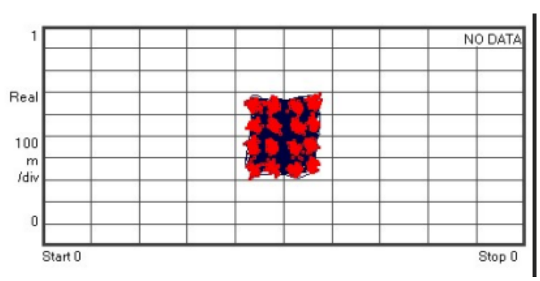


Fig. 16: Received I/Q constellation of a 3 GBd QAM-16 transmission over a 4-meter PMF. The LO is 134 GHz and EVM=11.7%, SNR=16.1 dB.

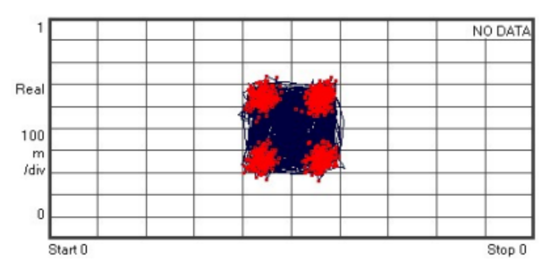


Fig. 17: Received I/Q constellation of an 8 GBd QPSK transmission over a 4-meter PMF. The LO is 134 GHz and EVM=23.0%, SNR=12.8 dB.

are IQ differential down to baseband. Packaged modules cover an RF frequency of around 120-150 GHz with a sideband suppression of 10 dB. To verify the capability of high data rate communication, a communication link is set up with the packaged transmitter and receiver over different lengths of PMFs. With 16-QAM modulation, the link demonstrates up to 48 Gbps data transmission over 1 meter PMF, 40 Gbps data transmission over 2 meter PMF, and 12 Gbps data rate over 4 meter PMF.

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