A 170-280 GHz InP HEMT Low Noise Amplifier

Alexis Zamora¹, Kevin M. K. H. Leong¹, Theodore Reck², Goutam Chattopadhyay², and William Deal¹
¹Northrop Grumman Corporation, Redondo Beach, CA 90278
²Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109 USA

Abstract—We present on-wafer and packaged measurements of a broad-band 170-280 GHz low noise amplifier based on high frequency InP HEMT technology. Discussed is the design and packaging of the CPW-based MMIC. Chip-to-waveguide transitions are monolithically integrated onto the MMIC to minimize losses at the transition within the split-block-waveguide housing. Packaged gain and noise figure are reported to be >10 dB, and < 7 dB, respectively, across the entire band of operation. Noise figure is < 6 dB on the 190-240 GHz band, with minimum dB, and < 7 dB, respectively, across the entire band of operation. Packaging of the CPW-based MMIC. Chip-to-waveguide transitions are monolithically integrated onto the MMIC to minimize losses at the transition within the split-block-waveguide housing. Packaged gain and noise figure are reported to be >10 dB, and < 7 dB, respectively, across the entire band of operation. Noise figure is < 6 dB on the 190-240 GHz band, with minimum dB, and < 7 dB, respectively, across the entire band of operation.

I. INTRODUCTION

With advancements in solid-state HEMT technology [1][2] it has been shown possible to develop low noise amplifiers with excellent noise and gain characteristics at millimeter and sub-millimeter wave frequencies. Though broad-band LNAs in the sub-300 GHz range could potentially include applications in imaging and communications [3], the primary motivation for designing the presented 170-280 GHz LNA stems from improving the RF front ends of existing receivers used for radiometry and atmospheric sensing. The Earth Observing System Microwave Limb Sounder (EOS MLS) [4], for instance, employs several radiometers to passively detect thermal emissions emanating from the upper troposphere, stratosphere, and mesosphere. Spectral lines of interest lie at 118, 190, 240, and 640 GHz and 2.5 THz. The frequency band of the presented amplifier simultaneously covers the 190 and 240 GHz bands which are used, primarily, to resolve the H2O, HNO3, O3 and CO spectral lines. By utilizing a single LNA capable of serving as the receiver front end for multiple EOS bands of interest, system complexity could be reduced saving on system cost, weight and power.

Other LNA results near the same frequency range were presented in [2,3]. In [2], A. Tessman et al demonstrate a GaAs mHEMT 243 GHz LNA, reporting a minimum noise figure of 5.6 dB at 243 GHz. [3] demonstrates the lowest noise figure measured to date at room temperature for LNAs in the WR4 band, reporting a noise figure of 4.8 dB and 5.2 dB at 220 GHz and 240 GHz respectively. This reference makes use of the same InP HEMT technology utilized in this paper. The work presented in this paper aims to achieve comparable noise figure over a wider bandwidth in order to provide multi-spectral line coverage. This paper elaborates on the broad-band InP HEMT LNA design and packaging, and provides room temperature measured gain and noise figure.

II. DESIGN AND PACKAGING

The microphotograph in Fig. 1 shows the fabricated 2-stage, single-ended LNA. A 2-stage topology was selected as noise performance will be measured at cryogenic temperatures in the future. Fewer stages are employed to minimize the chances of oscillation due to the enhanced gain that will result from being thermally cooled. Two 2-Finger 30 um devices were selected biased to a current density of 300 mA/mm with drain voltages biased to 1 V. At the frequencies of interest the 15 um finger lengths are sufficiently short to minimize distributed effects along the gate fingers. To properly model the HEMT’s small signal performance, transistor parasitic extractions are performed from de-embedded S-parameter data measured up to 110 GHz, relying on proper extrapolation to model the transistor at up to 280 GHz. Noise modeling follows the technique outlined in [7].

During the design phase noise-figure was carefully traded with bandwidth, targeting gain exceeding 10 dB across the 170-280 GHz band while minimizing noise-figure. Matching network design optimizations were performed in Agilent’s Advanced Design System (ADS), keeping stability considerations in mind. Resistors in the gate and drain bias paths are used to stabilize the amplifier. Coplanar waveguide (CPW) transmission lines are used rather than microstrip, primarily to reduce the inductance related to grounding the transistor source and bypass capacitors. RIE formed substrate vias are used to reduce substrate modes in the CPW integrated circuits.

The packaging of the amplifier was carried out using an on-chip waveguide transition. As described in [6], this type of transition was used to eliminate the inductance due to RF bondwires which tends to limit higher frequency bandwidth. The chip and MMIC cavity dimensions have been carefully analyzed to eliminate cavity modes within desired bands of operation and suppress higher order waveguide modes. Based on full wave analysis the chip size was set to 1150x450 um. Thickness of the MMIC is 25 um. To characterize the MMIC-to-waveguide dipole transitions, two dipoles were placed back-to-back separated by a 50 Ω, 716 um long, CPW transmission line (Fig. 1a) and measured to yield the results.
shown in Fig. 2b. We obtain the insertion loss of a single dipole transition by removing the line loss and waveguide loss from the measurement, and halving the result, thus reporting the insertion loss of a single dipole to be 0.4 dB at 220 GHz, and 0.8 dB at 270 GHz.

III. RESULTS

Fig. 3 shows the on-wafer measurement de-embedded up to the amplifier’s 50 Ohm input/output reference planes taken on probe-able versions of the MMIC depicted in Fig. 1. As a single test-set is incapable of covering the entire 170-280 GHz bandwidth of the amplifier, the MMIC is characterized on both WR3 and WR5 test stations. The plot in Fig. 4 shows measured room temperature noise figure and gain for the packaged LNA over the 180-270 GHz. Gain exceeds 10 dB over the entire band of operation, and noise figure is below 7 dB. Measurements were performed at JPL, and details regarding measurement setup may be found here [8].

IV. SUMMARY

We report measured and packaged data on a 170-280 GHz LNA. Packaged gain was measured to be > 10 dB with packaged noise figure <7 dB across the entire band of operation. Noise figure was measured to be <6 dB over the narrower 190-240 GHz band, with lowest noise figure being 5.3 dB at 200 GHz. The two-stage LNA was designed with future cryogenic testing in mind, and constrained to a 2-stage topology for stability considerations when cooled.

REFERENCES


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