Results from ALMA Band 2 cryogenic LNA pre-production run

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***Abstract*—We present the results of a pre-production run of cryogenic low noise amplifiers developed for the upcoming ALMA Band 2 receiver project. We will characterise 14 units against a full set of technical specifications set by ALMA. The ongoing measurements indicate a state-of-the-art noise performance achieved over an extended W-band being fully compliant to specifications. For the first six units we measure Tnoise < 22 K (67 GHz – 90 GHz), with a minimum of 15 K at 76 GHz, and < 30 K (90 GHz – 116 GHz) at 15 K operation temperature.**

***Keywords*—Cryogenic, high-electron-mobility transistors (HEMTs), low-noise amplifiers (LNAs), metamorphic HEMTs (mHEMTs), millimeter wave (mmW), monolithic microwave integrated circuits (MMICs), noise, radio astronomy, W-band**

I. Introduction

The application of radio astronomy sets challenging requirements for noise performance of receiver components and for higher frequencies mandates cryogenic operation. In particular this hold true for the first components of the receiver signal chain, and therewith for a first-stage low noise amplifier. For the Atacama Large Millimeter/submillimeter Array (ALMA), the European Southern Observatory (ESO) has decided to move forward with Band 2 that will cover the entire 67 GHz – 116 GHz atmospheric window. A single signal chain in a receiver cartridge developed by a consortium of international partners is to be used. Similar to the pre-production approach on cartridge level, ESO had awarded the MPIfR/IAF consortium as a potential component supplier a small pre-production batch of LNA units. Performance is evaluated against an extensive specification sheet and, additionally, series production readiness is verified.

A cryogenic LNA covering extended W-band operation using standard WR10 waveguides has been developed. At the heart an ultra-low noise performance MMIC using 50-nm gate length metamorphic HEMT (mHEMT) technology developed at Fraunhofer IAF is used. Here the active device layers are grown on GaAs substrates by means of a metamorphic buffer. This technology has matured over the recent years to provide state-of-the-art cryogenic noise performance, concluding in a benchmark W-band LNA design that is basis of our ALMA Band 2 LNA contribution [1]. The LNA package is a MPIfR WR10 split-block design with quartz substrate waveguide probes at input and output.

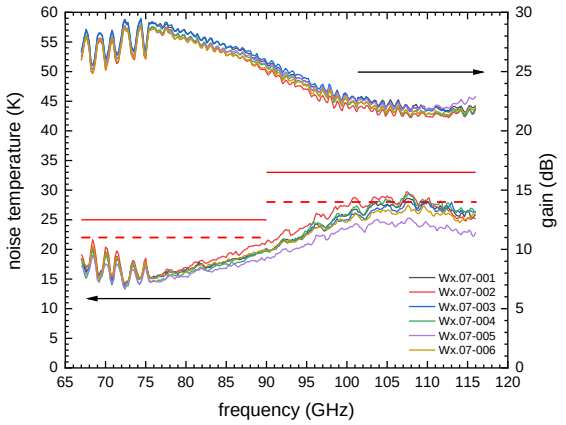

Fig. 1. Noise temperature and gain measured at 15 K for the first six pre-production units. The solid and dashed lines indicate the 100% and 80% requirement on maximum noise temperature, respectively. The standing wave features at low band edge are assumed to be an artefact from the measurement setup.

II. Results

The pre-production units are evaluated against requirements set by technical (e.g. cryogenic and RT S-parameters, noise, gain, gain/phase stability), environmental, mechanical and RAMS specifications. We will present these results for the full 14-unit pre-production run and detail on LNA and package design, our methodology to ensure a high enough production yield, and functionality of the cryogenic test setups involved. As an example, in Fig. 1 noise temperature and gain performance for the first six pre-production units measured at 15 K operation temperature using the cryogenic test-setup at ESO, Munich [1] is plotted. The results closely match those of early prototype units using MMICs from a different wafer. This emphasises uniform performance of MMIC production and packaging process and confirms reproducibility of production.

References

[1] F. Thome, et al., "A 67–116-GHz Cryogenic Low-Noise Amplifier in a 50-nm InGaAs Metamorphic HEMT Technology", *IEEE Microwave and Wireless Components Letters*, vol. 32, no. 5, pp. 430-433, May 2022, doi: 10.1109/LMWC.2021.3134462.

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