# Demonstrator of Cryogenic Multibeam Receiver with MMIC LNAs for 75-116 GHz

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*Abstract*— **We describe the design of a nine-element multibeam receiver demonstrator for the 75-116 GHz (W-band). The design consists of a cryogenic 3×3 dual-polarization focal plane array (FPA) based on individual reimaging optics for the corrugated horns, and employs an innovative "active OMT" with two cascaded mHEMT MMIC LNAs packaged in each of the polarization channels of the OMT waveguide structure. The RF signals from the cryogenic array active OMT outputs are linked, through WR10 waveguides, to three-pixel sideband separating mixer (2SB) modules located at room temperature, attached to the baseplate of the cryostat. One of such modules converts six RF signals from one line of the array (1×3×2 pols) down to the 4-12 GHz IF band, thus providing a total of 12 IF outputs (USB and LSB). The optics of the FPA demonstrator was designed and optimized for high-efficiency broadband operation on the IRAM 30-m telescope at Pico Veleta, Spain.**

***Keywords—Receiver, optics, OMT, MMIC, LNA, mixer, sideband separation, cryogenics.***

## I. Introduction

Under the auspices of the AETHRA (Advanced European Technologies for Heterodyne Receiver for Astronomy) WP5.1 project, funded by the European Union's Horizon 2020 research and innovation programme, we developed a multipixel W-band FPA demonstrator [1] composed of cryogenic modules and room temperature down-conversion modules based on metamorphic HEMT semiconductor MMIC LNAs [2] and MMIC mixers [3] for the 75-116 GHz band. Here, we present the design of the receiver.

## II. Receiver Design

Fig. 1 shows a 3D model of the FPA receiver cryostat with room-temperature reimaging optics designed for the IRAM 30-m radio telescope. The details of the inner part of the receiver cryostat, including the full 3×3 cryogenic array of pixels, are shown in Fig. 2. The optical design is based on nine corrugated feed-horns and individual fully reflective frequency-independent optics (Fig. 3) that couple the signals from the telescope sub-reflector. The HDPE vacuum window consists of 3×3 antireflection-coated sub-windows. A PTFE Infrared Filter at ~70 K and a Goretex filter at ~15 K reduce the thermal loading on the coldest stage, at ~15 K. The cryostat internal details are shown in Fig. 4.

Two of the key modules of the receivers are the cryogenically cooled active OMT (described in [4], see Fig. 2), based on four W-band MMIC LNAs (two MMICs per polarization channel), and the room temperature three-pixel downconverter module, shown in Fig. 5.

Each of the nine active OMT modules has a small footprint, with a size compatible with the 44 mm spacing between the pixels. An active OMT module is based on a square waveguide input and on two standard WR10 waveguide outputs, in line with the input, each delivering a total gain of ≈45 dB for the two independent linear polarization channels.

The three three-pixel downconverter modules adopt a dual-sideband separating mixers (2SB) downconversion scheme, where each 2SB subassembly delivers two 4-12 GHz IF output signals, the USB (Upper Sideband) and the LSB (Lower Side Band). A tuneable 14.50-17.33 GHz baseband LO is injected into each of the three-pixel downconverter modules. The downconverter is based on fully-integrated InGaAs MMIC sub-harmonic mixers that include LO-multiplier and IF-LNA.

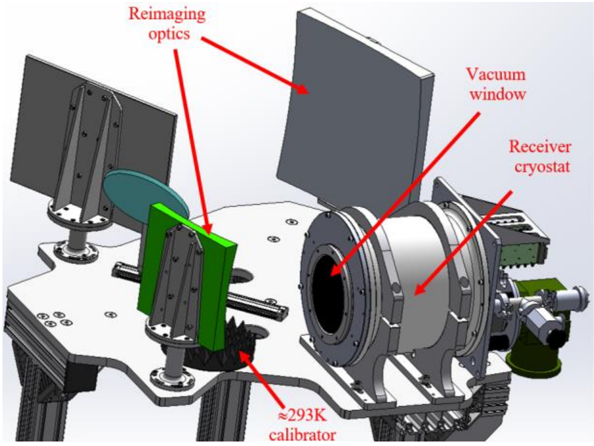


Fig. 1. Design of the receiver array demonstrator on the mechanical frame for the IRAM 30-m telescope.

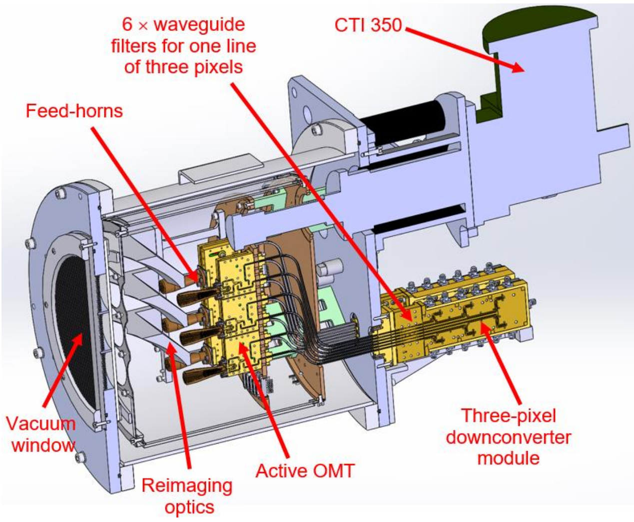


Fig. 2. Cross-cut view of the dual-polarization nine-pixel cryogenic MMIC receiver array with room-temperature sideband separating three-pixel downconverter modules. The reimaging optics and active OMT modules are cryogenically cooled at ~15 K inside the cryostat by a commercial cryocooler (Cryodyne CTI 350).

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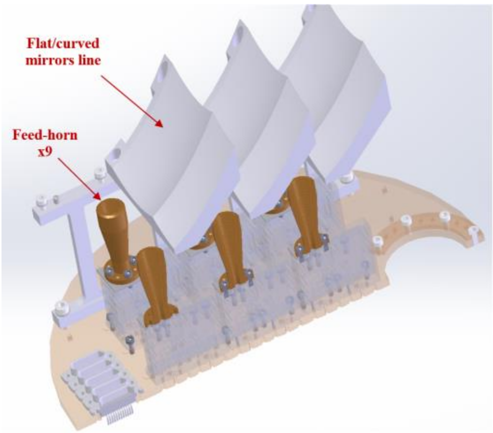


Fig. 3. Cross-cut view of the cryostat 15 K stage with fully reflective cryogenic optics for the nine individual pixels.

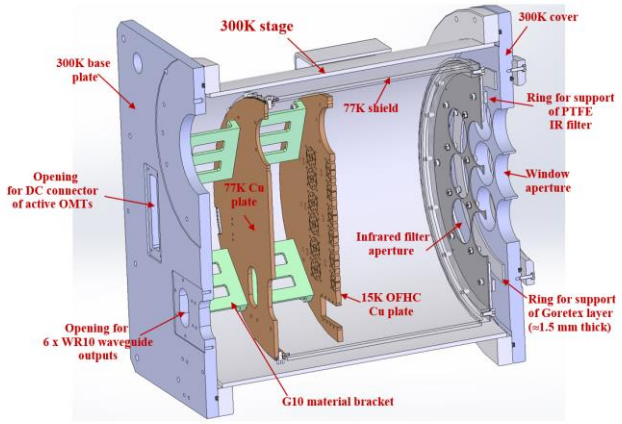


Fig. 4. Cross-cut view of the cryostat showing the 15 K and 77 K cryogenic stages, the location of the IR filters, and the G10 brackets for thermal isolation of the stages.

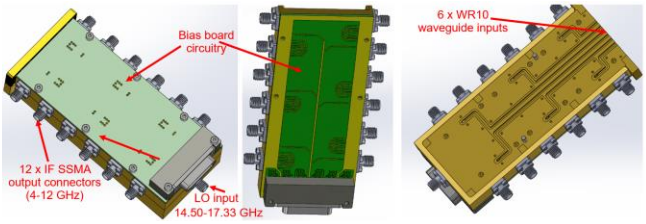


Fig. 5. Three views of the three-pixel dual-polarization dual-sideband separating mixers downconverter module.

The receiver is biased by an M&C (Monitor and Control) unit specifically developed for this project. The M&C unit adopts independent boards for biasing the cryogenic LNAs and the downconverter modules.

The receiver subassemblies were constructed and tested. Then, the array demonstrator was assembled using only one line of three active OMT modules (the one containing the central pixel) and one of the three single-pixel modules. Laboratory tests of the system were successfully carried out at the room and cryogenic temperatures, resulting in low-noise broadband performance close to predicted values across the full 75-116 GHz band. Then, the receiver was installed on the IRAM 30-m telescope, Pico Veleta, Spain, and successfully used to conduct radio astronomy observation tests.

## III. Conclusion

We presented an innovative design of a cryogenic focal plane array receiver suitable for radio astronomy observation in W-band. The array utilizes active OMT incorporating low-noise MMIC LNAs, three-pixel dual-polarization sideband separating modules, and a dedicated M&C and bias module for the LNAs and the downconverters. The receiver was assembled and successfully tested on the IRAM 30-m telescope.

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