# Dual-Band SIS Receiver Design for Atmospheric Physics Research

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*Abstract*—**IRAM is currently studying and developing a complete dual-band (2 mm and 1.3 mm wavelengths) single-polarization SIS (Superconductor-Insulator-Superconductor) receiver for the Max Planck Institute for Solar System Research (MPS) which will be used to carry out atmospheric physics research.**

## I. Introduction

In this paper, we summarize the main characteristics and specifications of a dual-band receiver for the 2 mm (127-179 GHz) and 1.3 mm (200-276 GHz) bands. We show a preliminary 3D CAD concept and highlight the adopted technical solutions.

## II. Receiver Description

The dual-band receiver will be based on state-of-the-art sideband separating (2SB) SIS mixers that have recently been designed for the new NOrthern Extended Millimeter Array (NOEMA) band 2 and band 3 receivers (see [1]). Each mixer provides two ~8 GHz wide Intermediate Frequency (IF) outputs, named Lower Side Band (LSB) and Upper Side Band (USB), thus providing four IF channels in total for the complete receiver.

The goal for this all-in-one receiver is to meet ALMA-type (Atacama Large Millimeter Array) specifications over a broad IF band. The specifications are indicated in Table I.

The 2SB mixers will be mounted in a custom made cryostat, cooled with a 3-stage Sumitomo coldhead (RDK-3ST), identical to the one adopted for the NOEMA cryostat. The thermal budget analysis will be provided during the conference.

The optical signal path will cover a wide frequency range, allowing the use of single vacuum window, IR filter and two refocusing mirrors in common to both bands. A single broadband wire grid splits two linear polarized signals and re-directs them towards two independent single-polarization corrugated feed-horns, one for each band. The cryogenic optical module, comprising the mirrors, the grid and the feed-horns, will be cooled at 4 K together with the 2SB SIS mixers. This design makes the structure simple, relatively compact and lightweight. Views of the receiver design are shown in Fig. 1 and Fig. 2.

The IF cryogenic section comprises low-loss isolators and low noise HEMT (High Electron Mobility Transistor) amplifiers covering 3.8-11.7 GHz; they are also located in thermal contact with the 4 K stage to minimize noise temperature and maximize amplitude stability.

TABLE I
DUAL-BAND RECEIVER SPECIFICATIONS SUMMARY TABLE

| Parameters | 2 mm Band | 1.3 mm Band |
|---|---|---|
| RF port freq range | 127-179 GHz | 200-276 GHz |
| LO port freq range | 138.6-171.3 GHz | 207.8-264.4 GHz |
| IF band | 3.8-11.7 GHz 2SB | 3.8-11.7 GHz 2SB |
| Polarization | Single, linear | Single, linear |
| SSB receiver noise measured at dewar window, including warm optics | <65K 80% of RF <108K full RF band | <83K 80% of RF band <138K full RF band |
| Image band suppression | >10dB, with allowance: | |
| | 10% <10dB | |
| | 1% <7dB | |
| | Globally over all LO settings | |
| IF output power 3.8-11.7 GHz | -20dBm +/- 2dB | |
| IF power variations | 8 dB p-p full band | |
| Output IF channel VSWR | 1.4:1 | |
| Amplitude stability: Allan variance 0.05s…100…300s | 4.0E-7, 3.0E-6, respectively | |
| Cross Polarization | -20dB | |

A four-channel IF module will be located outside the cryostat at room temperature and will comprise amplification stages, signals equalization, total power detectors and variable digital attenuators, to set the outputs at suitable power levels.

Two independent E-band Local Oscillator (LO) Gunn units will be cascaded with frequency multipliers to allow generation of the final oscillator frequency signals at 2 mm and 1.3 mm (we will use a doubler for Band 2 and a tripler for Band 3). The receiver will allow simultaneous observation in both signal bands.

The receiver control electronics will be based on EtherCAT and will be developed in house; it will control the SIS junctions, the cryogenic amplifiers as well as cryogenic temperatures probes for monitoring the temperature of the dewar inner stages.

The receiver will be installed on a dedicated mechanical frame which will also support the warm optics.

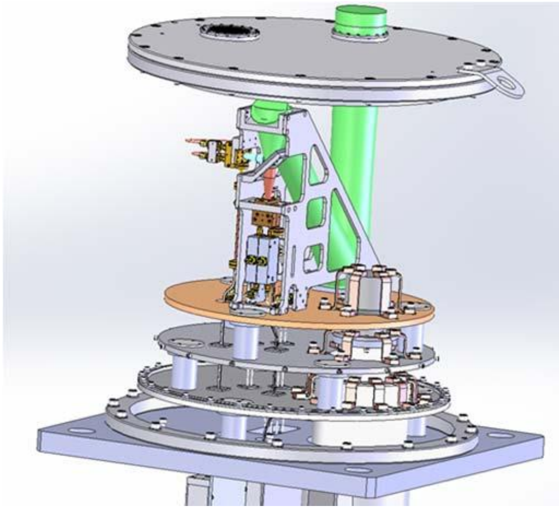

Fig. 1. Inner view of the current dual-band receiver design showing the arrangement of the cryogenic module and the different cryogenic stages.

Fig. 2. View of the dual-band receiver showing the signal and calibration windows, and placement of the cryogenic cold-head and control electronics. Warm optics is not shown.

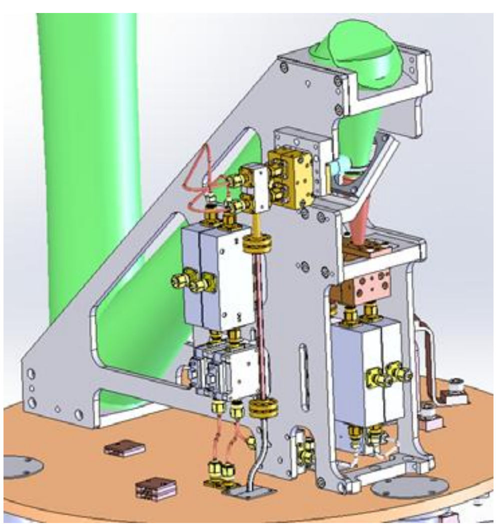

Fig. 3. View of the 4K stage cold optics structure with the two refocusing mirrors,.

A preliminary design study for the vacuum window and Infrared (IR) filter was carried out by using commercial electromagnetic simulation software. Windows and IR filters will be realized in, respectively, HDPE and Teflon, and will have triangular grooves as matching layer on each surface. The predicted results of the window plus filter cascade shown in Fig. 3 indicate that wideband performance can be achieved over a bandwidth that simultaneously covers the 2 mm and 1.3 mm bands (127-276 GHz) with a reflection coefficient below -22 dB. This represents performance degradation of only ~3 dB in return loss with respect to a single band design.

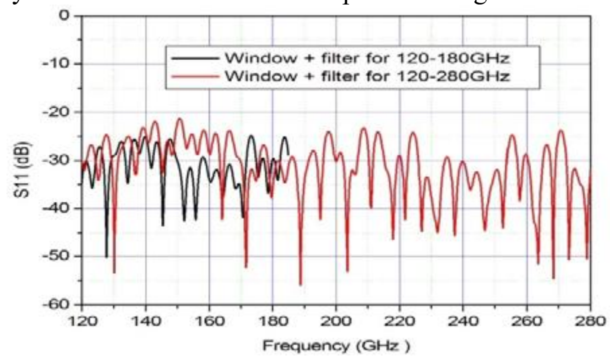


Fig. 4. Comparison between simulated reflection coefficient from a cascade of wideband (for dual-band) and single band window and infrared filter.

## III. Expected Results

Because the main components of the dual-band receiver (SIS mixers, cryogenic IF sections, warm IF amplification stages) will be similar to those developed for the NOEMA receiver, we expect the two instrument to deliver very similar performance.

Therefore, typical NOEMA band 2 and band 3 receiver integrated noise temperature, noise temperature in the IF bandpass, image band suppression, amplitude stability, IF power variations test results will be shown in the conference poster.

## IV. Conclusion

This abstract has described ongoing and preliminary dual-band receiver design concept taking place at IRAM. During the conference, more detailed description and results will be provided.

## References

[1] D. MaierJ. Reverdy, L. Coutanson, D. Billon-Pierron, C. Boucher and A. Barbier,"Fully Integrated sideband-separating Mixers for the NOEMA receivers" *24th Int. Symp. on Space THz Technol.*, Moscow, Russia, 27-30 April, 2014.