Dual Band Receiver Design for Atmospheric Physics Research

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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.

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. 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 2SB mixers will be mounted in a custom made cryostat (w x h = 550 mm x 650 mm), cooled with a 3-stage Sumitomo coldhead (RDK-3ST), for which the thermal budget is shown below.

The sidewall, top and bottom plates of the cryostat will be made of Al 5083 O-H111, for reduced weight, with polished surfaces to reduce emissivity. The 77K and 15 K plates will be made of Al AW 2017 A, respectively nickel plated and chemically polished, with 8 mm thickness. The 4K plate will be made of polished OFHC copper. The 77K and 15K shields will be made of polished Al 1050 H24 with CU-A1 covers. MLI is envisaged.

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 will split two linear polarized signals and re-direct 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 below.

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.

A four-channel IF module will be located outside the cryostat at room temperature and will accommodate band pass filters, amplification stages, signals equalization and attenuators, to set the outputs at suitable power levels with dedicated gain flatness.

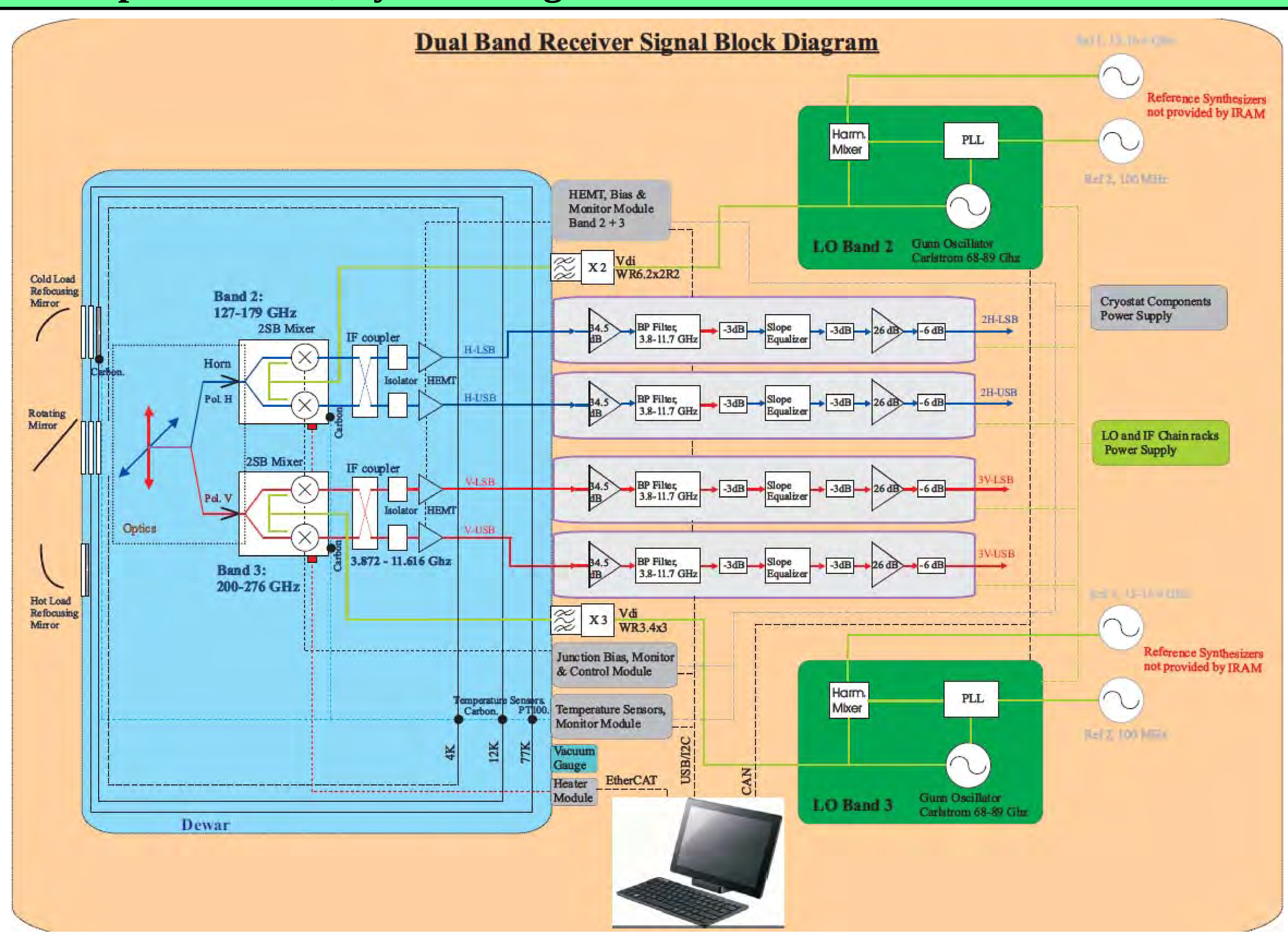
Two independent E-band Local Oscillator (LO) Gunn units will be cascaded with frequency multipliers to allow generation of the final oscillator frequency signals at 2 mm and 1.3 mm (we will use a doubler for Band 2 and a tripler for Band 3). The receiver will allow simultaneous observation in both signal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

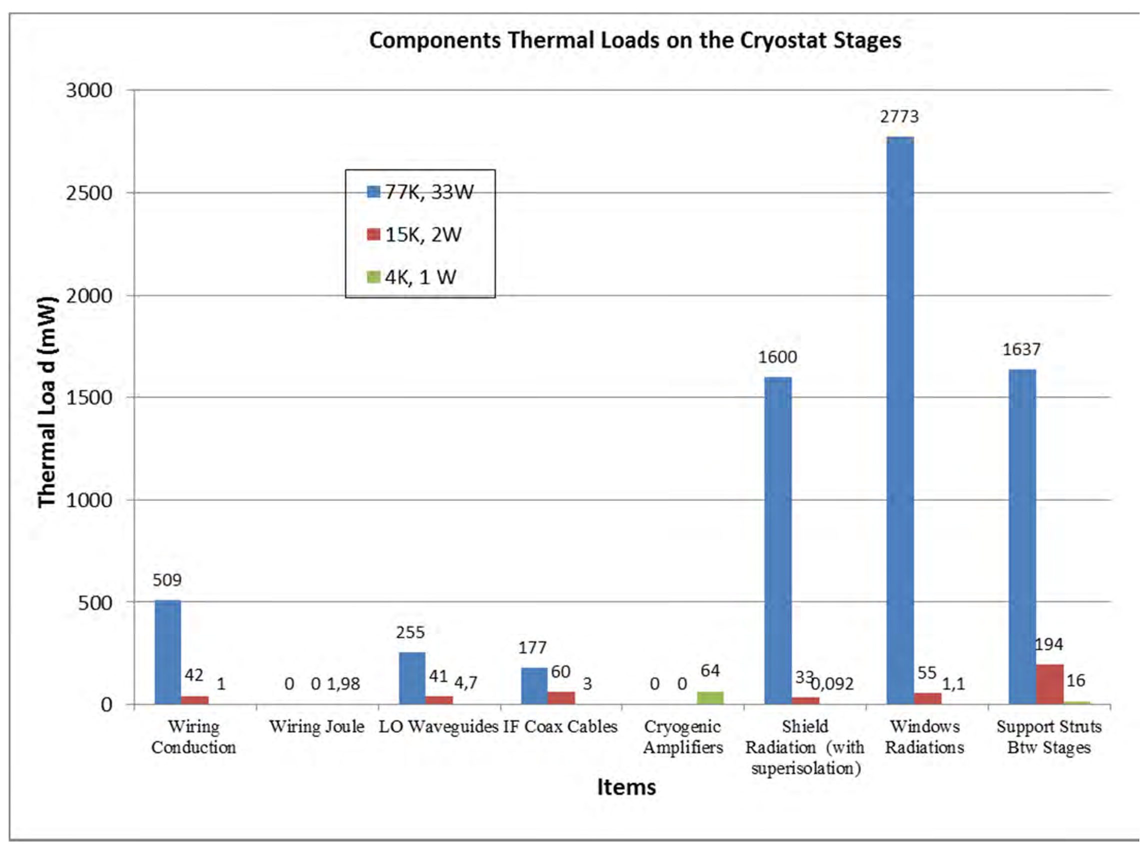
The receiver control electronics will be based on USB-I2C and CAN buses developed in house; they will control the SIS junctions, the cryogenic amplifiers as well as cryogenic temperatures probes for monitoring the temperature of the dewar inner stages, 2SB mixers and cold load.

The receiver will be installed on a dedicated mechanical frame which will also support the warm optics. A rotating flat mirror will be positioned in front of the signal window and will direct the signal to: atmosphere - hot load refocusing mirror– atmosphere – cold load refocusing mirror successively. The whole optical bench with the three mirrors and the motor will move forth and back with high accuracy in order to find the minima of the Bessel functions (Fourier-Bessel spectrum created by the reflections) for optimum atmosphere calibration purposes.

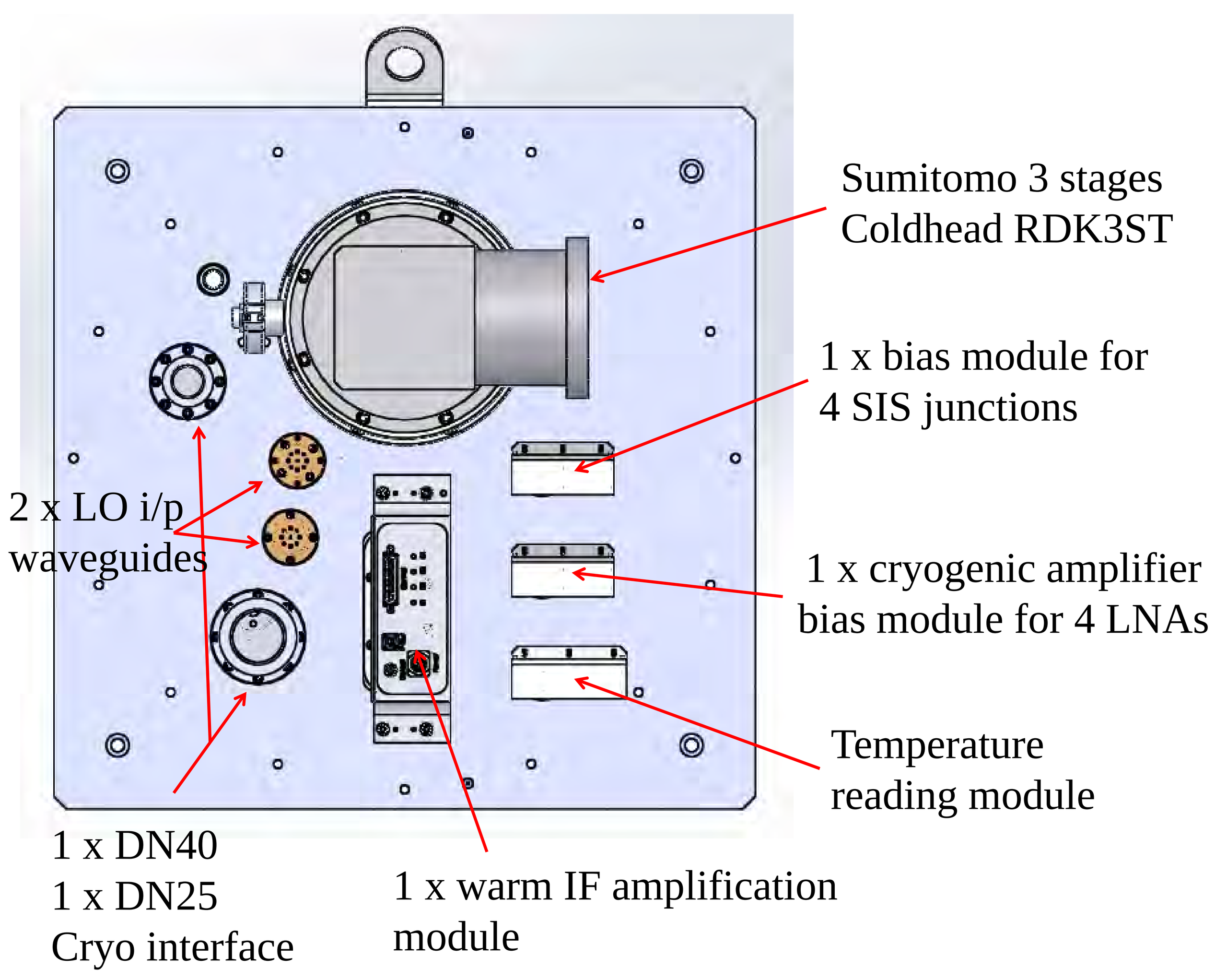
Specifications, System Diagram and Thermal Load Calculations

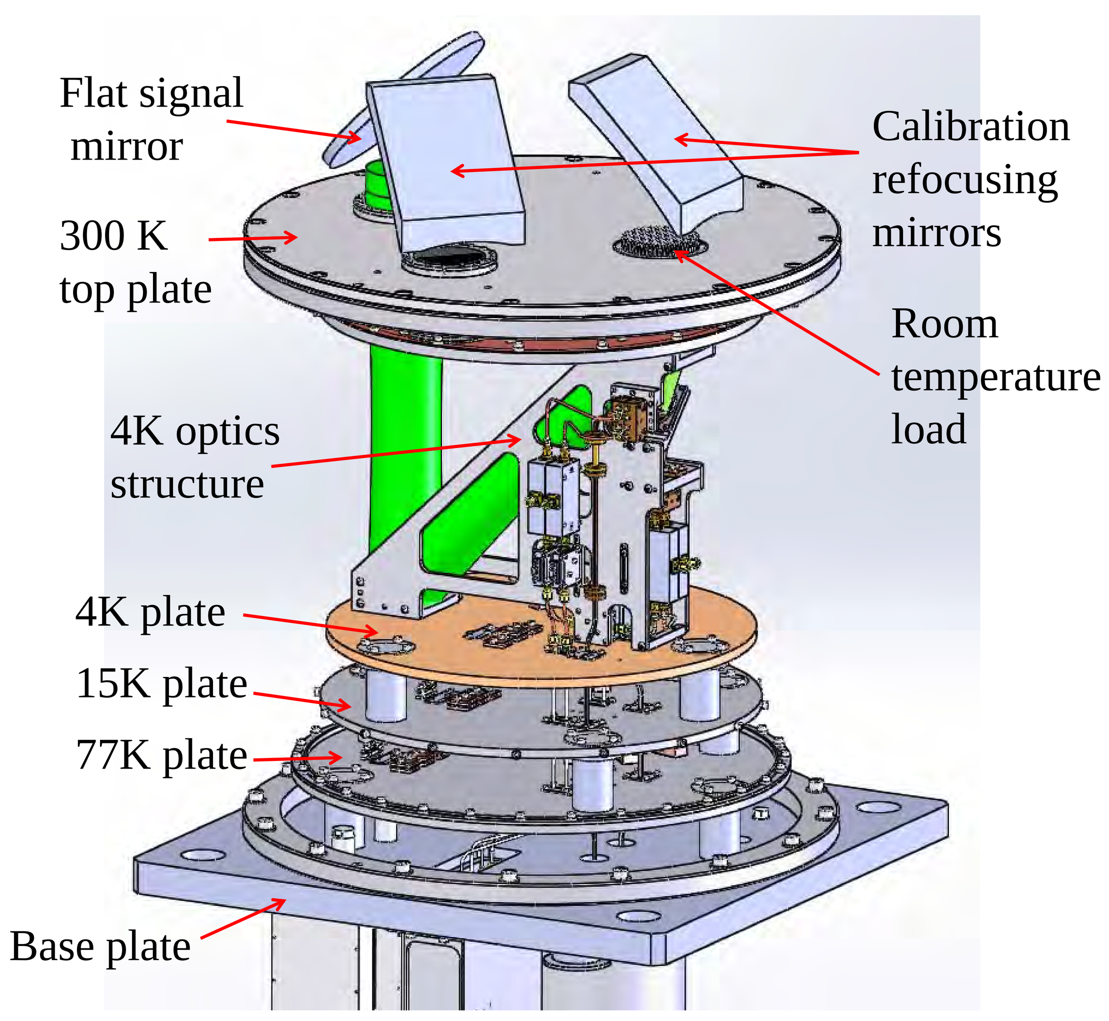
Parameters	2 mm Band	1.3 mm Band
RF port freq range	127-179 GHz	200-276 GHz
LO port freq range	138.6-171.3 GHz	207.8-264.4 GHz
IF band	3.8-11.7 GHz 2SB	3.8-11.7 GHz 2SB
Polarization	Single, linear	Single, linear
SSB receiver noise measured at dewar window, including warm optics	<65K 80% of RF <108K full 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 to -35 dBm	
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	
Horn Cross Polarization	-20dB	

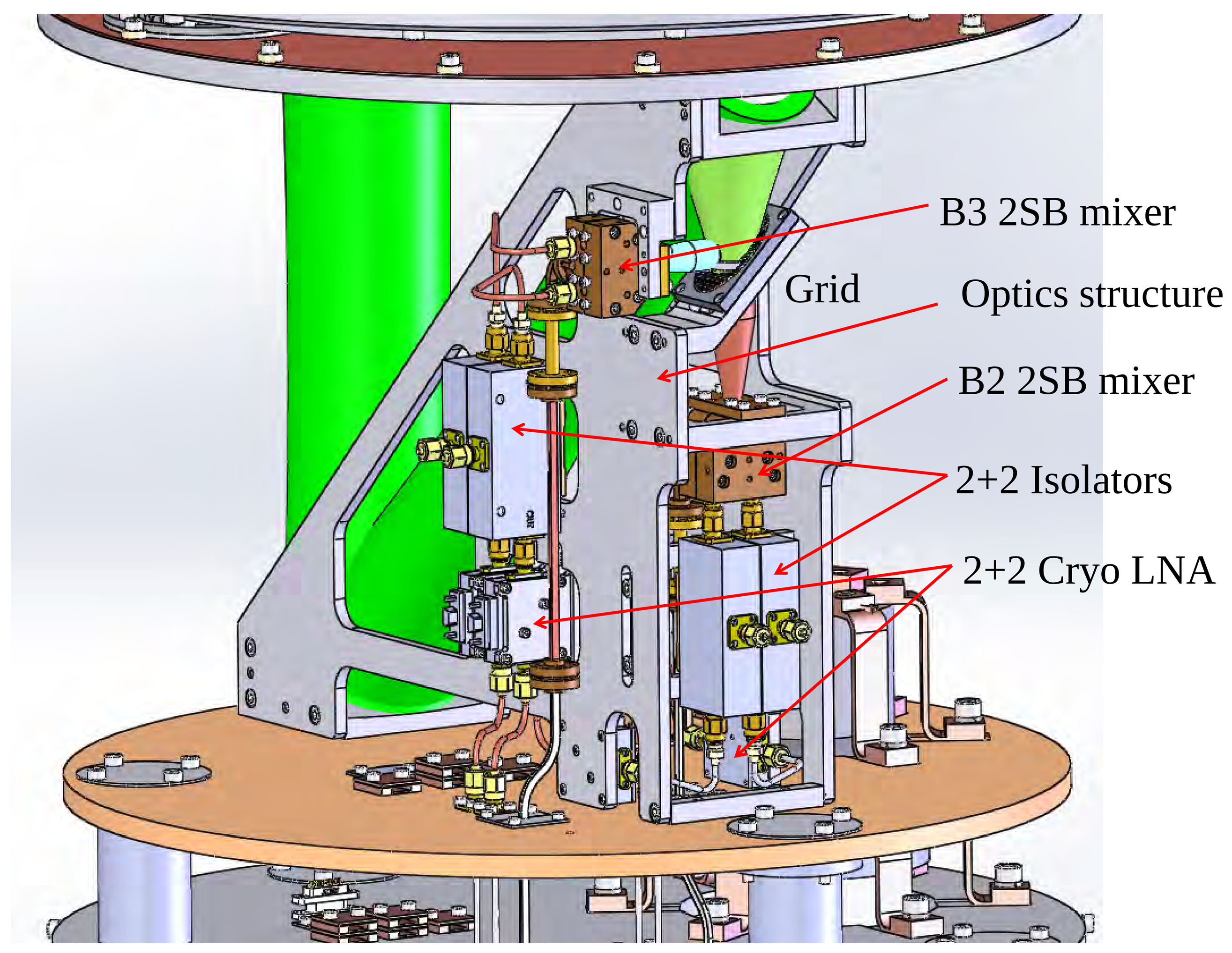




3D CAD VIEWS







Typical Expected Performances (from NOEMA Receiver #07 data)