Publication Year	2016
Acceptance in OA@INAF	2020-05-25T14:29:05Z
Title	The control system of the 3 mm band SIS receiver for the Sardinia Radio Telescope
Authors	LADU, Adelaide; ORTU, Pierluigi; SABA, Andrea; PILI, Mauro; Gaudiomonte, F.; et al.
DOI	10.1117/12.2232703
Handle	http://hdl.handle.net/20.500.12386/25150
Series	PROCEEDINGS OF SPIE
Number	9914

The control system of the 3 mm band SIS receiver for the Sardinia Radio Telescope

A. Ladu*, P. Ortu*, A. Saba*, M. Pili*, F. Gaudiomonte*, A. Navarrini*, E. Urru*, T. Pisanu*,
G. Valente*, P. Marongiu*, G. Mazzarella**

* INAF-Cagliari Astronomy Observatory, via della Scienza 5, Selargius, Italy
** Università degli studi di Cagliari, via Marengo 3, Cagliari, Italy

ABSTRACT

We present the control system of the 84-116 GHz (3 mm band) Superconductor-Insulator-Superconductor (SIS) heterodyne receiver to be installed at the Gregorian focus of the Sardinia Radio Telescope (SRT). The control system is based on a single-board computer from Raspberry, on microcontrollers from Arduino, and on a Python program for communication between the receiver and the SRT antenna control software, which remotely controls the backshort-tuned SIS mixer, the receiver calibration system and the Local Oscillator (LO) system.

Keywords: Astronomical receiver, millimeter waves, SIS mixer, Raspberry, Arduino, Radio telescope, SRT, cryogenics.

1. INTRODUCTION

The Sardinia Radio Telescope [1], a challenging scientific project of the Italian National Institute for Astrophysics (INAF), is a new, general-purpose, fully-steerable 64-m diameter radio telescope designed to operate with high efficiency across the 0.3-116 GHz frequency band. The telescope is located 35 km North of Cagliari, Sardinia, Italy, at about 600 m above sea level. The technical and scientific commissioning of the telescope was completed and an early science program started in February 2016. The antenna is based on a shaped Gregorian optical configuration that is obtained by a “nearly” parabolic primary mirror, and by a “nearly” elliptical secondary mirror. Such a configuration allows us to reduce the standing waves between the two reflectors and to improve the antenna efficiency. The receivers will be located at six focal positions: Primary (F1), Gregorian (F2) and Beam-Wave Guide (F3, F4, F5, F6), allowing us to observe in different frequency ranges: 300 MHz-20 GHz in F1, 7.5-115 GHz in F2 and 1.4-35 GHz in F3, F4, F5, F6. The telescope is primary active surface consists of 1008 aluminium panels (with a panel manufacturing RMS<70 µm) and of 1116 electromechanical actuators under computer control that compensate the gravitational deformation of the backup structure. The primary reflector was aligned to an RMS of ~290 µm using photogrammetry. Work is in progress to improve the total optics surface accuracy down to an RMS of ~150 µm using microwave holography, which will allow high-efficiency observations up to the highest frequencies (~100 GHz).

Observations at ~3 mm wavelengths with SRT will enable us to study a very wide range of phenomena in radio astronomy, ranging from the study of the interstellar medium and the formation of stars in cold gas clouds in our Galaxy and external ones, to the astrochemistry, up to the evolution of galaxies at low and high redshifts.

In this paper, we present the status of the development of a 3-mm band cryogenic receiver, one of the new frontends planned for installation in the secondary (Gregorian) focus of SRT, which will join the already commissioned receivers operating in P-, L-, C- and K-band. The instrument is an old-generation receiver designed and built at IRAM (Institut de Radioastronomie Millimétrique), which was deployed at the Plateau de Bure Interferometer (PdBI) until 2006.

Millimeter, Submillimeter, and Far-Infrared Detectors and Instrumentation for Astronomy VIII,
edited by Wayne S. Holland, Jonas Zmuidzinas, Proc. of SPIE Vol. 9914, 991423
© 2016 SPIE · CCC code: 0277-786X/16/$18 · doi: 10.1117/12.2232703

Following its decommissioning, it was purchased by INAF-OAC (Astronomical Observatory of Cagliari) with the goal of testing the performance of the active surface of SRT at its highest operational frequencies of approximately 100GHz, and of performing initial mm-VLBI and single-dish astronomical observations.

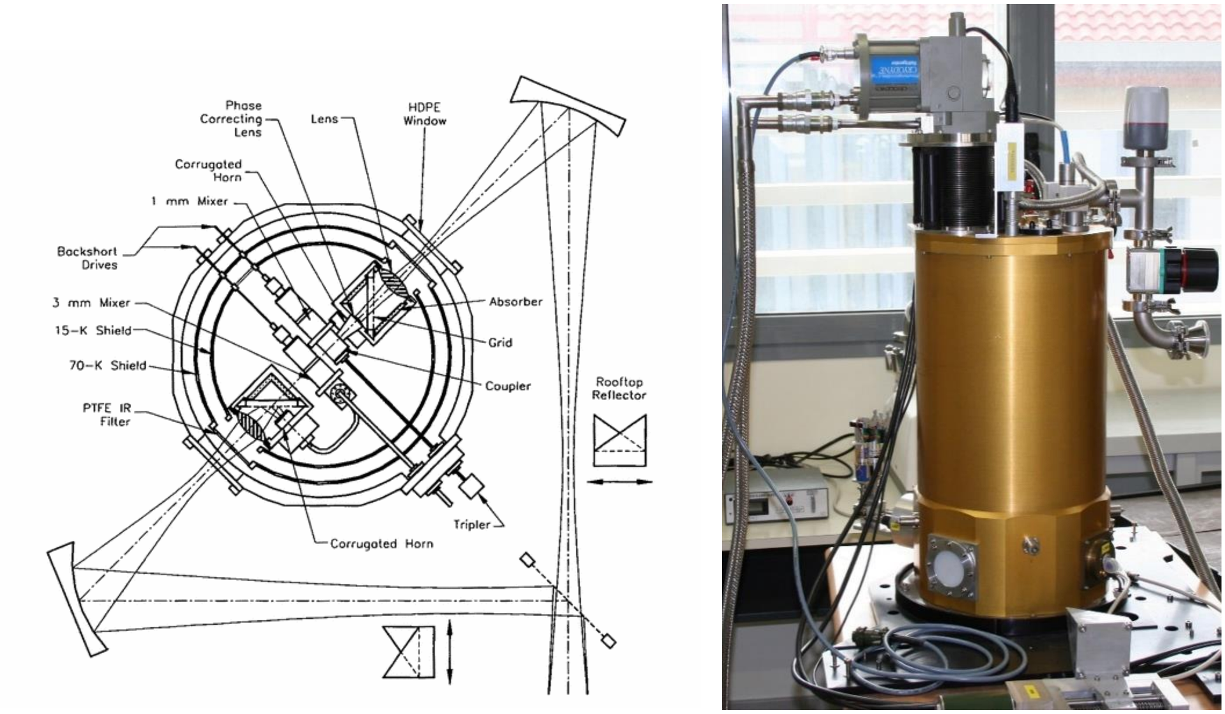


Fig.1. IRAM 3 mm receiver: a) Schematic showing the optical arrangement and the cryostat inner components b) photo of the instruments.

The receiver we purchased from IRAM (Fig. 1) originally covered two frequency bands: the ~3 mm band (84 – 116 GHz) and the ~1.3mm band (210 – 248 GHz) [2-4]. A broadband polarization grid at the input of the ex-PdBI receiver splits two orthogonal, linearly polarized signals across ~84-248 GHz into two different optical paths, each of which is received in one of the two bands. However, only the single polarization 3 mm band can be observed with SRT, while the 1.3 mm channel remains unused. Each receiver channel is based on a backshort-tuned Single Side Band (SSB) SIS mixer that operates at the physical temperature of 4.2 K, with very good performances in terms of noise figure. The cryogenic temperature of 4.2 K was provided by a 10-inch diameter high thermal conductivity plate in thermal contact with a vessel of liquid helium. This vessel is located inside a hybrid cryostat (HDV10 from Infrared Laboratories) with three cryogenic stages where a CTI 350CP cold head provided two additional cooling stages at ≈20 K and ≈80 K. The Intermediate Frequency (IF) signal has an instantaneous bandwidth of 500 MHz (1.3 – 1.8 GHz) on both receiver channels. An ambient and cryogenic calibration loads are available for the 3 mm and for the 1.3 mm receiver channel.

In the next sections, we present two important modifications made to the original design in order to allow the integration of the receiver at SRT. These modifications are relative to the control system and to the local oscillator system.

2. THE CONTROL SYSTEM

Since the IRAM receiver was originally designed for the PdBI antenna, the control cards that were supplied for monitoring and controlling the receiver were entirely without on-board intelligence and unable to operate the instrument. For this reason, a new receiver control system had to be developed in order to adapt the instrument to the SRT. In particular, our work focused on developing the on-board intelligence in all these cards for tune and remote control of the receiver and on developing the software interface for integrating the control of the instrument into the SRT antenna control software.

Three control boards were supplied by IRAM: two were used to control the backshort-tuned SIS mixer and one was used to control the receiver calibration system. An additional control board is used for controlling an ALMA (Atacama Large Millimeter Array) Band 3 Local Oscillator, which we purchased from NRAO (National Radio Astronomy Observatory). In fact, rather than using the traditional Gunn-based local oscillator employed in the past at IRAM for pumping the SIS mixer, we intend to utilize the electronically tuned local oscillator developed at NRAO for the ALMA project.

The proposed control system for the 3 mm receiver we intend to install on SRT is innovative. We developed a new architecture to efficiently control the instrument that is based on a single-board computer from Raspberry, on microcontrollers from Arduino, and on a Python program for communication between the receiver and the SRT antenna control software. Particular care was taken to minimize the Radio Frequency Interferences (RFI) that are self-generated by Raspberry and Arduino.

The control system architecture consists of a single-board computer, Raspberry Pi 2 (Model B) [5], which controls three different microcontrollers, Arduino UNO REV3 (ATMEL ATmega 328P) [6]. Each Arduino microcontroller controls one of the following control boards of the receiver: the backshort-tuned SIS mixer, the receiver calibration system and the ALMA local oscillator (Fig. 2.1).

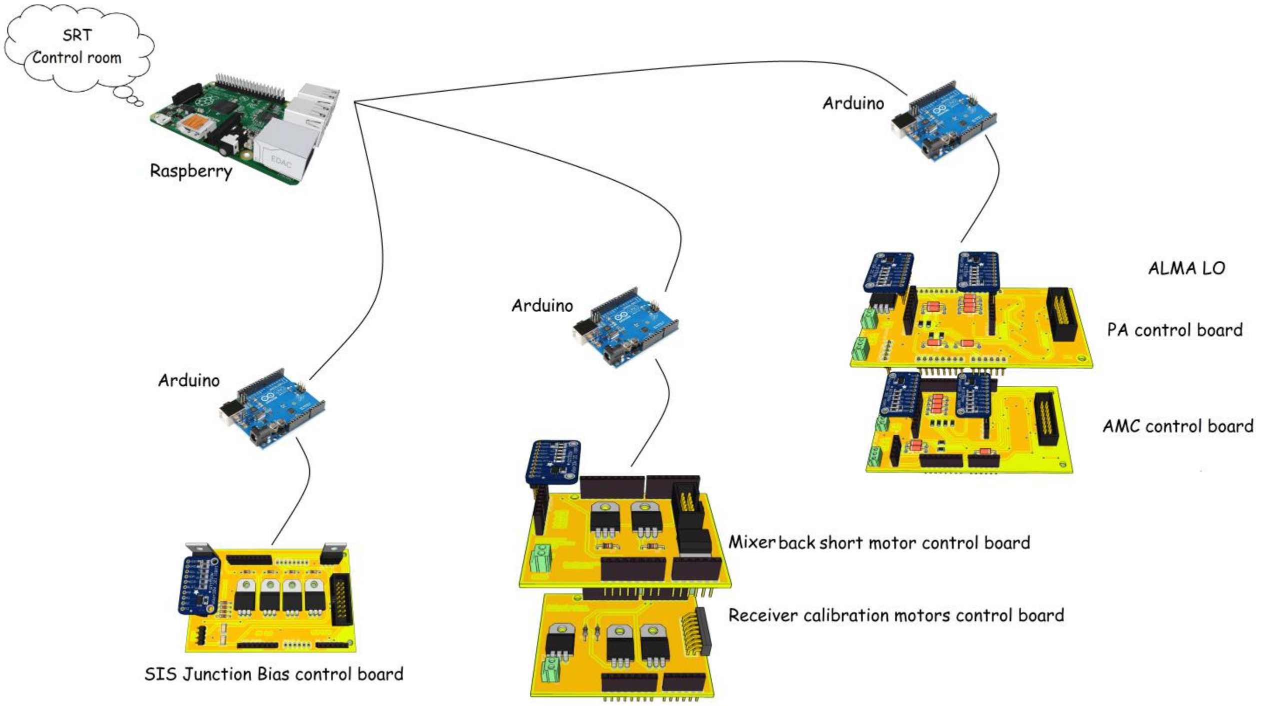


Fig. 2.1. The proposed control system architecture of the 3 mm SIS receiver for the Sardinia Radio Telescope.

Fig. 2.2 shows the fully-assembled rack for the 3-mm SIS receiver. The rack integrates the single-board computer Raspberry, the LO ALMA control boards, the SIS junction bias control board with the IRAM junction bias board, the backshort motor control board, and the calibration motors control board with the IRAM motor drive board. We enclosed all control boards in aluminium boxes in order to isolate potential signals self-generated by Arduino.

In the next sections, we describe the aforementioned control boards and the firmware developed to test them.

Fig. 2.2. Fully assembled racks for controlling the 3 mm SIS receiver for SRT.

2.1. Raspberry

The 3 mm band receiver needs a particular tuning sequence before it can start an astronomical observation. The tuning requires several steps. First, the local oscillator must be tuned and locked at the desired frequency. Then the backshort of the SIS mixer is set at the appropriate position for the chosen SSB frequency tuning, and the junction DC bias voltage is set. Finally, the LO power is adjusted to reach a prescribed pumped-junction DC current (of the order of 20 μA) [4]. Altogether, these tuning steps involve between 11 and 13 adjustments, which can be mechanical or electrical, yet this process must only take a few minutes and must be completely transparent to the final users (astronomers). For this reason, these adjustments must be a combination of LUT (lookup table) and optimization algorithms carried out under computer control. In order to carry out the aforementioned tuning, a single-board computer Raspberry Pi 2 (Model B) was chosen. This computer is the core of the new control system and it allows us to remotely control the receiver. We decided to use the Raspberry for three different reasons: it is a pocket computer, based on a quad-core processor that runs at 900 MHz with 1 GB of RAM; it is supplied with four USB ports and one Ethernet port and it is based on Linux open source software [6]. For these reasons, this small computer is flexible and easy to use. In addition, a preliminary RFI measurement confirmed that such computer is suitable for working in the radio astronomical environment.

Considering the radio astronomy (RAS) frequency allocation [7], we decided to measure the RFI generated by Raspberry in the frequency range between 100 MHz and 6 GHz. In order to identify the signals generated by the computer, we tested the device to its full capacity inside a shielded room. The test system consists of a log-periodic antenna, which operates in the frequency range between 250 MHz and 7 GHz, and is oriented toward the Raspberry and a R&S FSV40 Spectrum Analyser, external to the shielded room, to display the received signal from the antenna. Three different measurements were carried out in the shielded room:

- Raspberry OFF, to highlight all signals coming from known external sources, like DTT, UMTS, GSM etc. and to establish a reference level baseline;
- Raspberry ON without shield, to highlight all signals that are self-generated by the internal clock and Ethernet of the device;

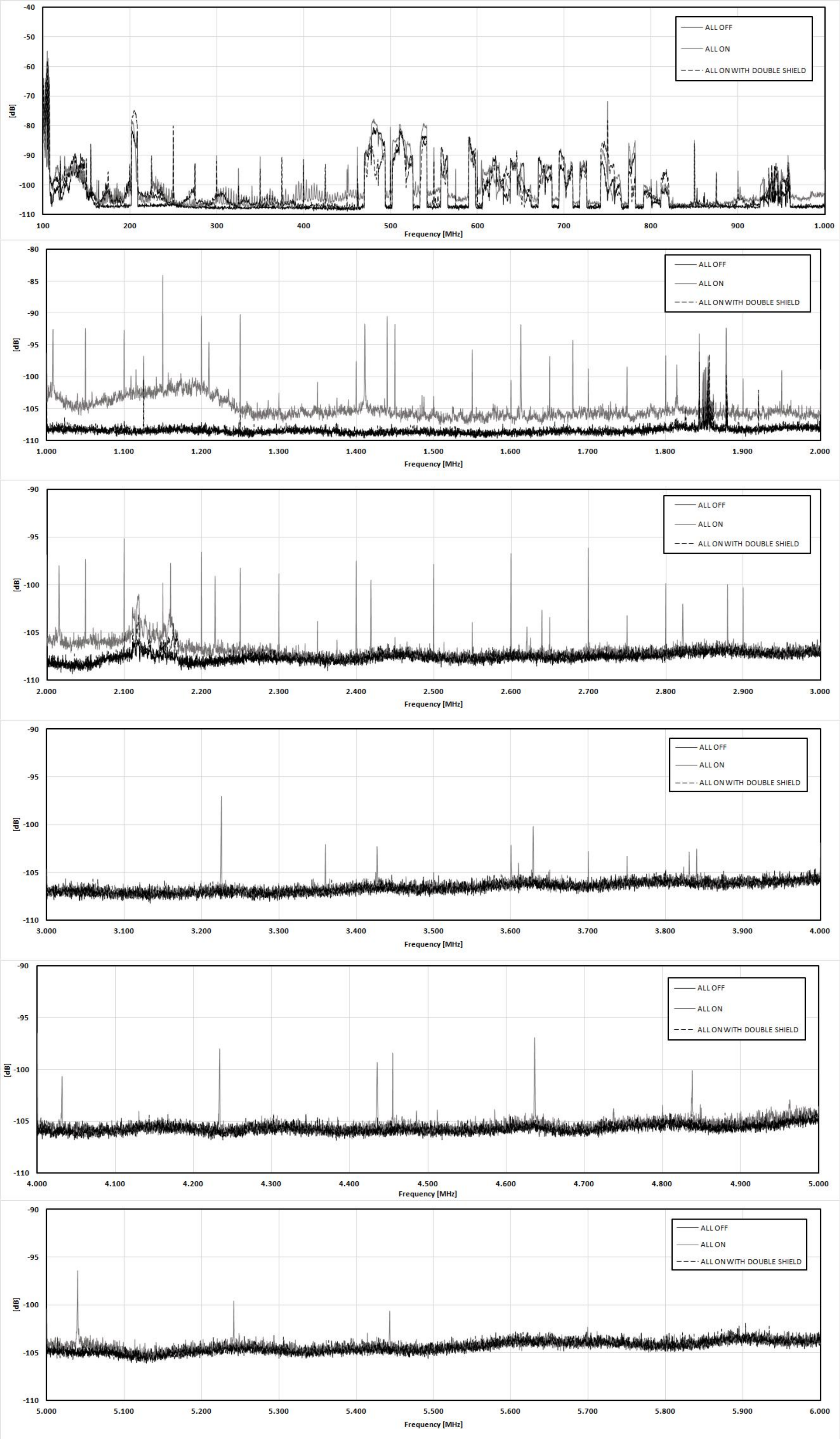


Fig. 2.1.1 Power spectrum of the Raspberry measured inside the shielded room.

- Raspberry ON with double shield, to highlight the strong attenuation of the signals that were self-generated by the device.

The power spectrum generated by the Raspberry in the three aforementioned configurations is shown in Fig. 2.1.1. We can see that if we enclose the Raspberry in a double aluminium box, the produced signals are greatly weakened. In particular, these signals are practically not present within the RAS frequency bands except that across the P-band (310-410 MHz]. In this case, the 3 mm receiver control system will be turned off during the astronomical observations in P-band.

In order to manage the tuning of the receiver and to allow the communication between the receiver and the SRT antenna control software, a Python program was developed. The Python (ver. 2.7) control software performs the following tasks:

- Search for the microcontrollers Arduino on the its USB ports sending the IDENTIFY command through the COM ports;
- Enable a SOCKET communication to the Raspberry on port 5025;
- Launch a demon that listens on the SOCKET in order to receive commands and return the required values;
- Translate the commands received via SOCKET in a format accepted by microcontrollers Arduino and vice versa.

The format of commands accepted is identical for three Arduino and consists of a list of 7-bytes for the input commands to the microcontrollers and a list of 3-bytes for the output commands. The commands of Raspberry are received via the Ethernet network and are strings of text as COMMAND_TYPE PARAMETER [VALUE]. The COMMAND_TYPE can be “GET”, if it is a value request command, or “SET”, if it is a value setting command. PARAMETER identify the function argument in “SET” and/or “GET”, i.e. SET POT_VALUE 100 or GET VGA_MINUS. The VALUE is used in “SET” command and unused in “GET” command.

2.2. SIS mixer bias control board

The 3-mm band heterodyne receiver is based on a SIS mixer, whose junction consists of two layers of superconducting metal (Niobium) separated by a very thin layer (few nanometer thick) of Aluminium oxide insulator. The SIS junctions have a typical size of the order of a few μm^2, and their integrated thin-film superconducting tuning circuitry sit on top of a quartz substrate, which is itself mounted across a waveguide. One side of the junction is connected through properly designed interconnecting circuitry to the outside of the mixer block, both to bring out the IF beat signal, and to provide the DC bias [4]. Fig. 2.3.1a shows the Junction Bias (JB) board developed by IRAM, which can be driven in voltage or current modes. Starting from an internal reference voltage, this control board provides the input junction voltage/current by using a DC motor with a potentiometer or provides the input junction current using a DAC. Two analogical outputs allow to trace I/V characteristics of the SIS junction.

Since this IRAM board is without on-board intelligence, we developed a further control board (Figs. 2.3.1b - 2.3.1c) to remotely manage it. The JB control board is equipped with a power supply stage, a readout stage and a motor control stage. The power supply stage has been carefully studied to provide the following voltage supplies: 5 V for digital logic circuit, ±15 V for operational amplifiers, 12 V for Motor-potentiometer and 5 V for the reference value to calibrate the potentiometer. The readout stage is equipped with a high-resolution ADC [10] to have the monitor point feedbacks of the junction bias (voltage and current values), the motor position (voltage value) and the DAC value. The motor control stage allows us to turn the motor-potentiometer using digital controls in order to set a given current/voltage value of the SIS junction. Furthermore, this stage allows us to set the voltage/current mode in the motor-potentiometer configuration or current mode in the DAC configuration.

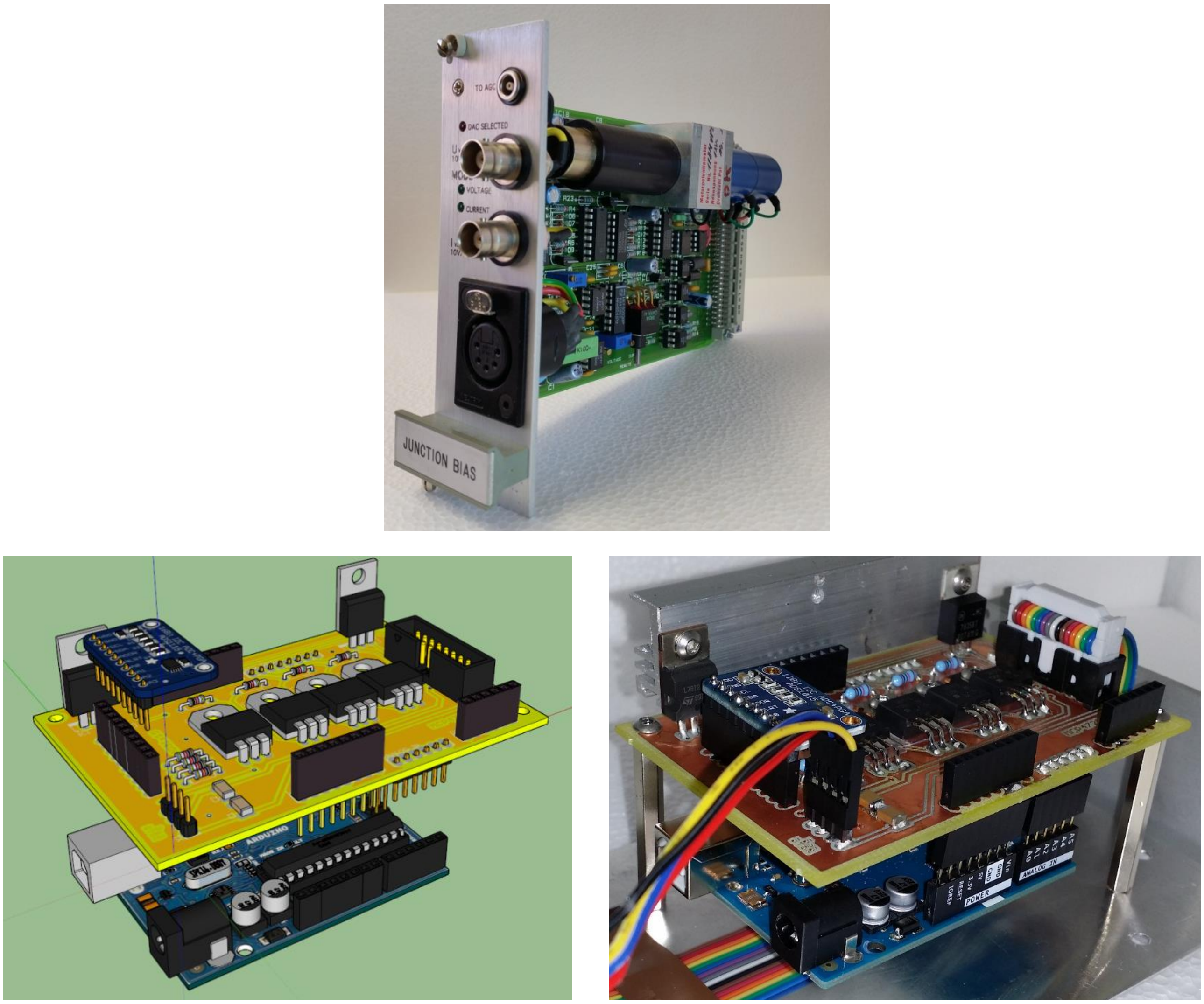
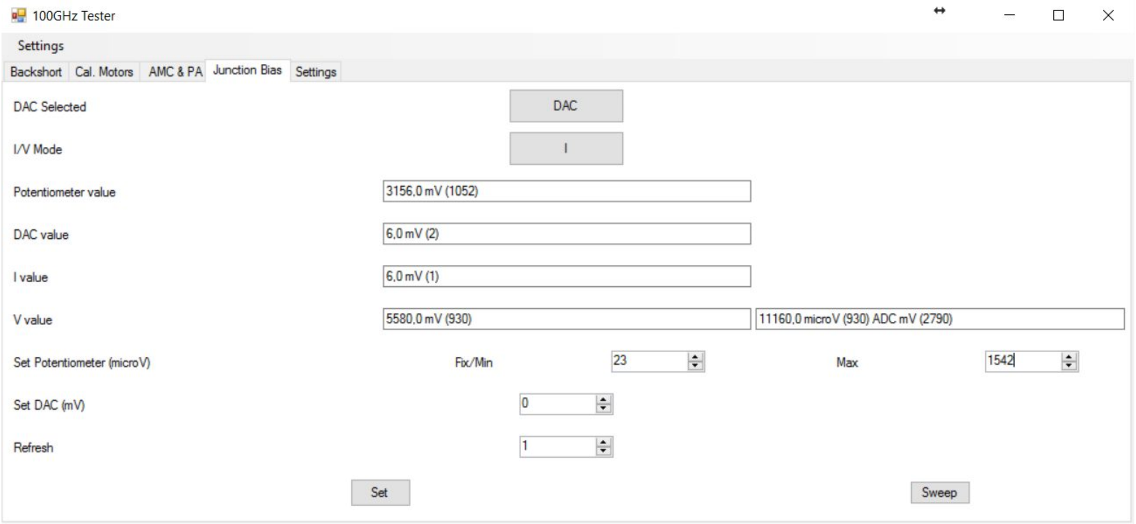


Fig. 2.3.1 a) SIS mixer junction bias module developed at IRAM; b) 3D rendering of the junction bias control board developed for SRT; c) junction bias control board.

In order to test the JB control board, we developed control software based on Microsoft Visual Basic .NET. The control software allows us to read all values coming from the ADC and set the voltage across the potentiometer or set DAC value in order to drive the SIS junction. The GUI of the JB control software is shown in Fig. 2.3.2.

A continuous monitoring by setting a time (seconds) in the "*Refresh*" box is foreseen. In addition, the "*Sweep*" button enables a continuous sweep of the potentiometer value between the "*Min/Fix*" value and "*Max*" value, which are previously set.



DAC Selected: DAC
I/V Mode: I
Potentiometer value: 3156,0 mV (1052)
DAC value: 6,0 mV (2)
I value: 6,0 mV (1)
V value: 5580,0 mV (930) 11160,0 microV (930) ADC mV (2790)
Set Potentiometer (microV) Fix/Min 23 Max 1542
Set DAC (mV) 0
Refresh 1

Fig. 2.3.2. GUI of the JB control software

2.3. Backshort motor control board

The SIS mixer uses a quarter-height waveguide with a single adjustable non-contacting backshort (Fig. 2.3.1) allowing the tuning with a good match of the junction impedance in the signal band, and to reject the image sideband of order 15 dB or higher at any frequency across the 84-116 GHz signal band [11-14].

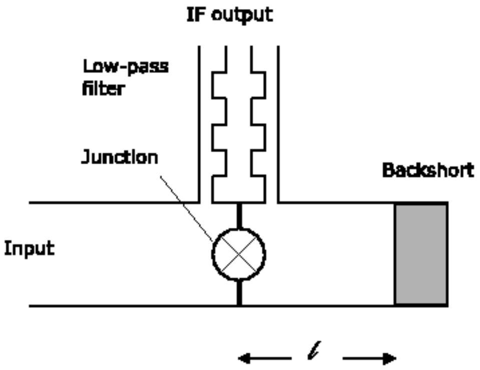


Fig. 2.3.1. A sketch of a SIS mixer.

The impedance seen by the SIS mixer, embedded with its integrated superconducting circuitry in the waveguide structure, is frequency-dependent. Thus, a suitable mixer tuning is obtained adjusting the length *l* of the waveguide section between the SIS junction plane and the backshort. Fig. 2.3.2a shows the backshort drive system developed by IRAM based on a DC motor with a potentiometer that moves the backshort forward or backward with respect to the junction. A board placed in the top of the device controls the motor movements. Very precise positioning is achieved by applying short pulses to the motors in order to achieve very fine steps.

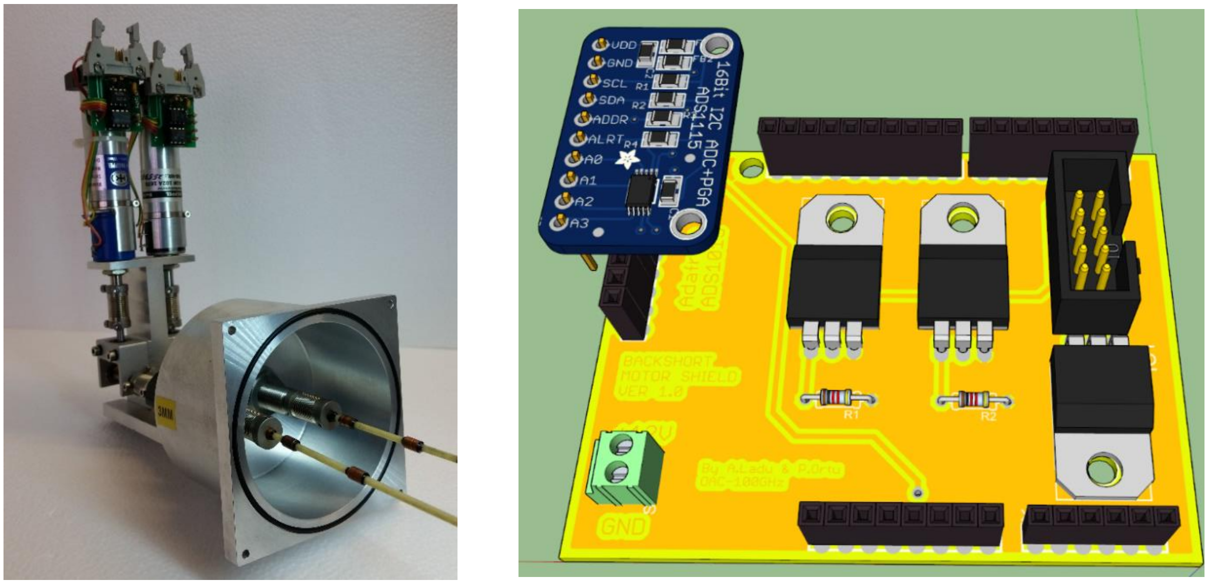


Fig. 2.3.2 a) IRAM Backshort system, b) 3D rendering of the SIS mixer backshort motor control board we developed for SRT.

Since this IRAM board is also without on-board intelligence, we developed another control board (Fig. 2.3.2b) to remotely manage it. The backshort motor control board is equipped with a power supply stage, a readout stage and a motor control stage. The readout stage is equipped with a high-resolution ADC [10] to have the monitor point's feedbacks of the backshort motor position (voltage value). The motor control stage allows us to turn the motor-potentiometer by using digital controls in order to place the backshort of the mixer in a given position from the junction.

2.4. Control board for the 3 mm receiver calibration motors

The system of internal calibration installed in the IRAM receiver consists of two loads, which are thermalized respectively at room and cryogenic temperatures, that allowus , through a Y-factor measurement, to derive the noise temperature of the Front-End at its vacuum window input. The hot load is an absorber with a square shape made of Emerson&Cumming AN72 material which can be moved in the receiver signal path with a DC motor. The cold load utilizes an absorber located at 4 K, which is illuminated from the single-polarization receiving system chain thanks to a movable rooftop mirror with normal angle of reflection and located at room temperature. The rooftop mirror can be moved in the receiver signal path with a DC motor. Such a mirror rotates the beam polarization by 90 degrees and reverses its direction to orient the receiver beam towards the cryogenic load. The rooftop mirror and the room temperature loads are installed in the optical path of the receiver, at the height of its beam waist (Fig. 1, left panel). Fig. 2.4.1 shows part of the calibration system with the rooftop mirror and load attached to the two DC motors.

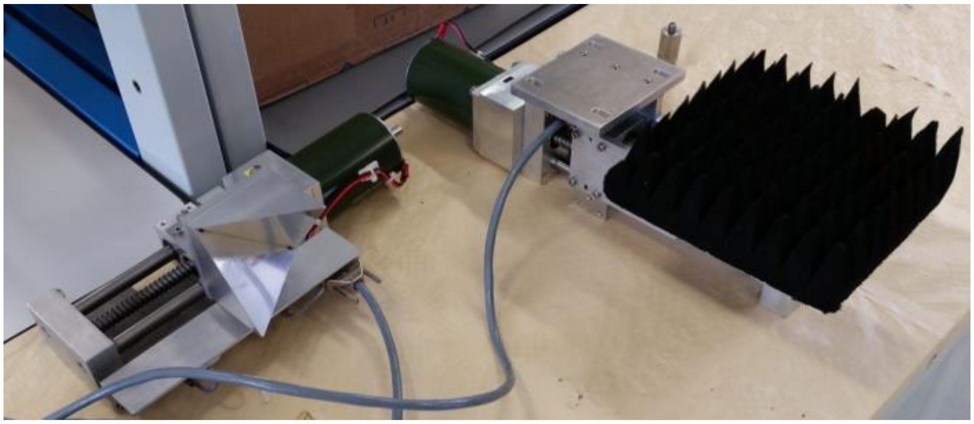


Fig. 2.4.1. Calibration parts connected to the motors: the rooftop mirror (used for the cryogenic calibrator) is on the left, the room temperature load is on the right.

The control of this calibration system was much easier to implement compared to the other control systems that were previously described. Only two positions are allowed ("on" the signal path and "off" the signal path) for the DC motors, and are given by the position of two inductive proximity switches. The IRAM table driver board controls these motors moving them between the first inductive proximity switch ("*Position 1*"), which corresponds to the rest position "off", and the second inductive proximity switch ("*Position 2*"), which corresponds to the working position "on", and vice versa. Since this IRAM board is also without on-board intelligence, we developed another control board (Fig. 2.4.2b) to remotely manage it. The calibration motors control board is equipped with a power supply stage and a motor control stage. The motor control stage allows us to move the DC motor between *Position1* and *Position2* and to know what their position is.

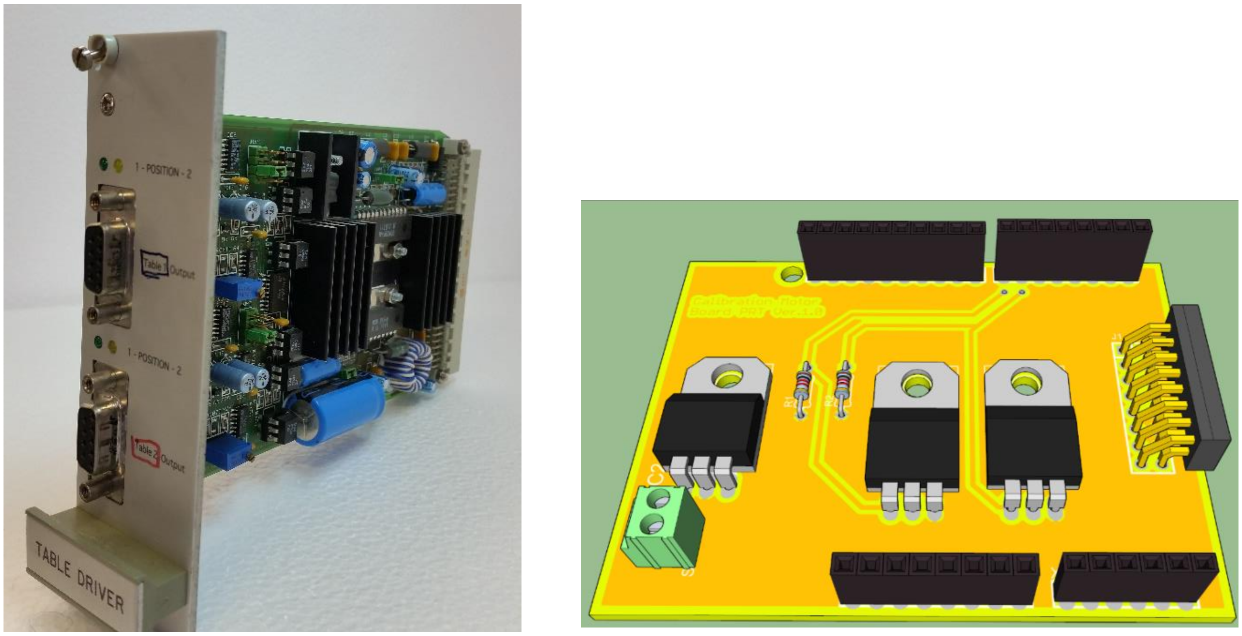


Fig. 2.4.2 a) Table driver developed by IRAM for the receiver calibration system, b) 3D rendering of the control board of the calibration motors we developed for SRT.

2.5. Motors' control board

The motors' control board is composed of the SIS mixer backshort motor control board and of the receiver calibration motors control board. Since these two cards have a relatively small number of signals to be controlled, we decided to use only one Arduino microcontroller to control both of them, as we can see in the Fig. 2.5.1.

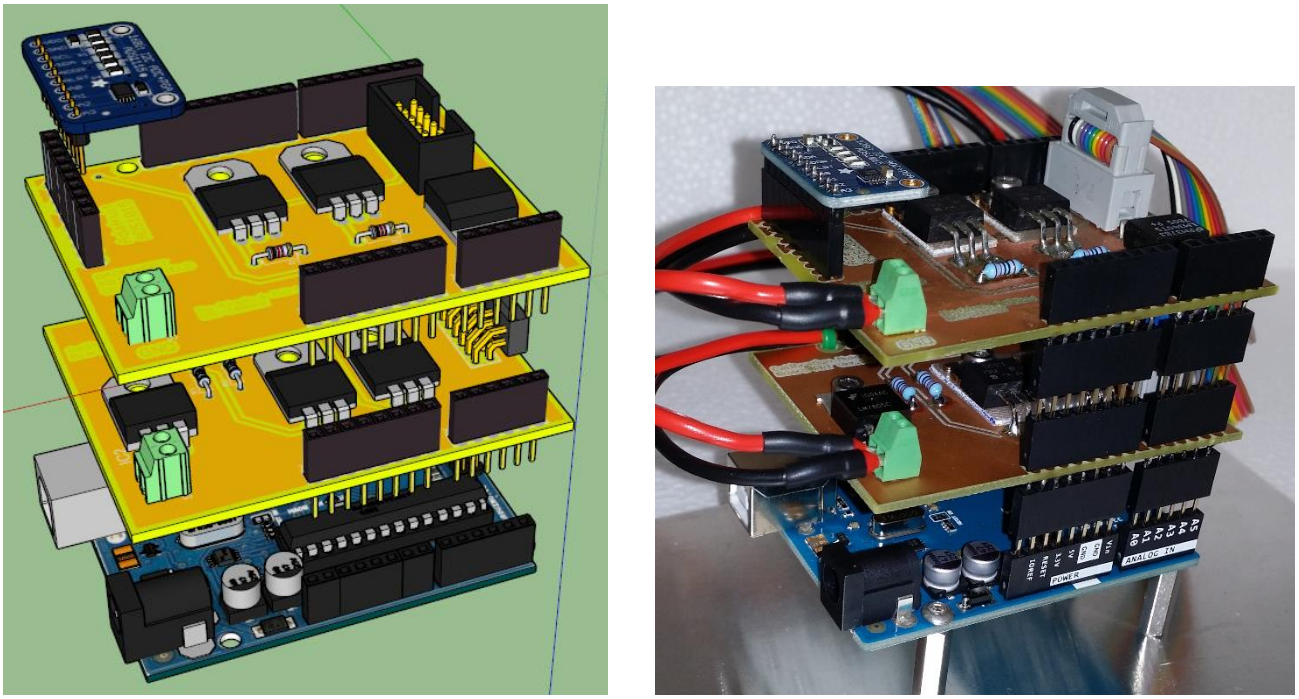
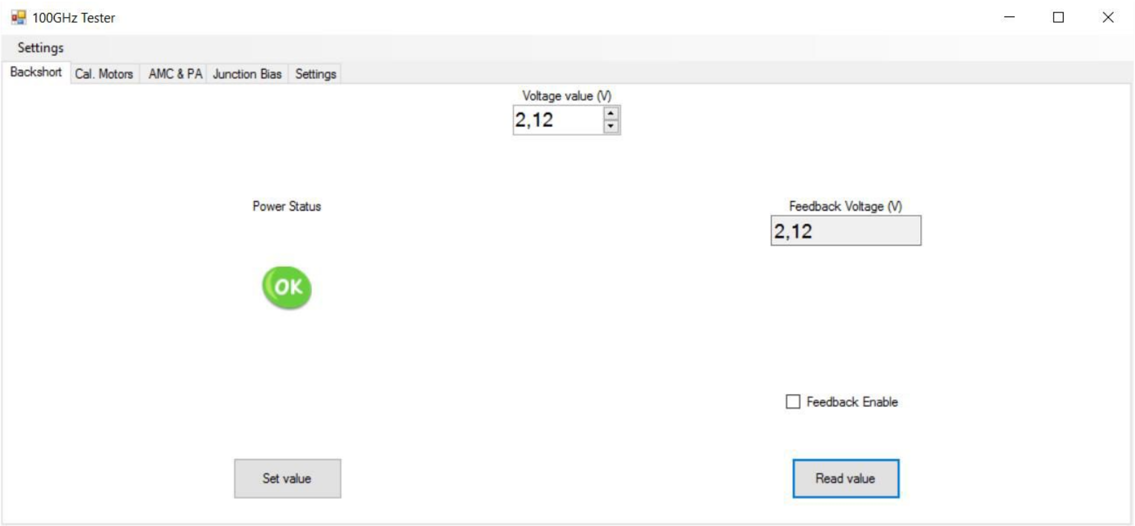


Fig. 2.5.1. a) 3D rendering of the motors' control board developed for SRT; b) Motors' control board.

In order to test the motors' control boards, we developed control software based on Microsoft Visual Basic .NET. The control software is divided into two parts. The calibration motor control software allows us to move the DC motors and to check their status. In addition, the software imposes the displacement of the motors one at a time. The backshort control software allows us to read all values coming from the ADC and set the voltage across the potentiometer. The GUI of the motors' control software are shown in Figs. 2.5.2. and 2.5.3.

A continuous monitoring of feedback voltage is foreseen in the backshort control section by enabling "*Feedback Enable*". In the Calibration motors' control section, two slider-bars allow us to move the DC motors and to know their position. Two status indicators signal any anomalies.



Voltage value (V): 2,12

Feedback Voltage (V): 2,12

☐ Feedback Enable

Fig. 2.5.2. GUI of the SIS mixer backshort control software

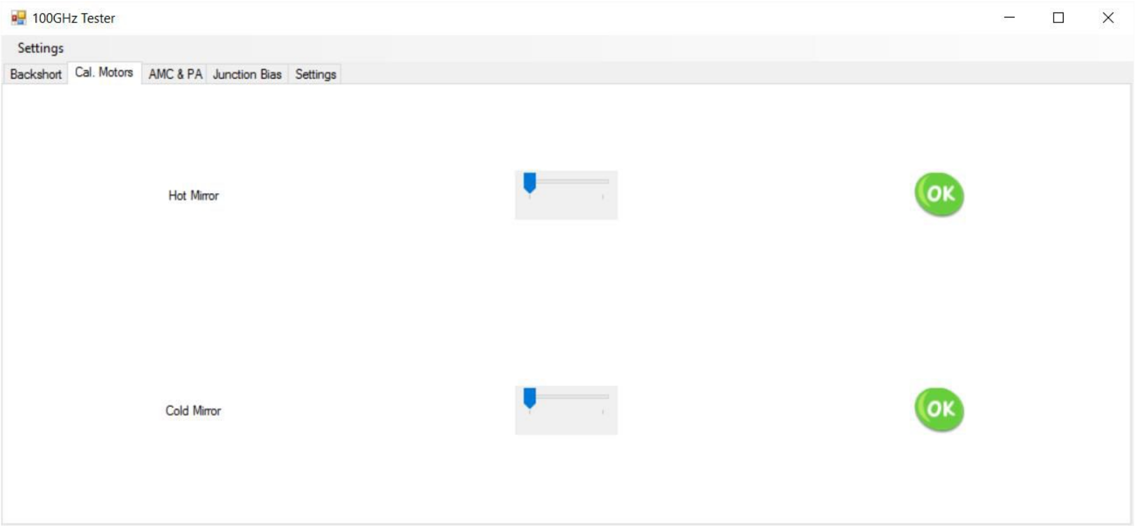


Fig. 2.5.3. GUI of the calibration motors control software.

3. THE LOCAL OSCILLATOR

3.1. Monitoring and control boards for the ALMA Local Oscillator at SRT

The local oscillator implemented in the IRAM PdBI telescopes to pump the 3 mm receiver was based on a traditional Gunn oscillator. An electronically-tuned Local Oscillator developed by the NRAO for the ALMA Band 3 (84-116 GHz) project [8] will be used to replace the Gunn system. The main parts of the ALMA Band 3 local oscillator are an Active Multiplier Chain (AMC) in cascade with a Power Amplifier (PA). We use an external signal generator (R&S SMF 100A) to generate a single-tone CW signal tuneable across 15.333-18.000 GHz with a power between +10dBm and +15dBm. Such an RF signal is subsequently frequency multiplied, filtered and amplified by the AMC module (multiplication by 6 by a MMIC doubler and a MMIC tripler and amplification by medium power 3 mm band MMIC amplifier) to yield an output between 92 GHz and 108 GHz, with an output power in the range 1-10 mW. The PA module splits the waveguide input signal coming from the AMC equally, and further amplify each of the two waveguide outputs (used in ALMA to pump the mixers of orthogonal polarization channels) of a user-controlled amount with an output power in the range 0.4 mW-1.6 mW (-4 dBm to +2 dBm), which is adjustable in 0.2 dB steps or less across the full ALMA Band 3 LO band (92-108 GHz). The specified RF band of the receiver for SRT (84-116 GHz) is the same as the ALMA Band 3. However, because the IF frequency range is only 1.25-1.75 GHz (500 MHz), rather than the 4-8 GHz IF employed by the ALMA Band 3 cartridge, the LO band required to cover the specified RF band is 85.75-114.25 GHz, larger than for ALMA Band 3. We made preliminary tests of the ALMA Band 3 LO system across the extended LO range required for our application in order to derive a value for the LO power at the LO band edges of our interest (85.75 GHz and 114.25 GHz), which fall outside the nominal ALMA Band 3 LO range. Upcoming laboratory tests of the fully assembled IRAM receiver with the local oscillator system will be able to demonstrate if the LO power at the band edges required for our operation in SRT is enough to correctly pump the SIS mixers of the IRAM receiver, and operate it with low noise performance [9]. Only one of the two output channels of the PA will be used for our purposes, while the other channel will be terminated.

In order to efficiently control two modules, we developed two control boards: one to manage the AMC and one to manage the PA. Since two modules require high DC power supplies (AMC/PA: +6V (1.5A), ±15V (500mA)), each control board is equipped with a power supply stage studied carefully in order to ensure a high stability with high currents. In addition, each control board is equipped with a further protection stage against surge due to possible malfunctions of two modules.

The control of the AMC module only includes monitor point feedbacks. In fact, it is not possible to set the bias in this particular AMC because value resistors installed are fixed. For this reason, the AMC control board is equipped with two high-resolution ADC (Texas Instruments ADS1115 fitted on Adafruit modules [10]) capable of reading all AMC voltages with high precision. These ADCs can easily measure four single-ended signals with 16-bit of resolution each. The device communicates through an I^2C interface, which is managed by the Arduino microcontroller.

The control of the PA module is more complex because it foresees that the setting of PA output power is done by independently adjusting the gate and drain voltages on each PA output channels. The PA gate and drain voltages are controlled by setting two programmable potentiometers, one for each channel. Communication and control of these potentiometers is accomplished over a 3-wire serial port, which allows us read and write the data. In this way, the gain of the amplification stage in each PA output can be remotely controlled. Therefore, to calibrate the amplifier gain, we implemented a SPI (Serial Peripheral Interface) bus to control and set the potentiometers using a microcontroller Arduino. The PA control board is also equipped with two high-precision ADC [8] that provide the monitor point feedbacks to ensure the correct polarization of all amplifier junctions.

Fig. 3.1.1 shows the ALMA LO, the 3D rendering of ALMA LO control boards, and the ALMA LO control boards.

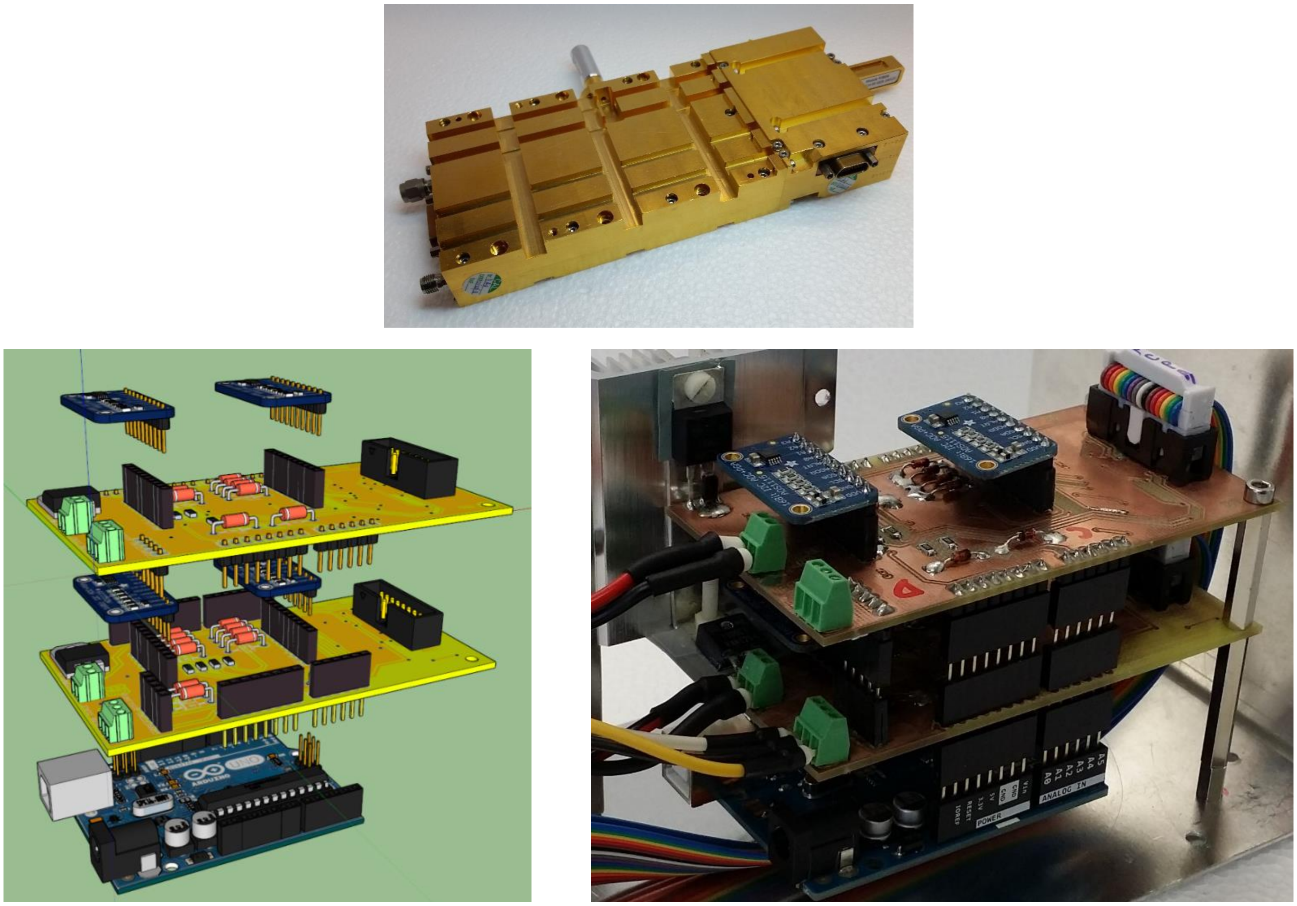
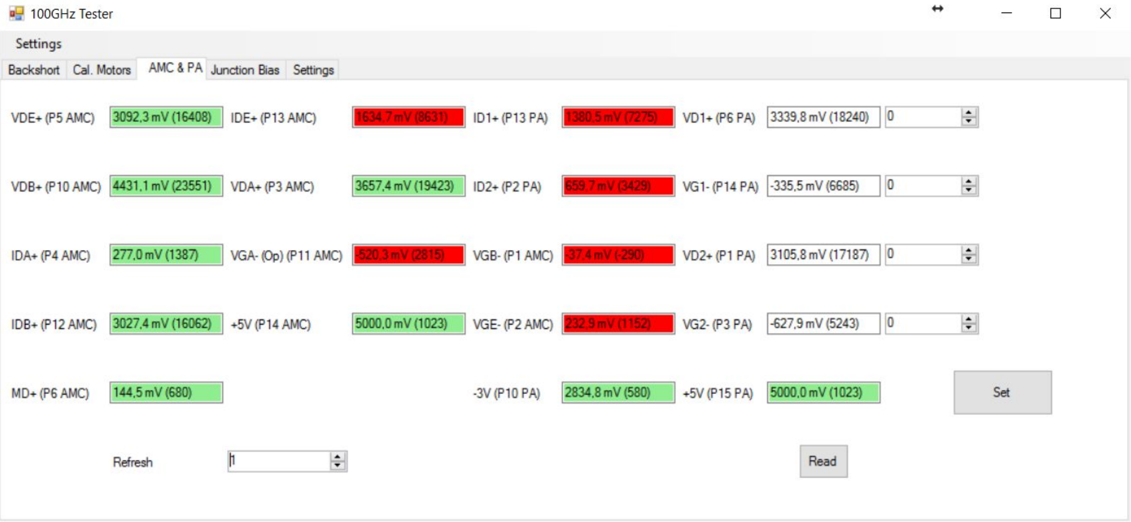


Fig. 3.1.1 a) ALMA LO, b) 3D rendering of ALMA LO control boards; c) ALMA LO control boards.

In order to test the LO control boards; we developed control software based on Microsoft Visual Basic .NET. The control software allows us to read all values of gate voltage monitor and drain current monitor of the AMC and PA modules coming from the ADCs. We implemented a I^{2}C bus to ensure the communication between the ADCs and Arduino, and enabled the communication on the SPI bus between the digital potentiometers and Arduino to allow the setting of the values of drain and gate voltages of the amplifiers. These potentiometers foresee 34-bits, 17-bit for each device, divided as follows:

- 1st bit is unused;
- 2nd bit ÷ 9th bit set the value of drain voltage of the first channel;
- 10th bit ÷ 17th bit set the value of gate voltage of the first channel;
- 18th bit is unused;
- 19th bit ÷ 26th bit set the value of drain voltage of the second channel;
- 27th bit ÷ 34th bit set the value of gate voltage of the second channel.

The GUI of the software we developed for the monitoring and control of the ALMA LO system is shown in Fig. 3.1.2. The PA control section is located on the right part of the interface and utilizes four boxes to set the byte values in a range between 0 and 255. A “*Read*” box allows us to have real-time feedback of points of AMC and PA. In addition, we have a continuous monitoring by setting a time (seconds) in the “*Refresh*” box. The values are highlighted in green, if they are within the normal operating range; otherwise, they are highlighted in red.



VDE+ (P5 AMC) 3092,3 mV (16408)
IDE+ (P13 AMC) 1634,7 mV (8631)
ID1+ (P13 PA) 1380,5 mV (7275)
VD1+ (P6 PA) 3339,8 mV (18240) 0

VDB+ (P10 AMC) 4431,1 mV (23551)
VDA+ (P3 AMC) 3657,4 mV (19423)
ID2+ (P2 PA) 659,7 mV (3429)
VG1- (P14 PA) -335,5 mV (6685) 0

IDA+ (P4 AMC) 277,0 mV (1387)
VGA- (Op) (P11 AMC) -520,3 mV (2815)
VGB- (P1 AMC) -37,4 mV (-290)
VD2+ (P1 PA) 3105,8 mV (17187) 0

IDB+ (P12 AMC) 3027,4 mV (16062)
+5V (P14 AMC) 5000,0 mV (1023)
VGE- (P2 AMC) 232,9 mV (1152)
VG2- (P3 PA) -627,9 mV (5243) 0

MD+ (P6 AMC) 144,5 mV (680)
-3V (P10 PA) 2834,8 mV (580)
+5V (P15 PA) 5000,0 mV (1023)

Refresh 1

Fig. 3.1.2. GUI of the control software we developed for controlling the ALMA LO system.

In order to verify the correct behaviour of the control software and of the ALMA LO system we measured the output power of the PA. Fig. 3.1.3 shows the measured output power of PA channel 1 obtained without adjusting/optimizing the drain voltage of the PA amplifiers (V_{D1}=1.67V and V_{G1}=-0.1V).

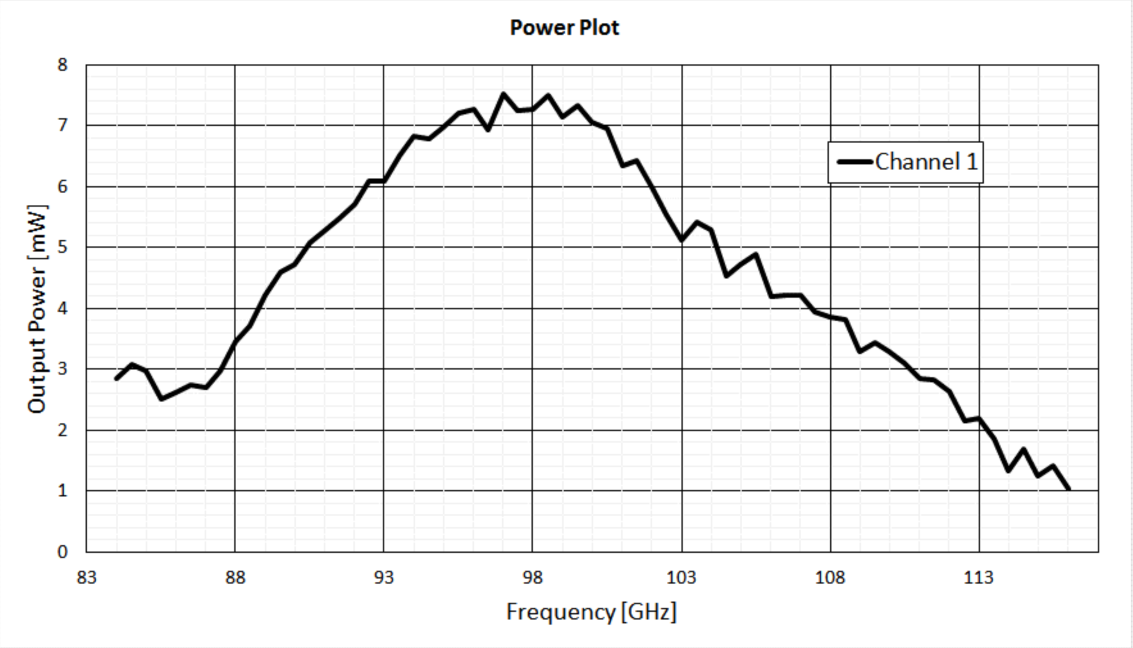


Fig. 3.1.3. Measured output power of channel 1 of LO ALMA.

4. CONCLUSIONS

A 3 mm band SIS receiver that operated for several years in one of the IRAM PdBI antennas is being retrofitted [15] for its future installation in the Gregorian focus of the Sardinia Radio Telescope. Two important modifications made to the original design have been presented. The first one consists of a new and innovative control system based on a single-board computer from Raspberry, microcontrollers from Arduino, and a Python program for communication between the receiver and SRT antenna control software. The second consist of a new control system for an electronically tuned ALMA Band 3 Local Oscillator that we purchased from NRAO.

ACKNOWLEDGMENTS

The authors wish to thank G. Serra for his assistance in the RFI measurements in a shielded room, and A. Poddighe and S.Pilloni for their technical assistance.

REFERENCES

[1] The Sardinia Radio Telescope. Web site: https://www.srt.inaf.it/

[2] J. Blondel, M.Carter, A.Karpov, B.Lazareff, F. Mattiocco and J. Lamb, "Dual-Channel SIS Receivers for the IRAM Plateau de Bure Interferometer", International Journal of Infrared and Millimeter Waves, Vol. 17(12), 2133-2144 (1996).

[3] M. Carter, "Optics for the HDV10 Dual Frequency Band Receiver for the Plateau de Bure Interferometer", IRAM Receiver Technical Memo, n°3, (1994).

[4] B. Lazareff, "IRAM Newsletter n°38" (January 1999).

[5] https://www.raspberrypi.org/products/raspberry-pi-2-model-b/

[6] https://www.arduino.cc/en/Main/ArduinoBoardUnoSMD

[7] J. Cohen, T. Spoelstra, R. Ambrosini, and W. Driel, "CRAF Handbook for Radio Astronomy", European Science Foundation, Third Edition, (2005).

[8] E. Bryerton, K. Saini, M. Morgan, M. Stogoski, T. Boyd and D. Thacker, "Development of Electronically Tuned Local Oscillators for ALMA", 30th Conf. on Infrared and Millimeter Waves & 13th Intl. Conf. on Terahertz Electron, (2005).

[9] K. Saini and J. Muehlberg, "Local Oscillator Driver Users Guide for Bands 3 through 10", ALMA Internal Report, (August 2013).

[10] https://www.adafruit.com/product/1085

[11] A. Navarrini, B. Lazareff, "Design of 129-174 GHz SSB SIS mixer for Band 2 of New Generation Receiver of IRAM PdB Interferometer", Proceedings of the 14th International Symposium on Space Terahertz Technology, p. 450-452, Tucson, AZ, USA, (April 22-24, 2003).

[12] A. Navarrini, B. Lazareff, "275-370 GHz DSB and SSB waveguide mixers employing a tuned Nb/Al-AlOx/Nb SIS tunnel junction", ALMA Memo n. 351, March, 2001. Available at: https://www.alma.nrao.edu/memos/html-memos/alma351/memo351.pdf

[13] A. Navarrini, "Development of DSB and SSB SIS Mixers for Radio Astronomy in the frequency band 250-370 GHz", PhD Thesis, Grenoble, France, (March 14 2002).

[14] A. Navarrini, A.-L. Fontana, D. Maier, P. Serres, D. Billon-Pierron, "Superconductor-Insulator-Superconductor Mixers for the 2 mm Band (129-174 GHz)", Journal of Infrared, Millimeter, and Terahertz Waves, Vol. 35, Issue 6, pp. 536-562, 2014 (DOI 10.1007/s10762-014-0076-x).

[15] A. Ladu, T. Pisanu, A. Navarrini, P. Marongiu, G. Valente, "A 3 mm band SIS Receiver for the Sardinia Radio Telescope", Proc. SPIE 9153 Millimeter, Submillimeter and Far-Infrared Detectors and Instrumentation for Astronomy VII, (July 2014).