CDT Yebes

AGGO S/X Bands Cryogenic Receiver Upgrade

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1. Introduction

This report summarizes the new design and characteristics of the S and X bands cryogenic receiver for the **Argentina – Germany Geodetic Observatory**, AGGO, developed at Technology Development Center, Yebes Observatory.

The receiver is based on a two stage closed cycle cryocooler (CTI-22), the cold stage below 20 K and the intermediate stage, below 70 K.

Specifications

Frequency bands*	S Band: 2.2-2.37 GHz X Band: 8.15-9.0 GHz
Physical Temperature	< 70 K radiation shield < 20 K cold stage
Pressure	$< 10^{-5}$ mbar
Pressure Leaks at room temperature (mainly outgassing)	$< 2 \cdot 10^{-5}$mbar·l/s
Gain	~ 38 dB at S band ~ 36 dB at X band
Noise Temperature	S band: < 10 K X band: < 15 K
Input	S band: N connector X band: waveguide WR-112 S band calibration: SMA X band calibration: SMA
Output	S band: SMA X band: SMA
Output impedance	50 Ω

* IVS Frequency Bands for Geodetic Observations.

2. Enhancements summary

- New bottom dewar flange keeping connection points and orientations.
    - Polishedinnersurface.
    - New vacuumvalveflange.
    - New vacuum sensor flange.
    - Flange design adapted to the cold head (easier He pipes connection).
    - Hermetic Fischer connectors for DC signals.
    - New SMA vacuum connectors.
- New 70 K radiation shield with multilayer insulation.
    - Polished top flange.
- New polished aluminum intermediate stage, 70 K.
- New copper cold stage, 20K.
- Thermal gap and golden piece adjustment.
    - X band transition (waveguide to SMA) and air line measurements.
- New vacuum window made of Halar.
- New DC wiring and RF cabling and external DC cables (housekeeping and LNAs biasing).
- New housekeeping devices.
    - Twovacuumtraps.
    - Two heating resistors and thermostats.
    - Two thermal sensor (new).
- New cold head CTI22 installation.
- New vitono-rings.
- Cooling and vacuum tests (leakage rate measurement).
- LNAs measurements (before installation).
- Receiver performance (noise temperature and gain).
- New Pfeiffer vacuum valve.
- New MKS Broad band vacuum sensor.
- Complete report (specifications, cryostat geometry, CAD drawings, vacuum and cooling tests results, LNAs specifications, user and maintenance manual, safety instructions…).

3. Cryostat geometry

Next figure show the cryostat design overview:

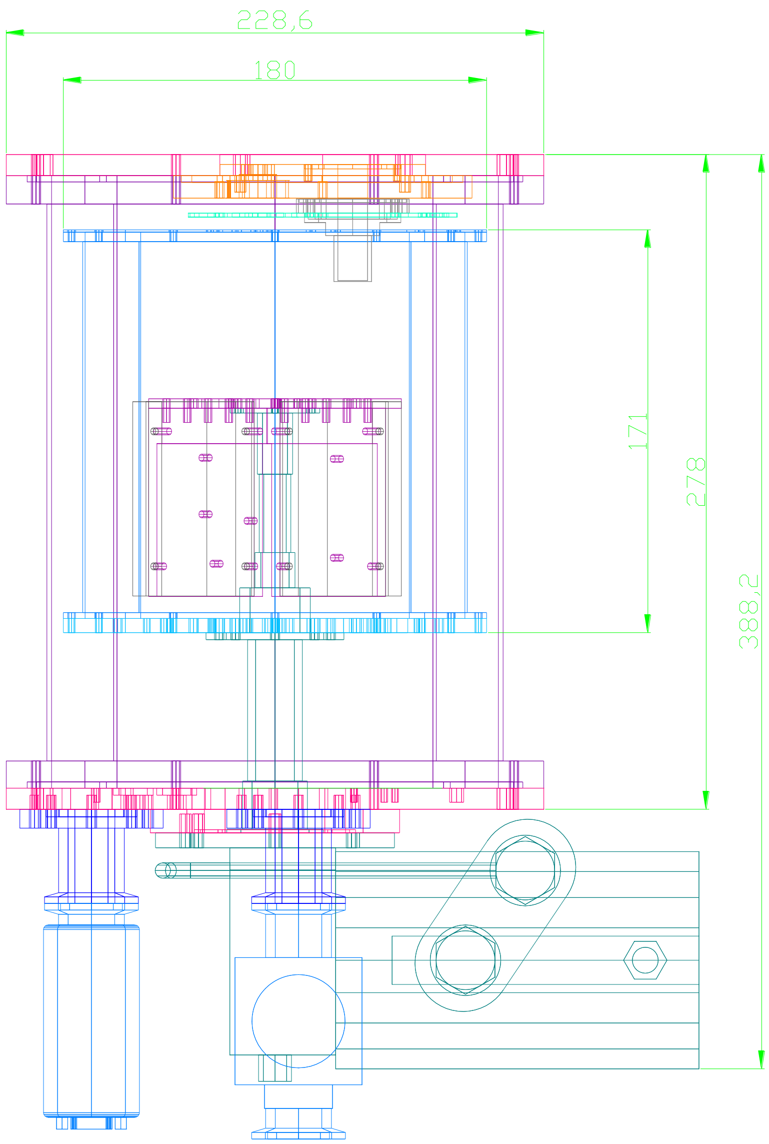


Figure 1.Cryostat overview (cold head (green), vacuum case (violet), radiation shield (blue), cold stage (violet).

The cryostat design is based on the previous cryostat installed at TIGO (Transportable Integrated Geodetic Observatory) in Chile. This new design has been performed carefully due to the little free space inside the cryostat and also taking into account the space in the receiver box.

The cryostat is built over a 22 CTI Model cold head inasteel made cylindrical dewar.At the top cover, a vacuum window lets the X band radiation go through, for the S band a hermetic N connector feedthrough is used. At the bottom cover there are the RF connectors for S and X bands outputs, the flanges for the pressure sensor and vacuum valve, DC cabling and housekeeping connectors.The S band calibration signal input is placed at the top cover and the directional coupler for the X band is outside the dewar, following the vacuum window.

Inside the cryostat, attached to the intermediate stage, there is analuminum made cylindrical radiation shield covered with multilayer insulation (MLI). The temperature of this stage is less than 68 K.Removing the radiation shield, the entire receiver can be easily reached. It is the coldest part of the receiver at,approximately,20 K. Both amplifiers are thermally attached to the copper made cold stage.

The RF cables that connect the amplifierswith the room temperature stage (SMA connectors) and the S band calibration signal inputare coaxial semi-rigid stainless steel cables,UT-085B-SS. The LNAs input cables are coaxial semi-rigid low-loss copper cables, UT-141C-LL.

3.1. Vacuum case

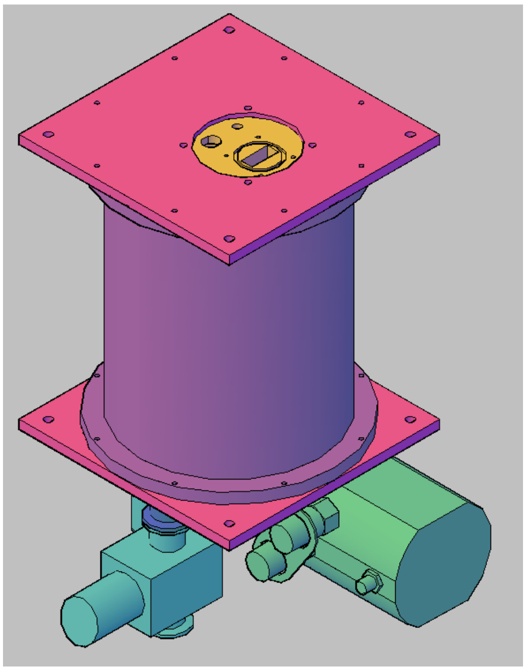


Figure 2.Vacuum case and cold head 3D view.

The dewar consists of three main parts: stainless steel cylinder, bottom flange and top flange. At the top cover the inputs for the X and S bands are presented (vacuum window for X band and N connector adapter for S band) and the S band calibration signal input. The dewar lower flange has several outputs for different uses:

- Cold head connection.
- Two apertures with a transition for the vacuum control (pressure sensor and vacuum valve).
- Three hermetic Fischer connectors for the housekeeping control and monitoring, and amplifiers biasing.
- Two SMA hermetic connectors for the RF output signals.

Inside the dewar, at the bottom cover, there is an aluminum plate to carry out the transition between room temperature DC wiring and the cryogenic wires, using DB connectors.

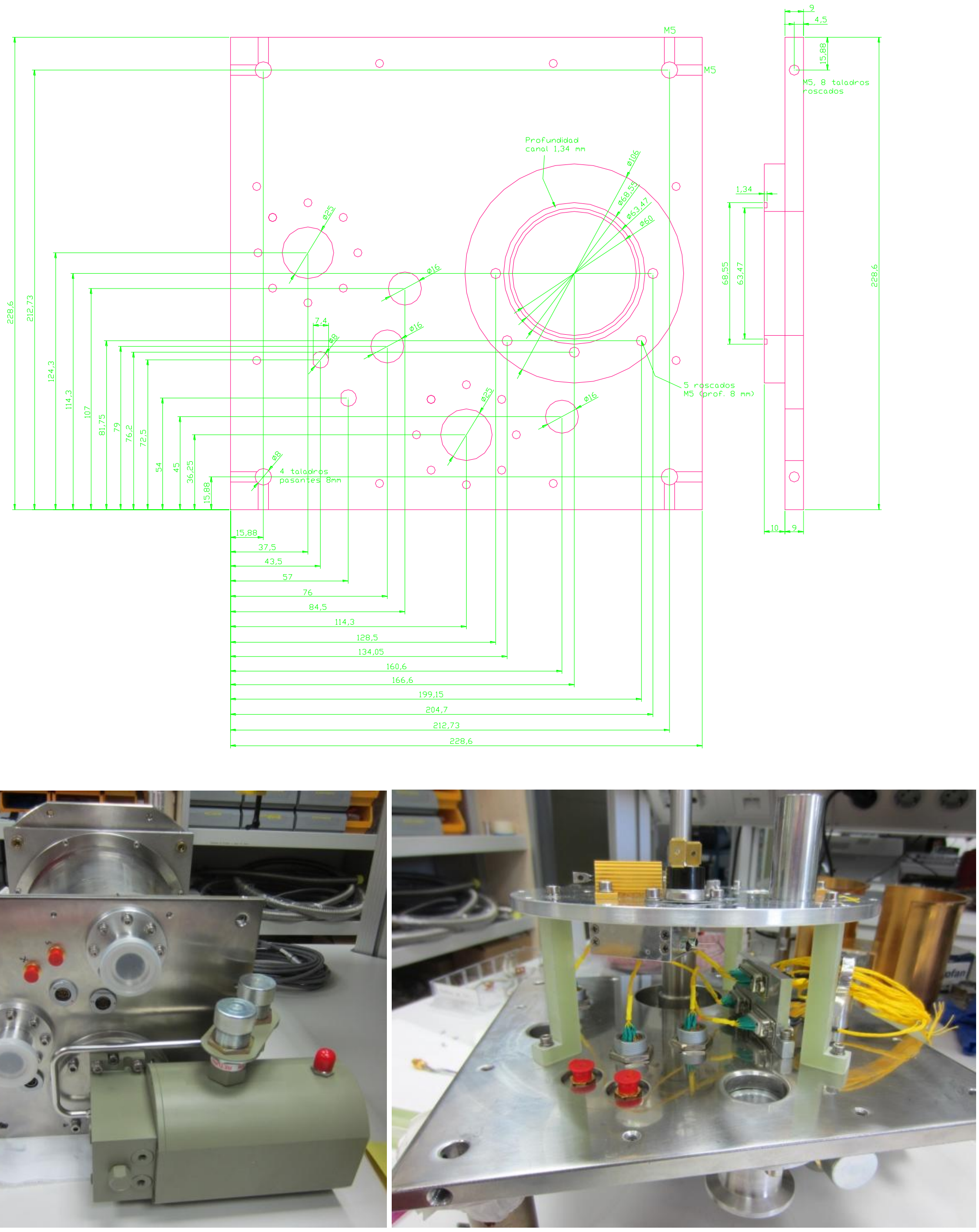


Figure 3. Dewar bottom flange.

3.1.1. Vacuum window*

The vacuum window goal is to allow transition (physical, electromagnetic and vacuum) between the signal and the X band branch inside the cryostat. For this receiver, a vacuum window made of Halar (Ethylene-Chlorotrifluoroethylenecopolyme, thickness 0.125 mm) was selected.

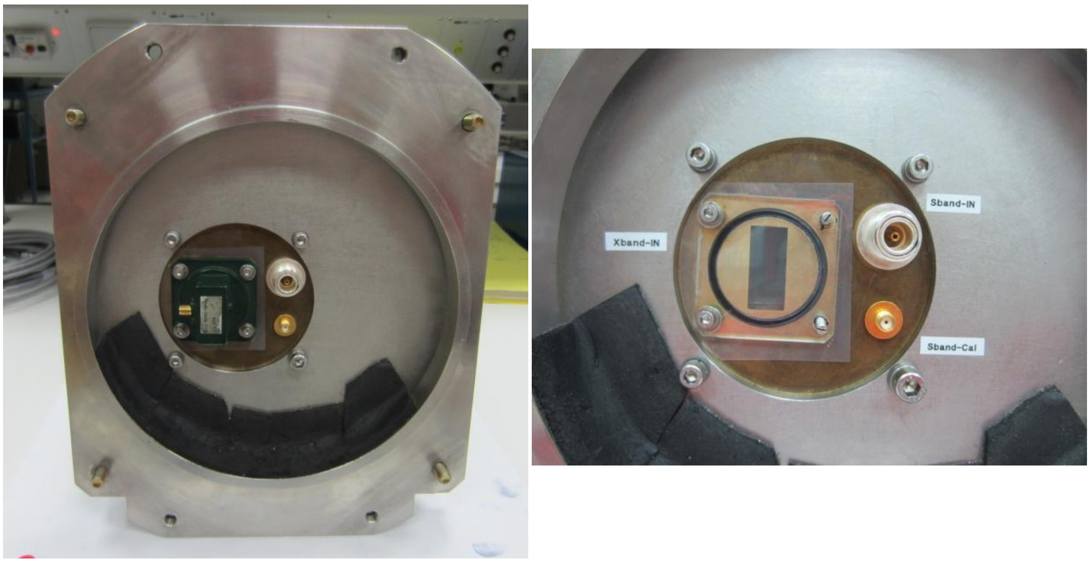


Figure 4.Dewar top flange and vacuum window.

* The goal of this vacuum window was to allow carring out the tests at Yebes Laboratories. Once the receiver is in Argentina the definitive one must be installed (it should be in AGGO attached to the X band waveguide directional coupler).

Figure 5. Vacuum window used at O´Higgins and Wettzell receivers.

3.1.2. Vacuum seals

O-rings with their main specifications and locations are presented in the table below:

Seal	Type	d_1 (mm)	d_2(mm)	Reference	Qty
Vacuum case – top flange and lower flange	OR VI	202.8	3.53	571.943	2
Vacuum window – golden transition	OR VI	34	2.5	461.979	1
Gelden transition – top flange	OR VI	110.72	3.53	305.643	1
Cold head –lower flange	OR VI	63.22	1.78	435.803	1
Vacuum system transitions – lower flange	OR VI	28	4	670.265	2

Table 1: Vacuum seals Epidor. [5]

3.2. Intermediate stage and radiation shield

The intermediate stage is an aluminum plate of 6 mm thickness and 180 mm diameter, screwed onto the first stage of the cold head. Attached to this plate there is an aluminum cylinder to cover the cold stage and reduce the radiation load. The radiation shield is covered with multilayer insulation, MLI (8 layers with a total thickness of ~4 mm) to reduce the radiation thermal load between the intermediate and cold stages.

The Mylar layers used are NRC-2, crinkled aluminized Mylar film 0.006 mm, with a reflectivity of 0.03. The NRC-2 exhibit excellent thermal insulation efficiencies when the pressure inside the receiver is less than 10^{-4} mbar(the pressure reach inside the dewar is usually below 10^{-6} mbar).

On the intermediate stage, there are placed several housekeeping devices: temperature sensor, heating resistor, thermostat and zeolites based vacuum trap. These devices have the following characteristics:

- Heating resistor: 100 Ω, 25 W.
- Zeolites regeneration resistor: the vacuum trap includes a 100 Ω and 2.5 W regeneration resistor.
- Temperature sensor: DT-670 Lakeshore Si-diode.
- Thermostat: 70° ± 3°.

The housekeeping devices allow to achieve a better vacuum inside the cryostat and help to warm up faster the receiver in case it is necessary.

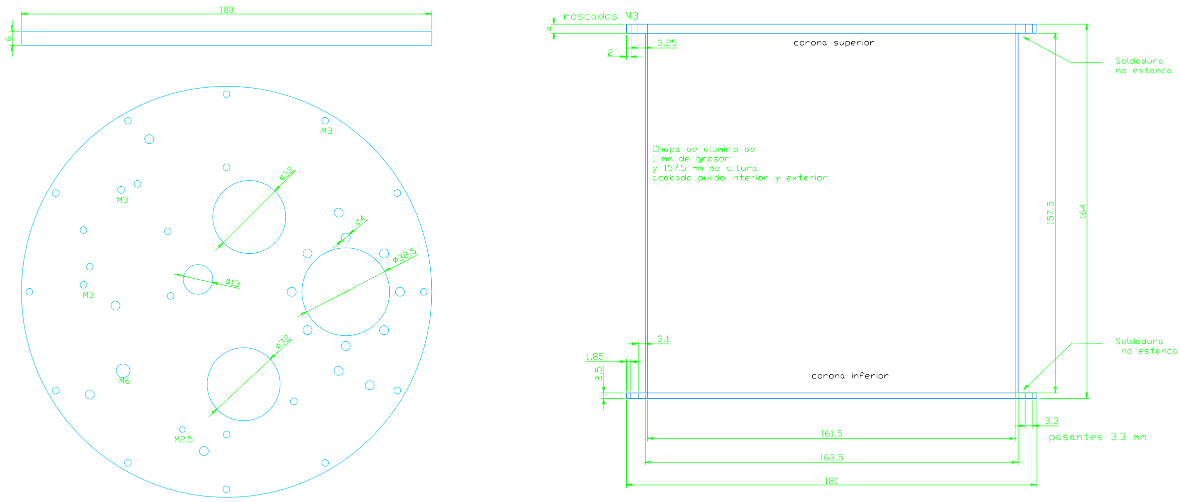


Figure6.Intermediate stage and radiation shield design.

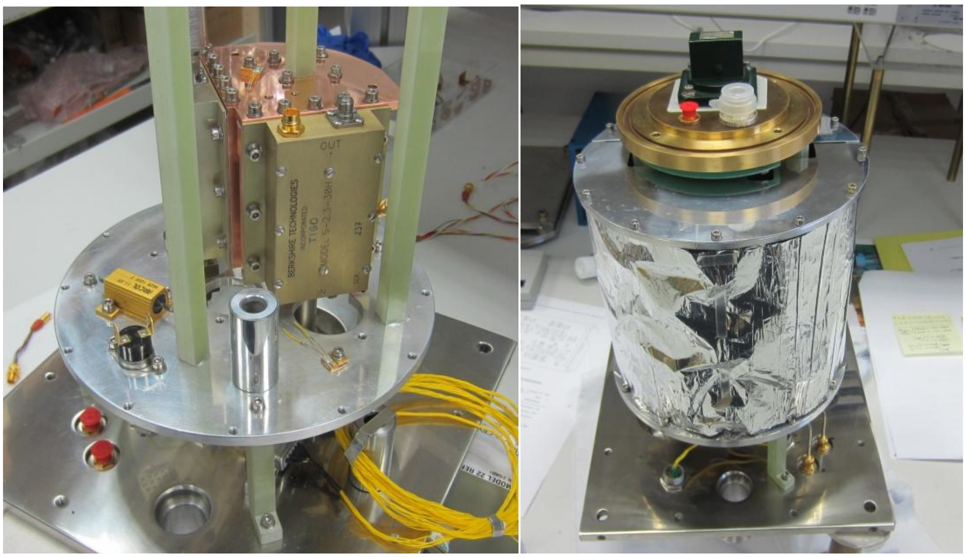
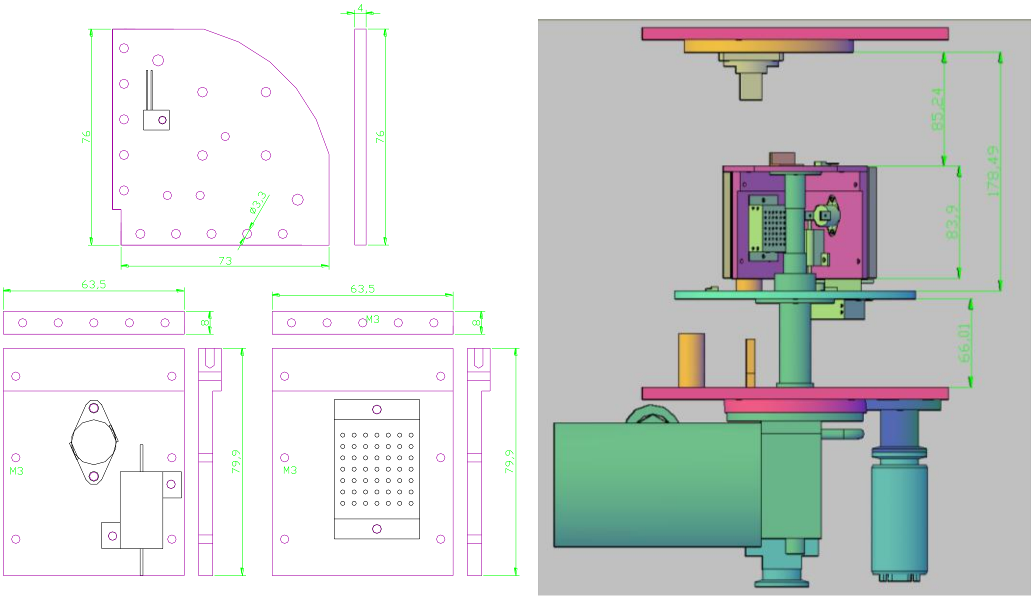


Figure7. Intermediate stage and radiation shield with multilayer insulation.

3.3. Cold stage



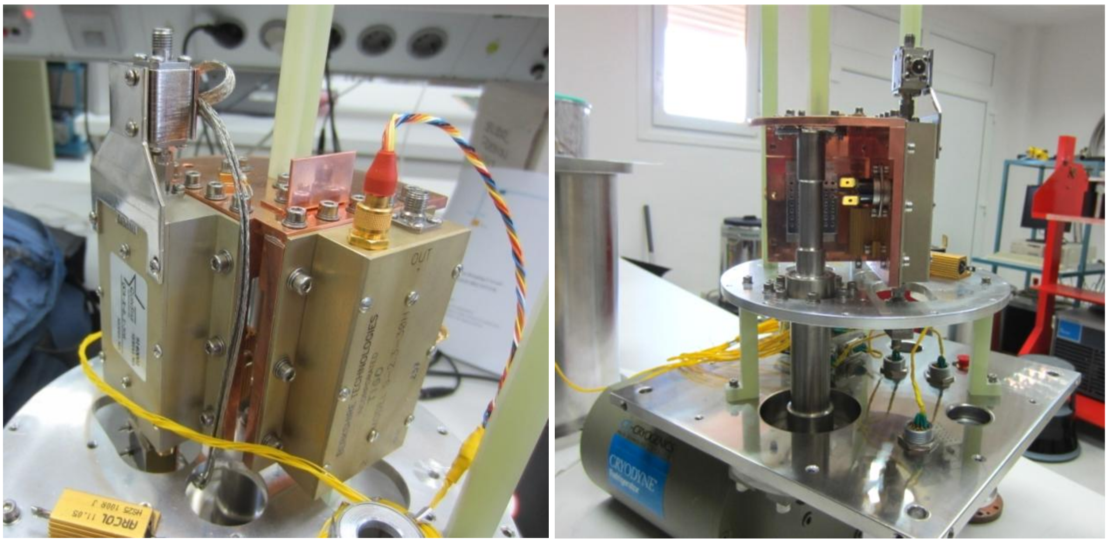


Figure8.Cold stage design with LNAs and housekeeping devices.

The cold stage consists of a three copper plates. The main one is directly attached to the cold head cold stage; the others are screwed to both sides of the first one. Attached to these plates are placed the vacuum trap, thermostat, heating resistor and the temperature sensor (same specifications than the used for the intermediate stage). The S and X LNAs and are attached to the lateral plates.

4. Amplifiers setting-up

The cryostat contains two low noise amplifiers:

LNA/Band	**Berkshire S-2.3-30H 237 S band**	**Quinstar QCA-X-8.5-30H, 91400001 X band**
Optimized between	2.1 – 2.4 GHz	8.0 – 9.0 GHz
Average noise temperature @15K	4.7 K	10.4 K
Average gain @15K	39.9 dB	38.6 dB
∆G(f)	1.2 dB	3.2 dB
Stages	3	3

Table 2. LNAs main specifications measured at Yebes Observatory.

LNAs Biasing

S band optimized between 2.1-2.4GHz

T=300K (optimum)

Vd1	Id1	Vg1	Vd2	Id2	Vg2	Vd3	Id3	Vg3
2.5	10	-0.71	2.5	10	-0.58	2.5	10	-1.01

T=300K (measured)

Vd1	Id1	Vg1	Vd2	Id2	Vg2	Vd3	Id3	Vg3
2.5	10	-0.7	2.5	10	-0.57	2.5	10	-0.99

T=15K (optimum)

Vd1	**Id1**	**Vg1**	**Vd2**	**Id2**	**Vg2**	**Vd3**	**Id3**	**Vg3**
2	**6**	**-0.66**	**2**	**6**	**-0.54**	**1.5**	**10**	**-0.81**

T=15K (measured)

Vd1	Id1	Vg1	Vd2	Id2	Vg2	Vd3	Id3	Vg3
2	6	-0.63	2	6	-0.53	1.5	10	-0.81

X band optimized between 8.0-9.0GHz

T=300K (with I/O isolators) (optimum)

Vd1	Id1	Vg1	Vd2	Id2	Vg2	Vd3	Id3	Vg3
2	15	-0.44	1	15	-0.26	1.5	15	-0.24

T=300K (with I/O isolators) (measured)

Vd1	Id1	Vg1	Vd2	Id2	Vg2	Vd3	Id3	Vg3
2	15	-0.43	1	15	-0.24	1.5	15	-0.22

T=15K (No isolators) (optimum)

Vd1	**Id1**	**Vg1**	**Vd2**	**Id2**	**Vg2**	**Vd3**	**Id3**	**Vg3**
2.5	**6**	**-0.66**	**1**	**5**	**-0.42**	**3**	**5**	**-0.64**

T=15K (with isolators) (measured)

Vd1	Id1	Vg1	Vd2	Id2	Vg2	Vd3	Id3	Vg3
2.5	6	-0.65	1	5	-0.35	3	5	-0.63

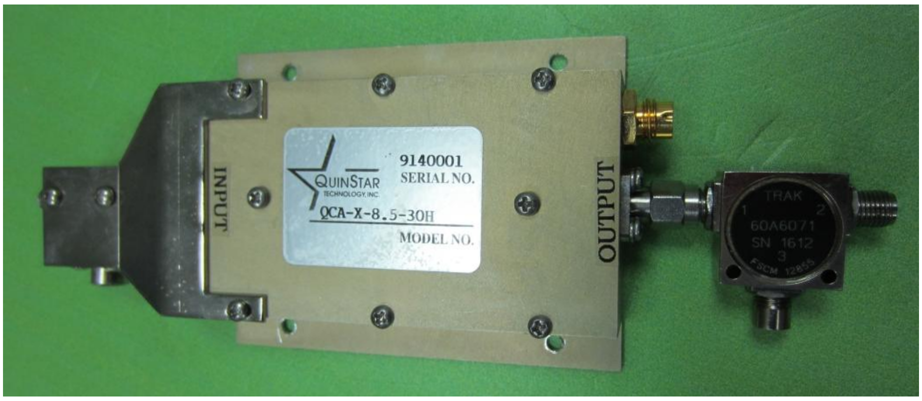


Figure9.X band LNA with I/O isolators.

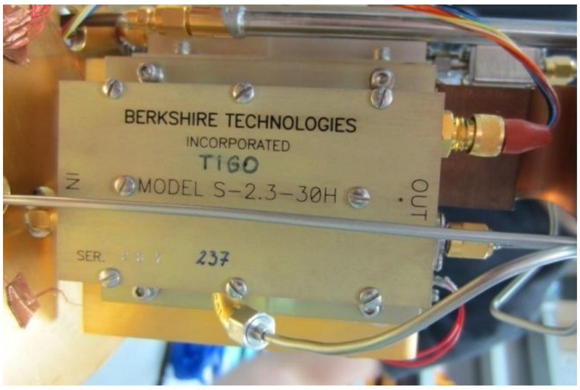


Figure10.S band LNA.

5. Internal and externalDC wiring

There are 3 hermetic Fischer connectors at the dewar bottom flange:

- One of them, with 16 pin, for monitoring signals and housekeeping.
- Two of them, with 11 pin, for the amplifiers biasing signals.

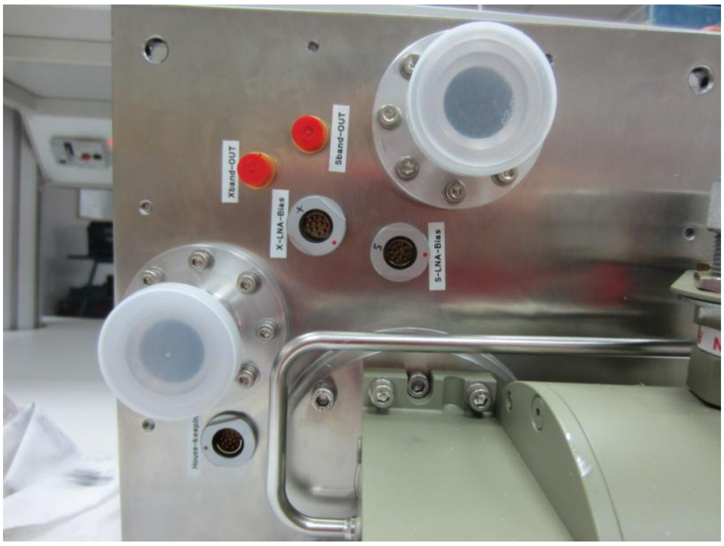


Figure 11. SMAs and Fischer connectors at dewar bottom flange.

Hermetic Fischer Connector	Description
Housekeeping	16 pin Pol2=
S-LNA-Bias	11 pin Pol1=
X-LNA-Bias	11 pin Pol2=

Next figures show the Fischer connectors pin-out (11 and 16 pin):

Figure 12. 11 pin Fischer ("wire" connector view (female), red point up).

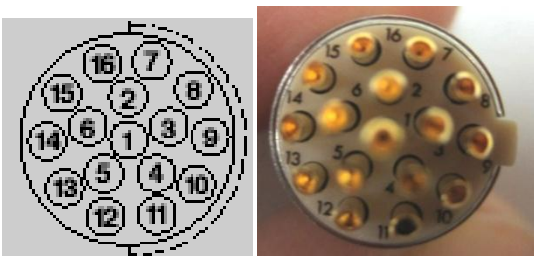


Figure 13. 16 pin Fischer ("wire" connector view (female), red point up).

The DC wiring has been done using small section long cables (Kynar 30 awg.) to reduce the conduction thermal load.

5.1.1. Low Noise Amplifiers biasing wiring

Next figures show the **amplifier biasing connectors pin-out**:

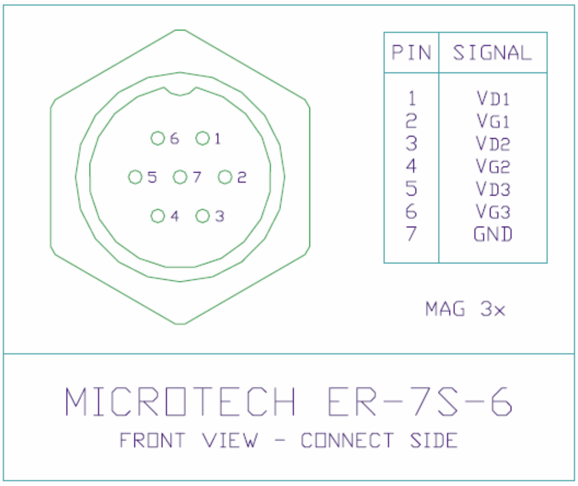


Figure 14.DC connector pin-out, S and X bands LNAs.

Biasing cables pin-out

Signal	Microtech Wiring side	DB9	Fischer Pin	Wire Color	DB9	Notes
V_{g3}	1	1	1	Black	7	Temporary end (for the tests carried out at Yebes)
V_{d3}	2	2	2	Violet	6	
V_{g2}	3	3	3	Grey	5	
V_{d2}	4	4	4	White	4	
V_{g1}	5	5	5	Red	3	
V_{d1}	6	6	6	Brown	2	
GND	7	7	7	Orange	1	

Table 3.**S band LNA**biasing cable (from the LNA to the external cable).

Signal	Microtech Wiring side	DB9	Fischer Pin	Wire Color	DB9	Notes
V_{g3}	1	1	1	Black	7	Temporary end (for the tests carried out at Yebes)
V_{d3}	2	2	2	Brown	6	
V_{g2}	3	3	3	Orange	5	
V_{d2}	4	4	4	Green	4	
V_{g1}	5	5	5	Yellow	3	
V_{d1}	6	6	6	Red	2	
GND	7	7	7	White	1	

Table 4.**X band LNA** biasing cable (from the LNA to the external cable).

5.1.2. Housekeeping wiring

At the room temperature stage (300 K), there is a 16 pin Fischer connector placed for the cryostat internal monitoring signals:heating resistors, zeolites regeneration resistors, temperature sensors and thermostats.

Signal	Description
Ti_+	Intermediate stage temperature sensor (+)
Ti_-	Intermediate stage temperature sensor (-)
Tc_+	Cold stage temperature sensor (+)
Tc_-	Cold stage temperature sensor (-)
Calef_on	Signal to activate the heaters after passing through the thermostat
Regen_on	Signal to activate the zeolites regeneration resistor
GND_res	Ground
Calef_mon	Heaters monitor
Regen_mon	Regenerators monitor

Table 5. Housekeeping signals description.

A 2.5-meters-lenght cable connects the receiver with the different housekeeping signals. At one end there is the 16 pin Fischer connector to be plugged to the receiver. The other end contains the following elements:

Signal	DB15	Fischer Pin	Wire color	DB25	Notes
Ti_+	1	1	Black	3-4	Temporary end (for the tests carried out at Yebes)
Ti_-	2	2	Grey	15-16	
Tc_+	3	3	White	6-7	
Tc_-	4	4	Red	18-19	
Calef_on	5	5	Orange		Open end
Regen_on	6	6	Yellow		
GND_res	7	7	Green		
Calef_mon	8	8	Blue		
Regen_mon	9	9	Violet		

Table 6.Housekeeping cable pin-out.

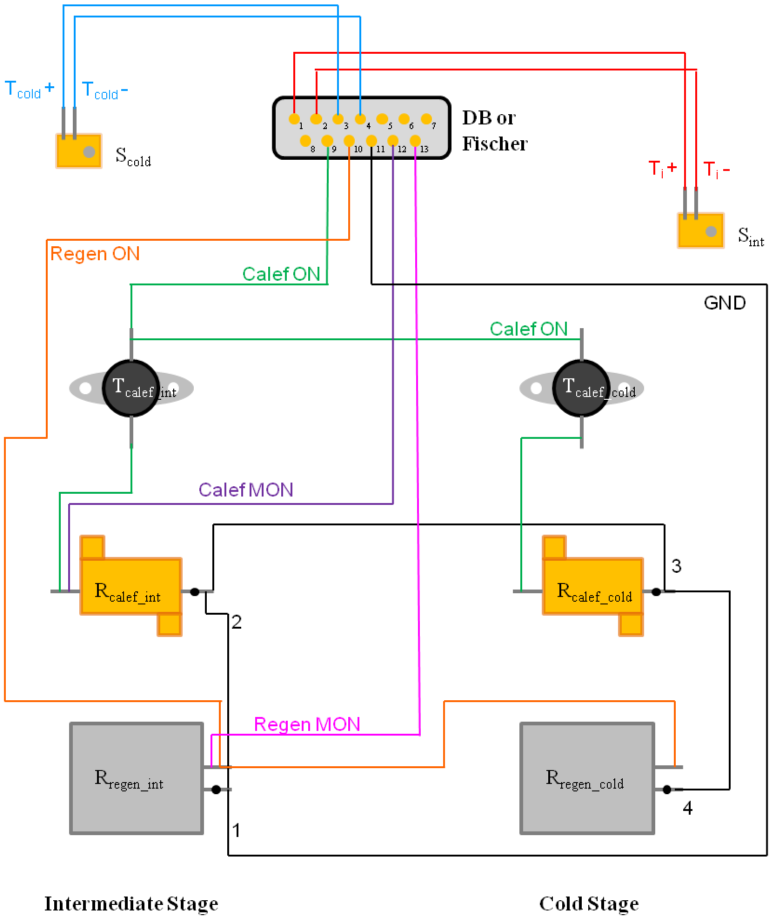


Figure 15.Housekeeping circuit scheme.

6. Cryogenic system

This receiver uses a Model 22CTI-Cryogenics Cold Head, with the following characteristics:

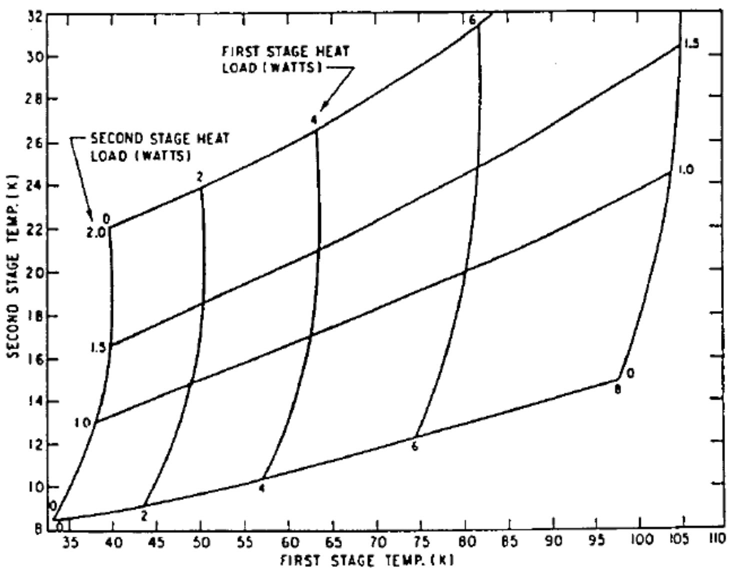


Figure16.22C cryodynecryocoolertypical refrigeration capacity (50 Hz).

7. Cryostat thermal and vacuum behavior

Several tests have been performed to determine the cryostat thermal and vacuum behavior. Cooling and pumping systems:

- Cold head: CTI 22.
- Compressor: CTI 8200, 220 V-50 Hz.
- Vacuum system:
  - Rotary pump and turbomolecular pump (Alcatel).
  - Vacuum sensors (MKS): Pirani sensor (pressure from atmospheric to 10^{-4} mbar) and cold cathode (pressure from 10^{-4} mbar to 10^{-8} mbar).

Measurement,**final results**:

- Intermediate stage temperature: **from 59 K @ 15°C (room temp.) to 68 K @ 25°C**.
- Cold stage temperature: **from 19 K @ 15°C to 22 K @ 25°C**.
- Vacuum **<10^{-6} mbar** (cryogenic vacuum).
  - Leakage rate $1.034 \cdot 10^{-5}$mbar·l/s ($1.402 \cdot 10^{-6}$ mbar/s) (volume 7.37l).
- Cooling down time:**<10 h.**
- Warming up time:≈13.5h (or <3.5hwith zeolites regeneration and heating resistors turned on).

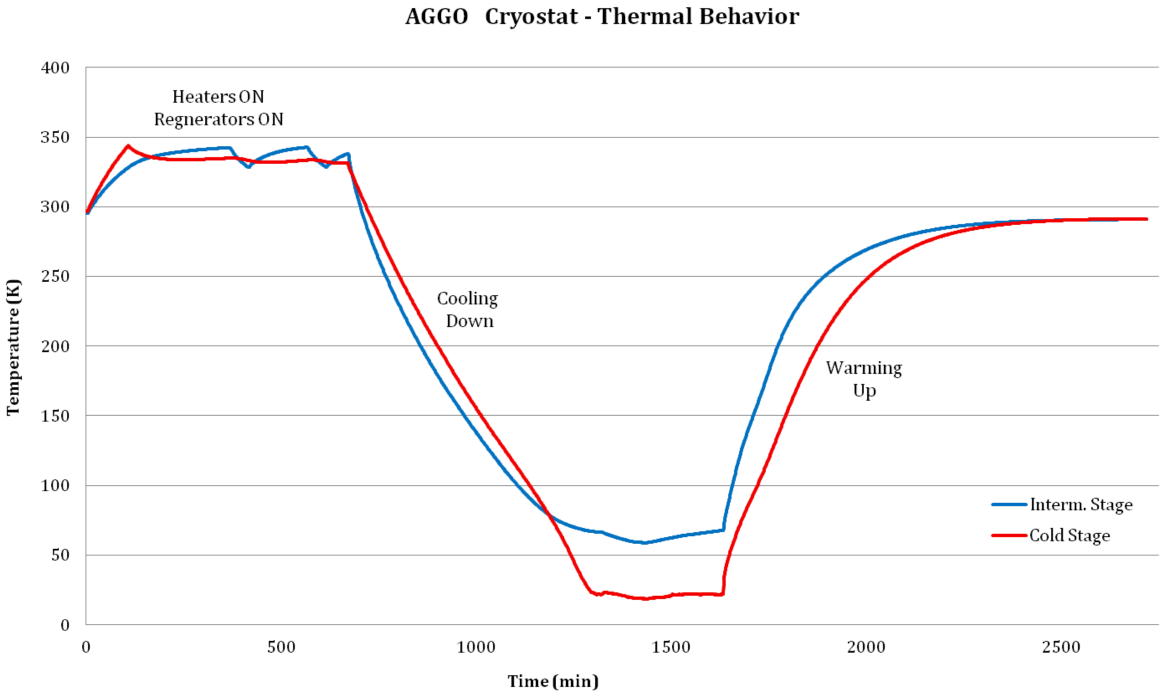


Figure 17.**Heating / Cooling down /warming up testing.**

- From ambient temperature it takes approximately 2 hours to reach +70°C in the cold stage (with heaters $V = -25V$ and regenerators $V = +6V$).
- Cooling down process takes 10 hours from ambient temperature down to final T_{cold} and T_{int}. Dewar pressure 1.3×10^{-7} mbar.Compressor pressure (dynamic) 290-300 psi.
- Warming up (without heaters) takes around 800 min.

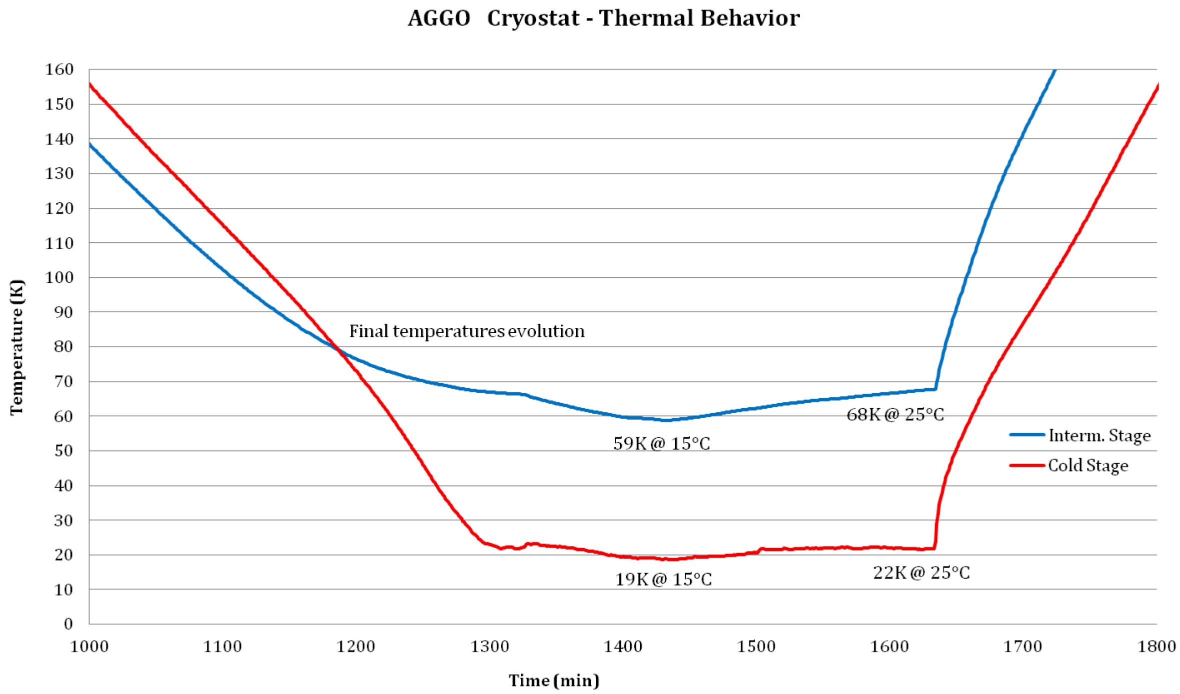
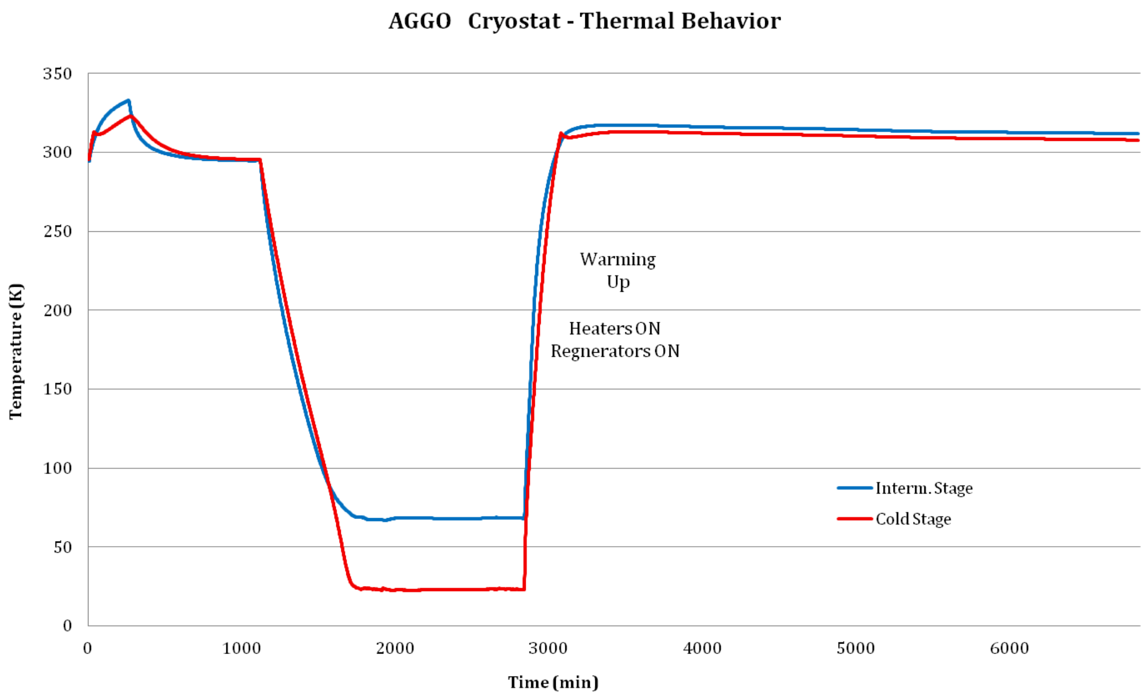


Figure 18.**Final temperatures evolution**depending on room temperature.



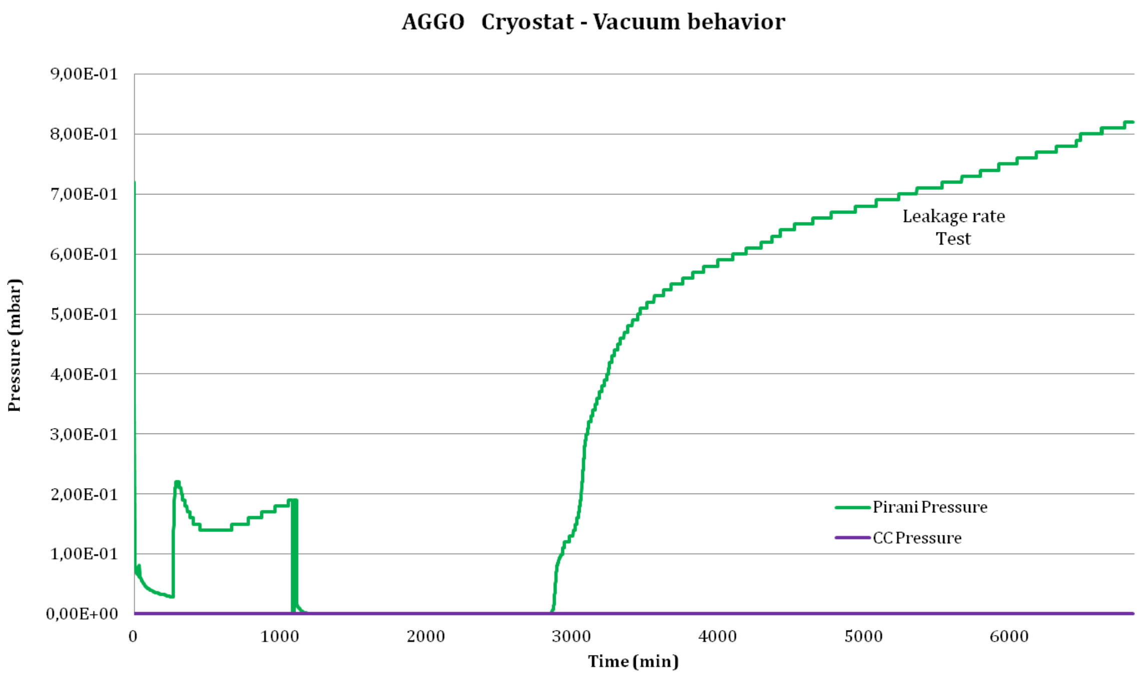


Figure 19.**Cooling and vacummtesting**.

- Warming up (with heaters ON) takes around 210 min.

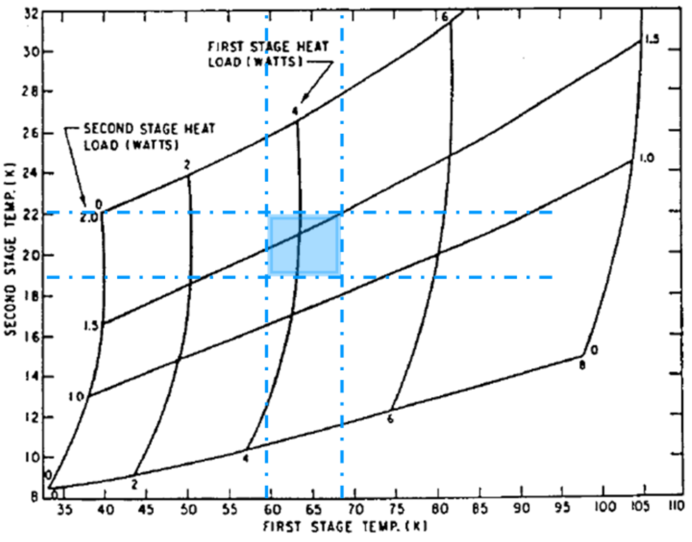


Figure 20.**Intermediate stage load (3.5, 4.7)W**, **cold stage load (1.3, 1.5) W**.

8. Receiver calibration: noise temperature, gain and coupling

The Y factor method has been used to calibrate the receiver (measure the noise temperature). The noise temperature measurement is carried out connecting the receiver input to different adapted loads with known temperatures.

When the load at the input has a temperature, T_H, the power at the output is P_H, hot load. If a second measure is done with a load with a different temperature, T_C, the power will be different, P_C, cold load. Then, the receiver noise temperature can be calculated by the following expressions:

$$T_{RX} = \frac{T_H - Y \cdot T_C}{Y - 1} \text{ where } \quad Y = \frac{P_H}{P_C}$$

This method is based on the hypothesis that the receiver behavior is linear between P_H and P_C.

The thermal loads used, for these measurements, are:

- Hot load: coaxial cable with SMA 50 Ω load at room temperature, ≈ 297 K.
- Cold load: coaxial cable with SMA 50 Ω load submerged in liquid nitrogen, ≈ 77 K.

The following results shows the receiver noise temperature without taking into account the losses due to the cables, SMA connectors, etc.

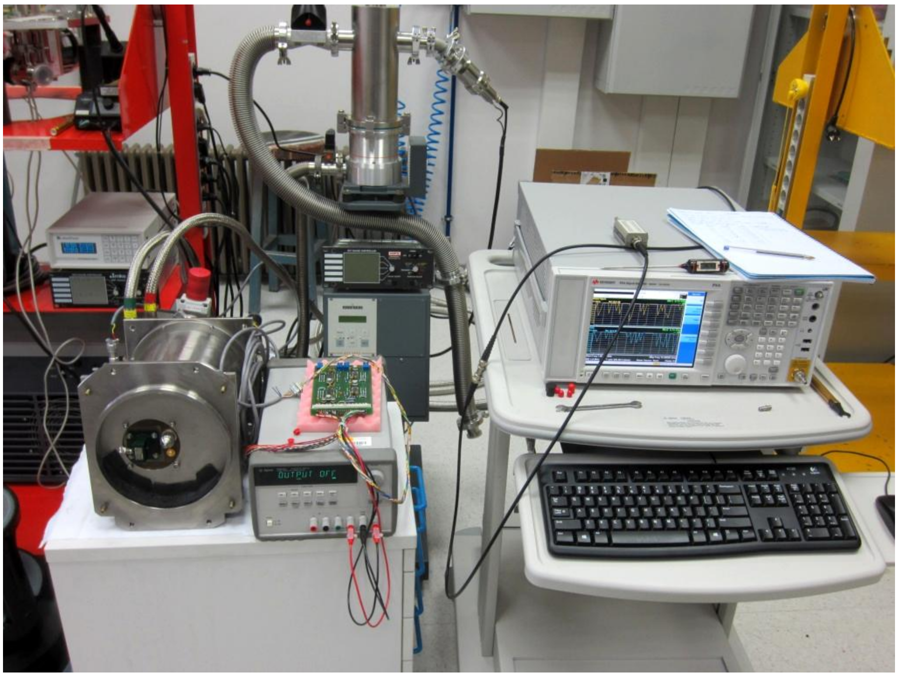
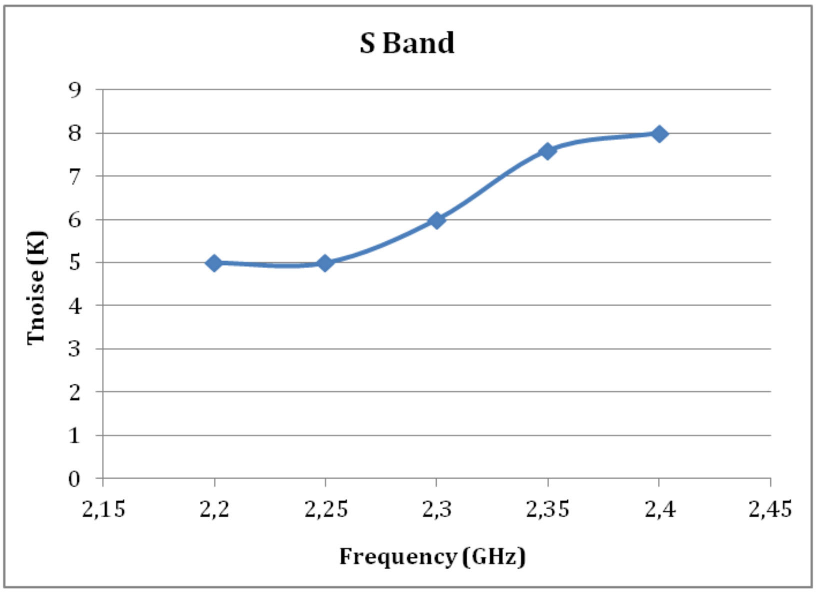


Figure 21.Receiver calibration.

Receiver Noise Temperature measured at cold temperature

S Band LNA, T_{cold}~22K	
T_H = 297 K	T_C = 77.3 K
Freq. (GHz)	**Noise Temp. (K)***
2.2	**5**
2.25	**5**
2.3	**6**
2.35	**7.6**
2.4	**8**
*T_{rx}affectedby RFI	

X Band LNA, T_{cold}~22K	
T_H = 297 K	T_C = 77.3 K
Freq. (GHz)	**Noise Temp. (K)**
8	**8.8**
8.2	**8.8**
8.4	**9.3**
8.6	**13.2**
8.8	**13.6**
9	**15.5**



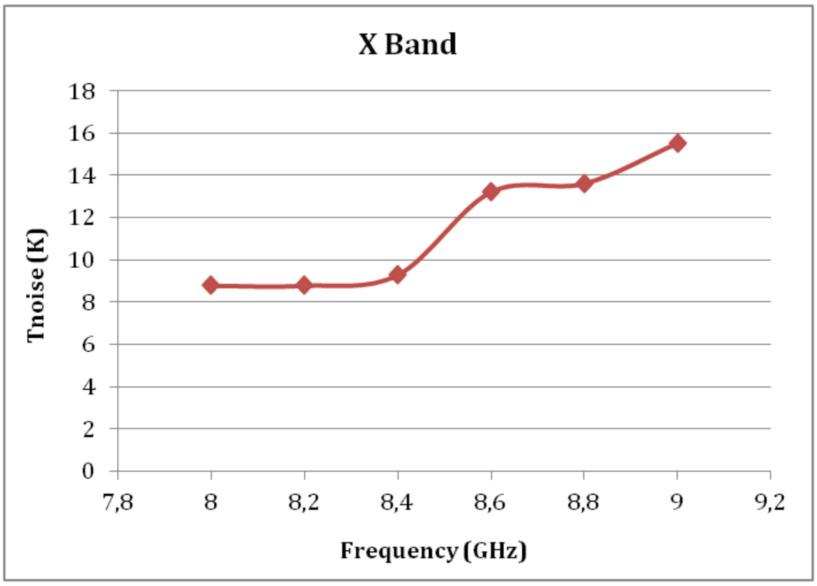
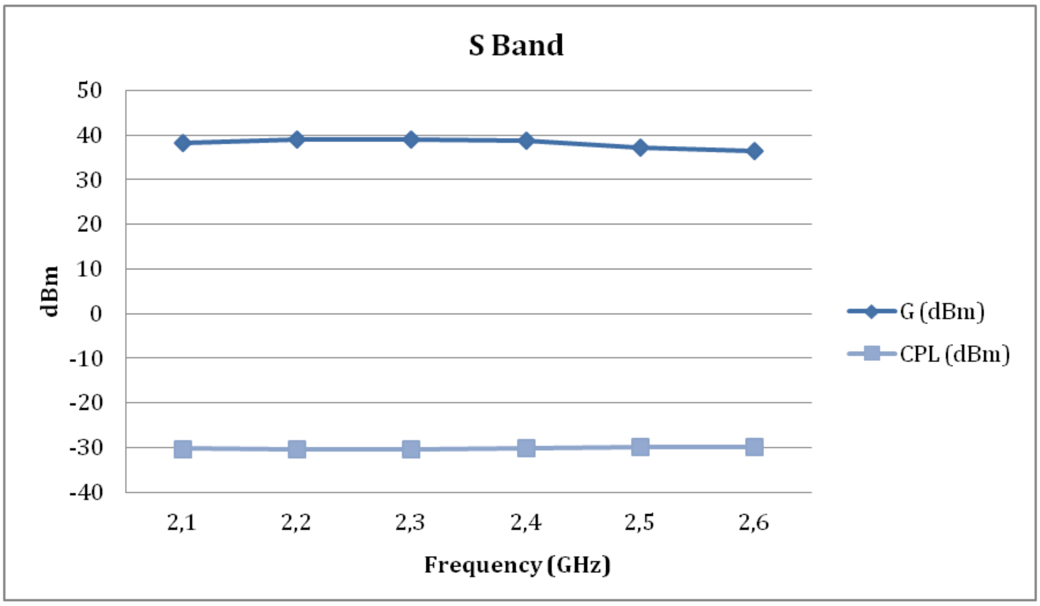


Figure 22.T_{RX} at cold temperature (**LNAs at ≈ 22 K**).

Receiver Gain and Coupling measured at cold temperature

S Band		
Freq. (GHz)	**Gain (dB)**	**Coupling (dB)**
2.1	38.3	-30.3
2.2	38.9	-30.5
2.3	39.1	-30.5
2.4	38.7	-30.1
2.5	37.2	-29.8
2.6	36.5	-29.9

X Band	
Freq. (GHz)	**Gain (dB)**
8	37.7
8.1	37.3
8.2	37.1
8.3	36.9
8.4	36.9
8.5	36.6
8.6	36.1
8.7	36
8.8	35.8
8.9	35.1
9	34.5



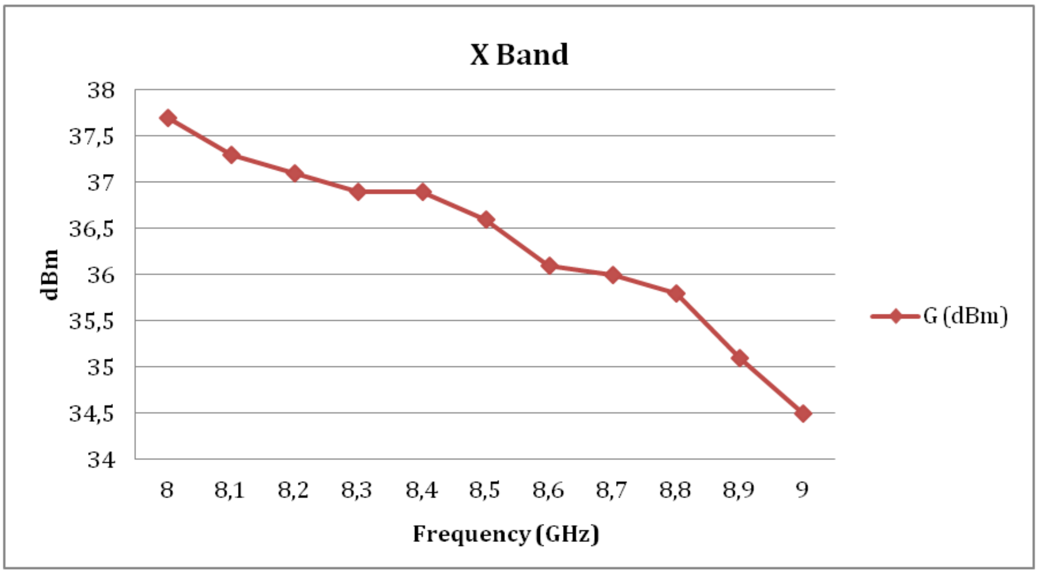


Figure 23. Gain and coupling at cold temperature (LNAs at ≈ 22 K).
At X band the directional coupler is outside the dewar.

9. Installation, first use and switch off

For receiver installation proceed as follows:

- Vacuum controller, temperature monitor system, LNA bias module and RF module must be switched off.

- **Pumping**
  - Connect housekeeping cable to the Fischer connector at cryostat rear side (Housekeeping).
  - Connect the vacuum controller to the vacuum sensor Quadmag.
  - Connect the vacuum valve to the corresponding vacuum flange (the valve must be closed).
  - Switch on the vacuum controller. The vacuum sensor will start the set up and a green led will light continuously when ready. The vacuum controller will show atmospheric pressure.
  - Switch on the temperature monitor (housekeeping cable has a (temporary) DB25 connector for a Lakeshore connector input). The temperature of the first 2 channels will be around room temperature.
  - Connect the vacuum system (rotary pump and turbomolecular) to the vacuum valve.
  - Start running the rotary pump for a few minutes.
  - Slowly open the valve. The vacuum level will start to decrease. During this procedure avoid any abrupt opening of the valve. When the vacuum is about 10^{-1} mbar, start turbomolecular operation.
  - Connect the regeneration resistor (yellow wire with an appropriate connector) to a power supply.
    - Green wire: GND
    - Yellow wire:+6 V, ≈118 mA
  - Connect the heating resistor (orange wire with an appropriate connector) to a power supply.
    - Green wire: GND
    - Orange: +25 V, ≈489 mA
  - Leave the system running in the above conditions for 12 hours. Then, the resistors can be turned off. The vacuum system should be pumping at least for 12 more hours.

- **Connecting the helium compressor**

  Warning! Be sure the helium pipes and compressor pressure is correct (as indicated in the user's manual) and they are not contaminated.
  - Remove all dust plugs and caps from the helium supply and return lines, compressor and cold head. Check all fittings.
  - Connect the helium return line between the compressor and the cold head.
  - Connect the helium supply line between the compressor and the cold head.
  - Verify proper helium supply static pressure (245 psi for CTI 8200 compressor). If the indicated pressure is not the specified by the compressor manufacturer, follow the instructions supplied by the manufacturer.
  - Connect the cold head cable between the compressor and the cold head.

Figure 24.O´Higgins cryostat vacuum and cooling test.

- **Connecting the LNAs biasing module**
    - Connect the LNAs biasing module to a power supply (+15 V, -15 V, GND). Power supply off.
    - Plug the S and X bands LNAs biasing cables between the LNA Bias Module and the cryostat (Fischer connectors).
    - The LNAs biasing points are already set up. In case a verification or change is needed, go to chapter 6.
    - Turn on the power supply (verify correct electric current values).

- **First use**

  After 24 hours pumping the system is ready to start the cooling down process.

  Warning!Be sure your vacuum system can be used during cooling process. For carrying out this process, (usually) it is necessary to have a rotary and a turbomolecular pump. Just using a rotary pump, at low temperatures, can cause vacuum inversion. It is important to verify the turbomolecular pump behavior during the process.

    - The pressure inside the receiver should be at $5 \cdot 10^{-3}$ mbar or lower.
    - Switch on the compressor.The temperatures will start decreasing.
    - The vacuum valve has to be opened until the intermediate stage reaches, at least,120K. If it is allowed by the pumping system, the valve can be opened until the system achieves the final temperatures.
    - After 10-11 hours the cryostat will reach its operational cryogenic temperature and pressure.

Temperature radiation shield	< 70 K
Temperature cold stage	< 20 K
Pressure	< 10^{-5} mbar

- **Switch off**

  For switching off the system proceed as follows:

    - Be sure that the pumping valve is closed.
    - Switch off the compressor.
    - Switch off the LNAs biasing module.

- Leave the cryostat warming to room temperature. This can be verified at the temperature monitor. This process can be accelerated by turning on the heating resistors (+25 V) and the zeolites regeneration resistors (+6 V).
- Once the system is at room temperature, open slowly the vacuum valve to achieve atmospheric pressure inside the cryostat.

Warning! Be careful with the temperature values when using zeolites regeneration and heating resistors to warm the cryostat. Once the final room temperature is achieved, do not to open the dewar immediately. It is necessary to wait for a few minutes for the temperature system to be stabilized with the resistors turned off. If the dewar is opened too soon, water vapor can appear inside the cryostat and it could cause damages.

10. References

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11. Appendix

11.1. Temperature sensors specifications

Silicon Diodes

DT-670-SD Features

- Best accuracy across the widest useful temperature range—1.4 K to 500 K—of any silicon diode in the industry
- Tightest tolerances for 30 K to 500 K applications of any silicon diode to date
- Rugged, reliable Lake Shore SD package designed to withstand repeated thermal cycling and minimize sensor self-heating
- Conformance to standard DT-670 temperature response curve
- Variety of packaging options

DT-670E-BR Features

- Temperature range: 1.4 K to 500 K
- Bare die sensors with the smallest size and fastest thermal response time of any silicon diode on the market today
- Non-magnetic sensor

DT-621-HR Features

- Temperature range: 1.4 K to 325 K*
- Non-magnetic package
- Exposed flat substrate for surface mounting

** Calibrated down to 1.4 K, uncalibrated (Curve DT-670) to 20 K*

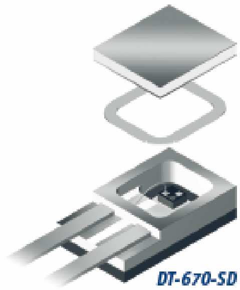
***CAUTION:** These sensors are sensitive to electrostatic discharge (ESD). Use ESD precautionary procedures when handling, or making mechanical or electrical connections to these devices in order to avoid performance degradation or loss of functionality.*

DT-670 Silicon Diodes

DT-670 Series Silicon Diodes offer better accuracy over a wider temperature range than any previously marketed silicon diodes. Conforming to the Curve DT-670 standard voltage versus temperature response curve, sensors within the DT-670 series are interchangeable, and for many applications do not require individual calibration. DT-670 sensors in the SD package are available in four tolerance bands – three for general cryogenic use across the 1.4 K to 500 K temperature range, and one that offers superior accuracy for applications from 30 K to room temperature. DT-670 sensors also come in a seventh tolerance band, Band E, which are available only as bare die. For applications requiring greater accuracy, DT-670-SD diodes are available with calibration across the full 1.4 K to 500 K temperature range.

The bare die sensor, the DT-670E, provides the smallest physical size and fastest thermal response time of any silicon diode on the market today. This is an important advantage for applications where size and thermal response time are critical, including focal plane arrays and high temperature superconducting filters for cellular communication.

PACKAGING OPTIONS BO, BR, CO, CU, CY, ET, LR, MT



DT-670-SD

The Lake Shore SD Package – The Most Rugged, Versatile Package in the Industry

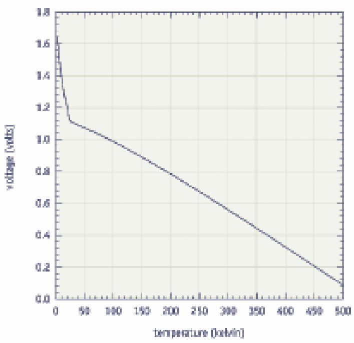
The SD package, with direct sensor-to-sapphire base mounting, hermetic seal, and brazed Kovar leads, provides the industry's most rugged, versatile sensors with the best sample to chip connection. Designed so heat coming down the leads bypasses the chip, it can survive several thousand hours at 500 K (depending on model) and is compatible with most ultra high vacuum applications. It can be indium soldered to samples without shift in sensor calibration. If desired, the SD package is also available without Kovar leads.

DT-621-HR Miniature Silicon Diode

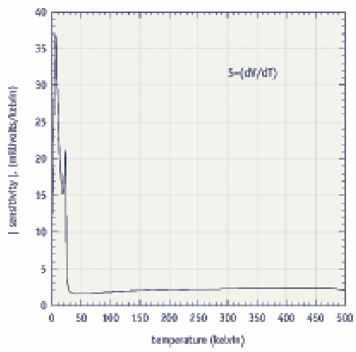
The DT-621 miniature silicon diode temperature sensor is configured for installation on flat surfaces. The DT-621 sensor package exhibits precise, monotonic temperature response over its useful range. The sensor chip is in direct contact with the epoxy dome, which causes increased voltage below 20 K and prevents full range Curve DT-670 conformity. For use below 20 K, calibration is required.

DT-621-HR

Typical DT-670 Diode Voltage Values



Typical DT-670 Diode Sensitivity Values



11.2. Vacuum Window Specifications

Technical Information - Ethylene-Chlorotrifluoroethylene copolymer Close

Ethylene-Chlorotrifluoroethylene copolymer

E-CTFE

We stock and supply the following standard forms:

Common Brand Names:	Halar
General Description:	General Description : An expensive, melt processable, semi-crystalline, whitish semi-opaque thermoplastic with good chemical resistance and barrier properties. It also has good tensile and creep properties and good high frequency electrical characteristics. Applications include chemically resistant linings, valve and pump components, barrier films and release/vacuum bagging films.

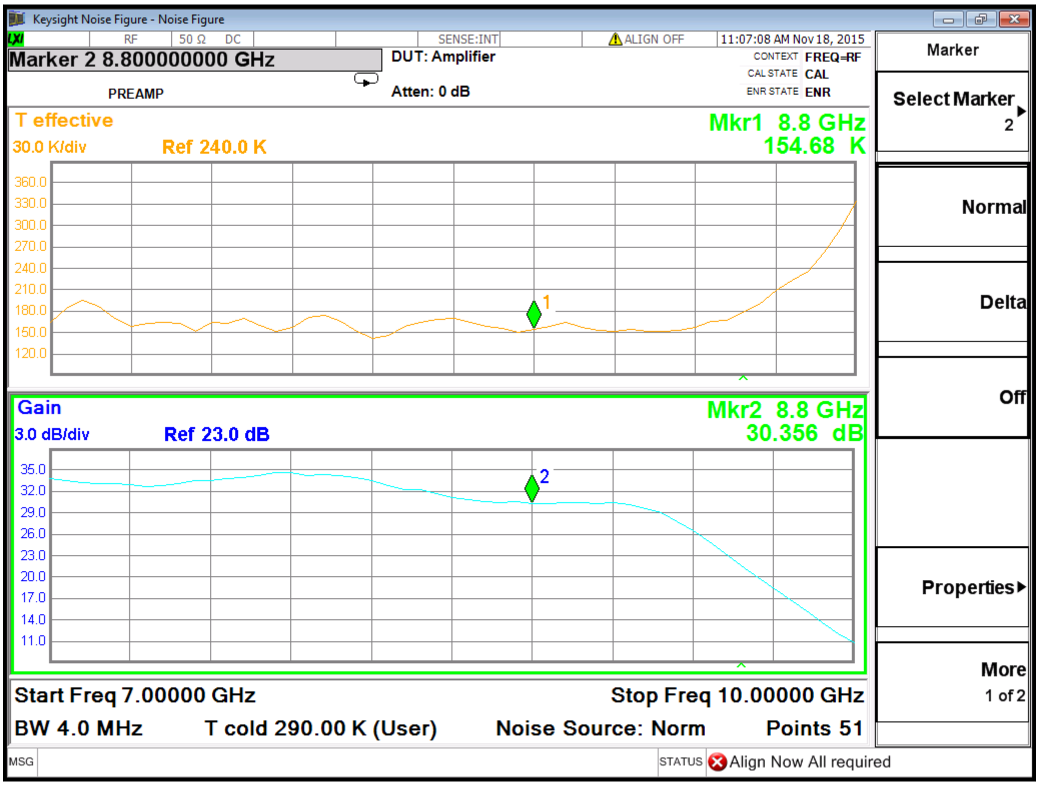
Physical Properties	
Density (g cm^{-3})	1.68
Flammability	V0
Limiting oxygen index (%)	60
Radiation resistance	Fair
Water absorption - over 24 hours (%)	<0.02

Thermal Properties	
Coefficient of thermal expansion (x10^{-6} K^{-1})	80
Heat-deflection temperature - 0.45MPa (C)	115
Heat-deflection temperature - 1.8MPa (C)	75
Lower working temperature (C)	-75
Thermal conductivity @23C (W m^{-1} K^{-1})	0.16
Upper working temperature (C)	130-170

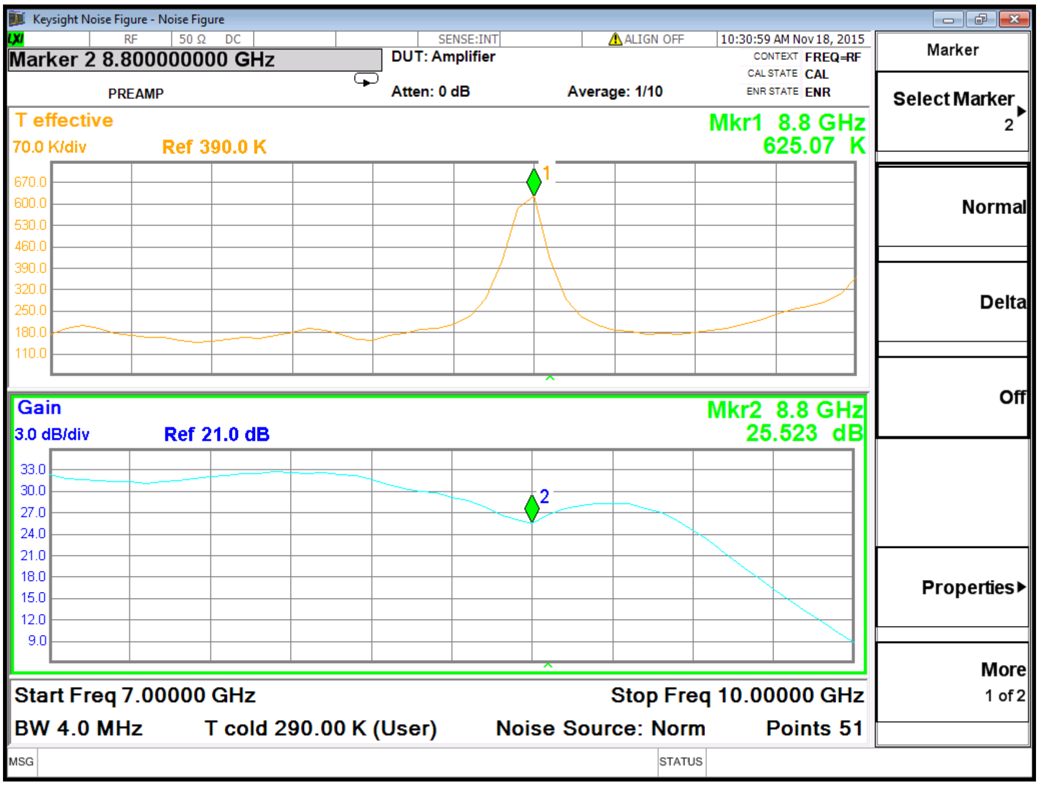
Ethylene-Chlorotrifluoroethylene copolymer.Goodfellow, FP33130.

11.2.1. Vacuum window tests

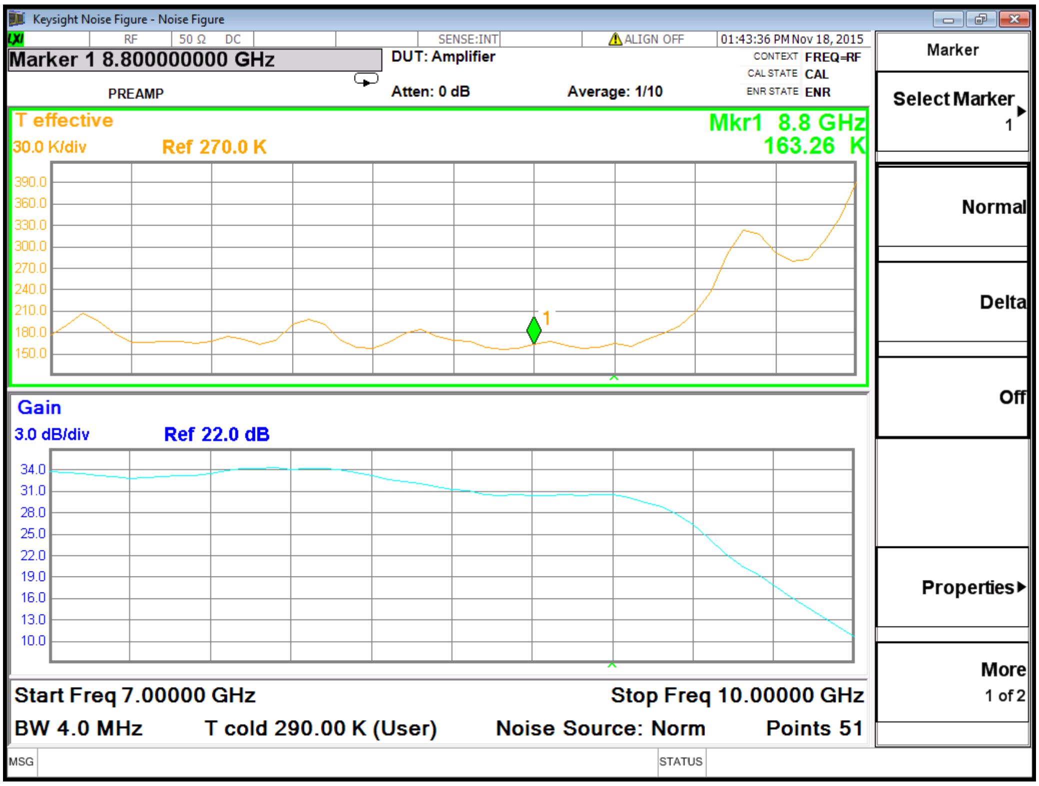
The vacuum window made of Halar was selected because other typical used materials, for example: Mylar (0.5 mm) generates resonances at X band. Next graphics show the measurements carried out at room temperature at X band: without vacuum window, using a Mylar vacuum window and using anHalar (0.125 mm) vacuum window.



X band T_{amb} (T_{RX} and Gain) without vacuum window.



X band T_{amb} (T_{RX} and Gain) with **Mylar vacuum window⇨Resonance @ 8.8 GHz**.



X band T_{amb} (T_{RX} and Gain) with **Halar vacuum window⇨NOResonance**.

11.3. DC wiring

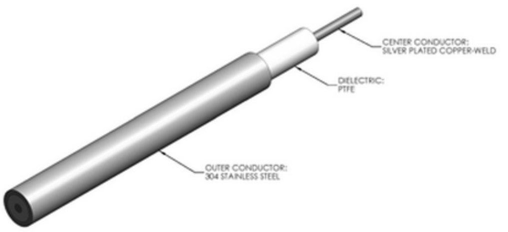
Small section wire Kynar 30 awg. specifications:

✔	Color de la Funda	Amarillo
✔	Corriente Nominal	0,4 A
✔	Diámetro Externo	0.5mm
✔	Filamentos del Núcleo	1 / 0,25 mm
✔	Forma del Cable	Unipolar
✔	Longitud	50m
✔	Material Conductor	Cobre Chapado en Plata
✔	Material de Aislamiento	Kynar
✔	Máxima Temperatura de funcionamiento	+130°C
✔	Número de Hilos	1
✔	Tamaño de los Hilos	0,25 mm
✔	Temperatura de Funcionamiento Mínima	-20°C
✔	Tensión Nominal	300 V
✔	Tipo	Cable envolvente Kynar
✔	Área Transversal	0,05 mm²

11.4. RF Cables

UT-085B-SS

Stainless steel 50 ohm semi-rigid cables are designed for applications where low thermal heat transfer is required such as cryogenic feed cables. Because these cables also utilize a solid PTFE dielectric, they are often the first choice for highly corrosive environments.



DIMENSIONS

DIMENSIONS	UNITS	UT-085B-SS
Outer Conductor Diameter	In	0.0865 ± 0.0010
	mm	2.1971 ± 0.0254
Dielectric Diameter	In	0.066 ± 0.001
	mm	1.676 ± 0.025
Center Conductor Diameter	In	0.0201
	mm	0.5105
length (maximum)	Feet	20
	Meter	6.10

MATERIALS

Outer Conductor		304 SS
Outer Conductor Plating		None
Dielectric		PTFE
Center Conductor		SP BeCu
Rohs Compliant		YES

MECHANICAL CHARACTERISTICS

Outer Conductor Integrity Temp.	°C	225
Operating Temperature (Max)	°C	200
Inside Bend Radius (Minimum)	In	0.250
	mm	6.350
Weight	lbs / 100ft	1.31
	kg / 100m	1.97

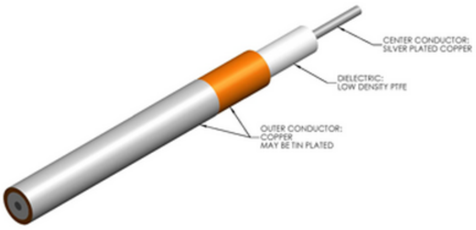
ELECTRICAL CHARACTERISTICS

Characteristic Impedance	ohm	50
Capacitance	pF / ft	29.0
	pF / m	95.2
Corona Extinction Voltage	VRMS @ 60 Hz	1800
Voltage Withstanding	VRMS @ 60 Hz	5400
Higher Order Mode Frequency	GHz	61.0
Attenuation (Db / 100 Ft Typical)	0.5 GHz	31.2
	1.0 GHz	44.4
	5.0 GHz	101.5
	10.0 GHz	146
	18.0 GHz	199.7
	26.5 GHz	246.2
	40.0 GHz	308.7
	50.0 GHz	349.5
	65.0 GHz	N/A
	90.0 GHz	N/A
Power (Watts Cw @ 20 °C, Maximum)	0.5 GHz	142.7
	1.0 GHz	100.5
	5.0 GHz	44.2
	10.0 GHz	30.9
	18.0 GHz	22.7
	26.5 GHz	18.5
	40.0 GHz	14.8
	50.0 GHz	13.1
	65.0 GHz	N/A
	90.0 GHz	N/A

Micro-coax semi-rigid cable UT-085B-SS.

UT-141C-LL

Low loss semi-rigid cables provide lower attenuation, better phase stability with temperature, and a higher operating temperature when compared to traditional solid PTFE semi-rigid cables. Low loss cables are available with both a copper or aluminum outer conductor.



DIMENSIONS

DIMENSIONS	UNITS	UT-141C-LL
Outer Conductor Diameter	In	0.141 ± 0.002
	mm	3.581 ± 0.051
Dielectric Diameter	In	0.1175 ± 0.0020
	mm	2.9845 ± 0.0508
Center Conductor Diameter	In	0.0403
	mm	1.0236
length (maximum)	Feet	20
	Meter	6.10

MATERIALS

Outer Conductor		Copper
Outer Conductor Plating		None
Dielectric		LD PTFE
Center Conductor		SPC
Rohs Compliant		YES

MECHANICAL CHARACTERISTICS

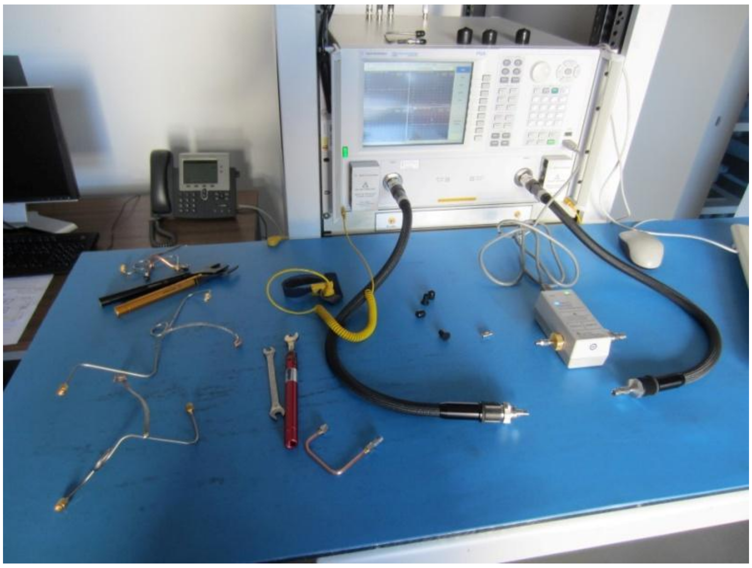
Outer Conductor Integrity Temp.	°C	250
Operating Temperature (Max)	°C	250
Inside Bend Radius (Minimum)	In	0.500
	mm	12.700
Weight	lbs / 100ft	3.18
	kg / 100m	4.77

ELECTRICAL CHARACTERISTICS

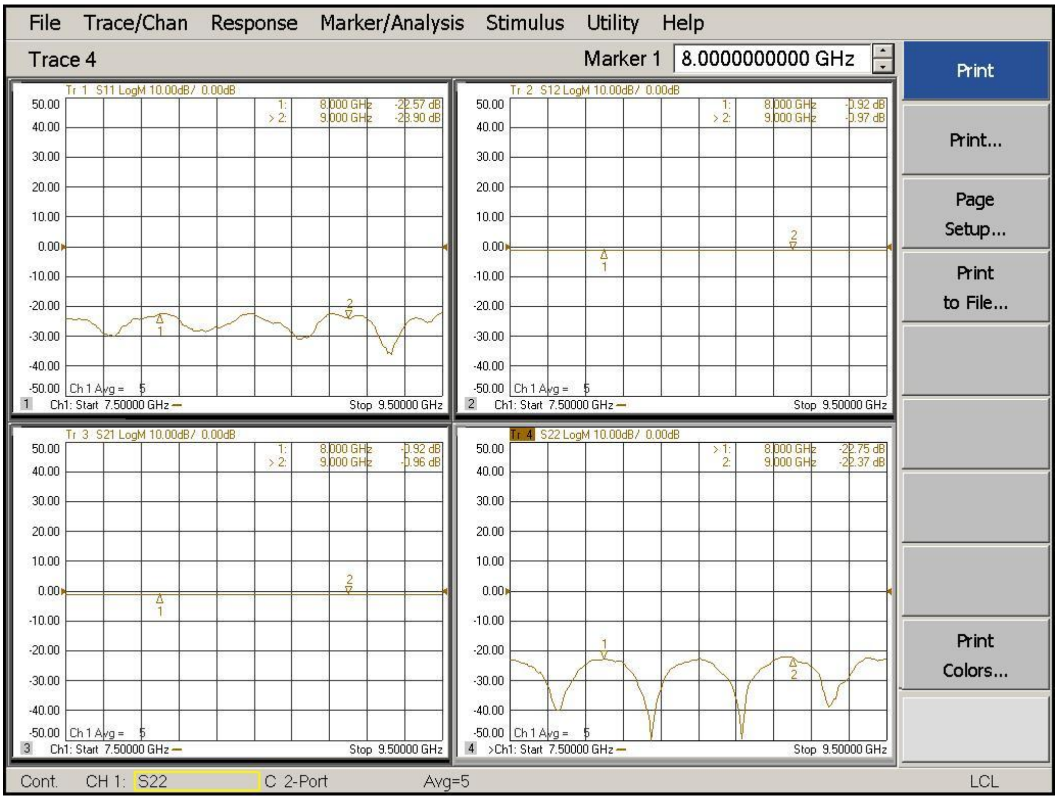
Characteristic Impedance	ohm	50
Capacitance	pF / ft	26.5
	pF / m	86.8
Corona Extinction Voltage	VRMS @ 60 Hz	2800
Voltage Withstanding	VRMS @ 60 Hz	8400
Higher Order Mode Frequency	GHz	37.0
Attenuation (Db / 100 Ft Typical)	0.5 GHz	7
	1.0 GHz	10
	5.0 GHz	23
	10.0 GHz	33.2
	18.0 GHz	45.6
	26.5 GHz	56.5
	40.0 GHz	N/A
	50.0 GHz	N/A
	65.0 GHz	N/A
	90.0 GHz	N/A
Power (Watts Cw @ 20 °C, Maximum)	0.5 GHz	839.4
	1.0 GHz	590.4
	5.0 GHz	258.3
	10.0 GHz	179.7
	18.0 GHz	131.5
	26.5 GHz	106.7
	40.0 GHz	N/A
	50.0 GHz	N/A
	65.0 GHz	N/A
	90.0 GHz	N/A

Micro-coax semi-rigid cable UT-141C-LL.

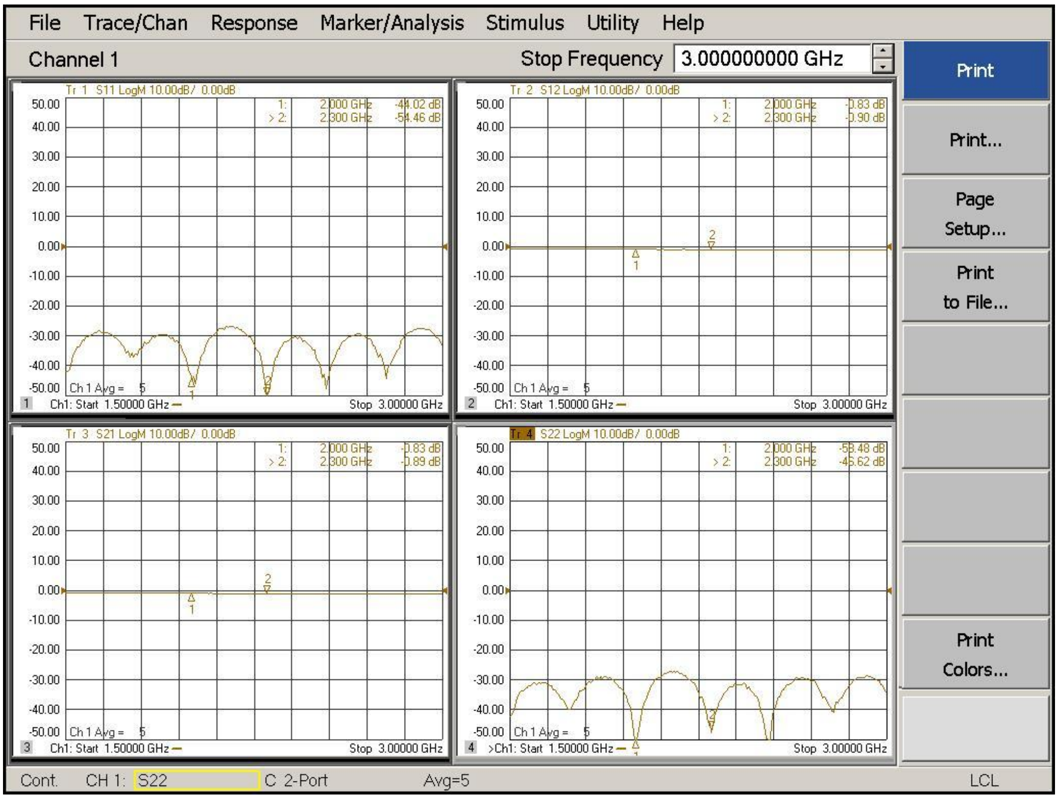
11.5. RF Measurements



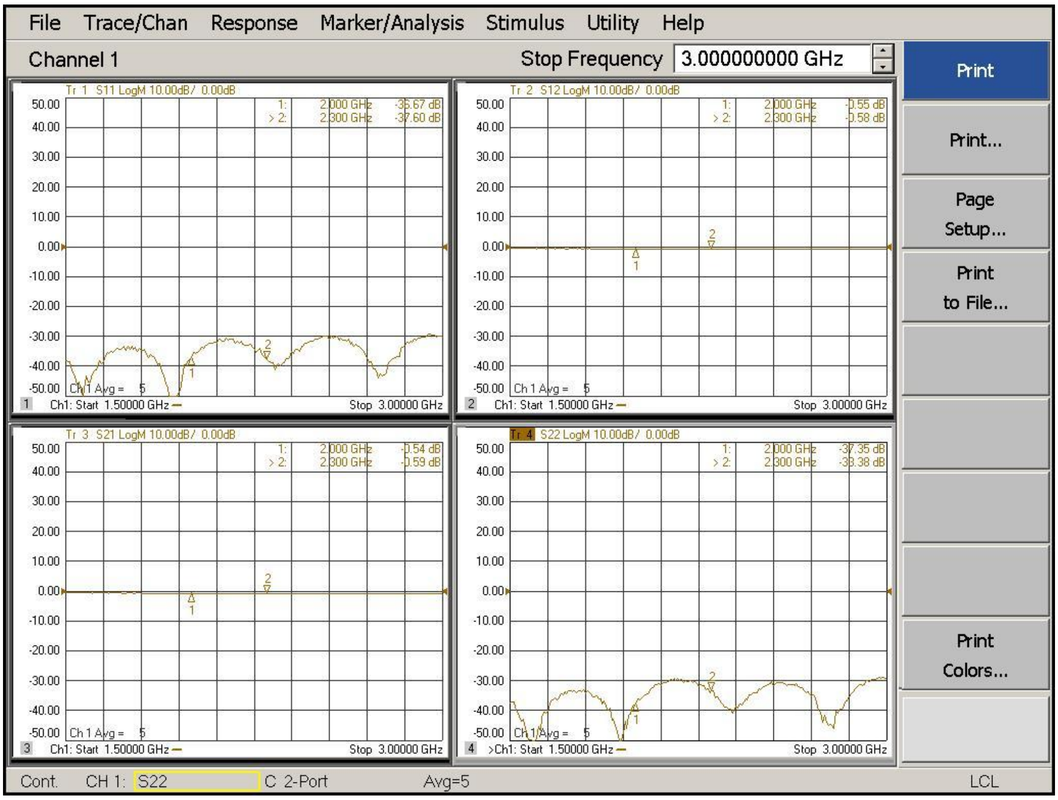
RF cables measurement setup.



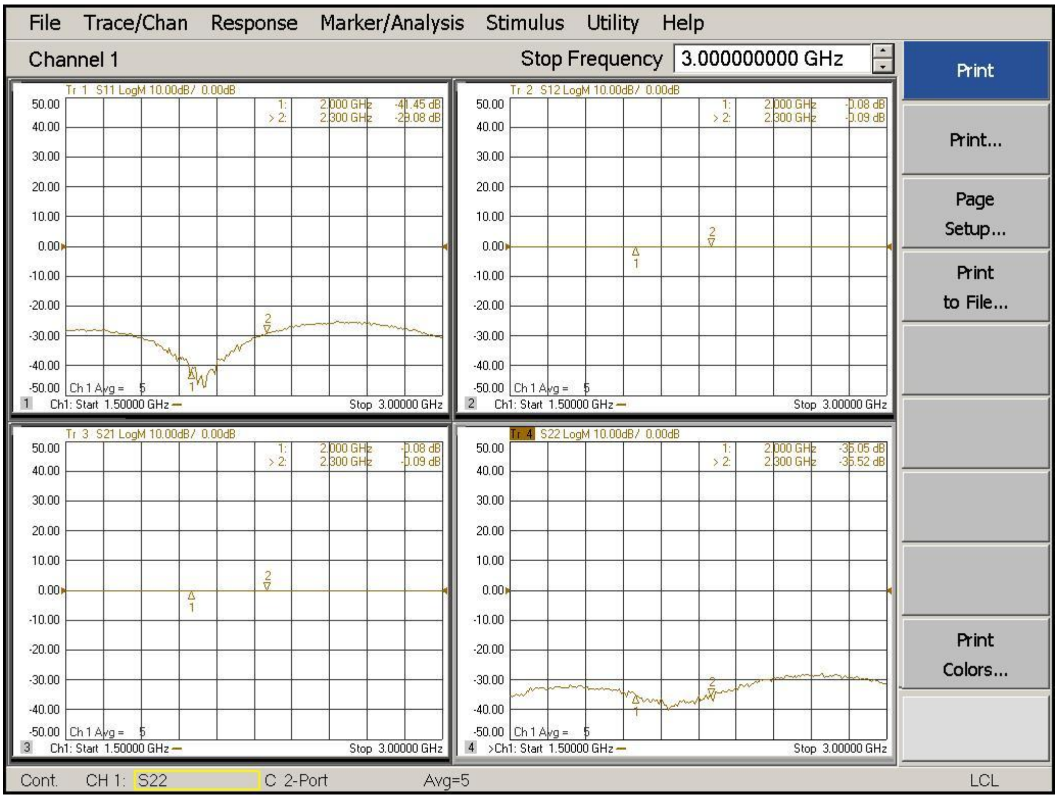
X band output (UT-85B-SS).



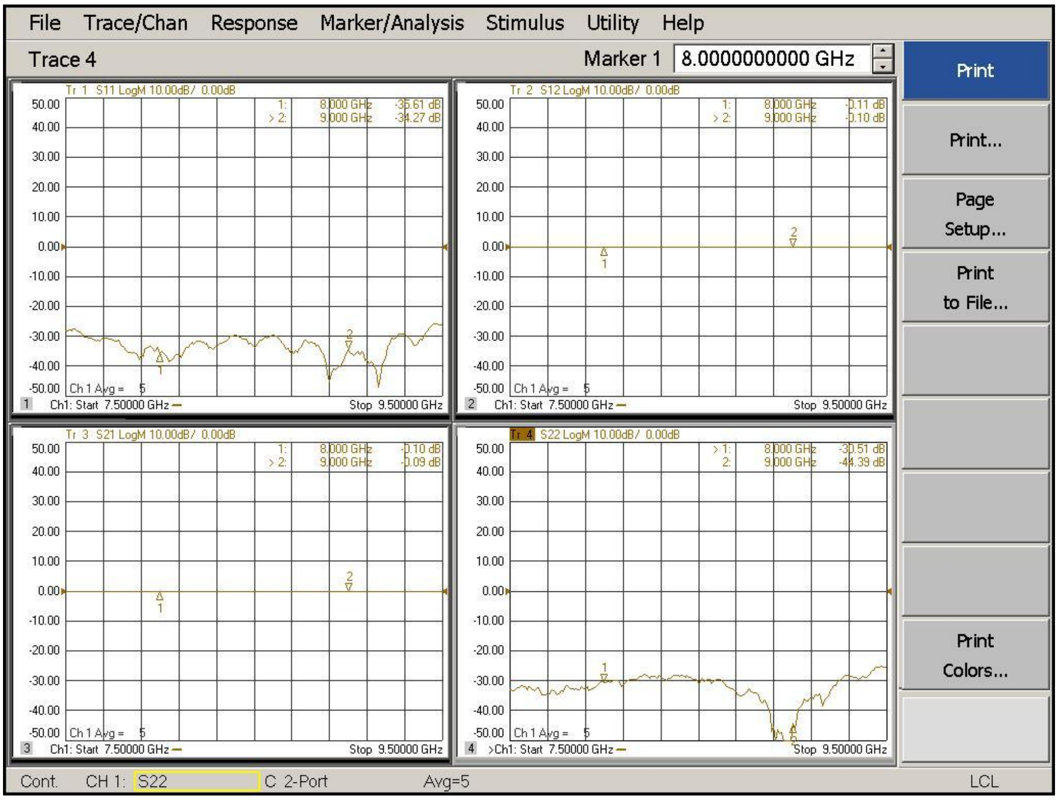
S band output (UT-85B-SS).



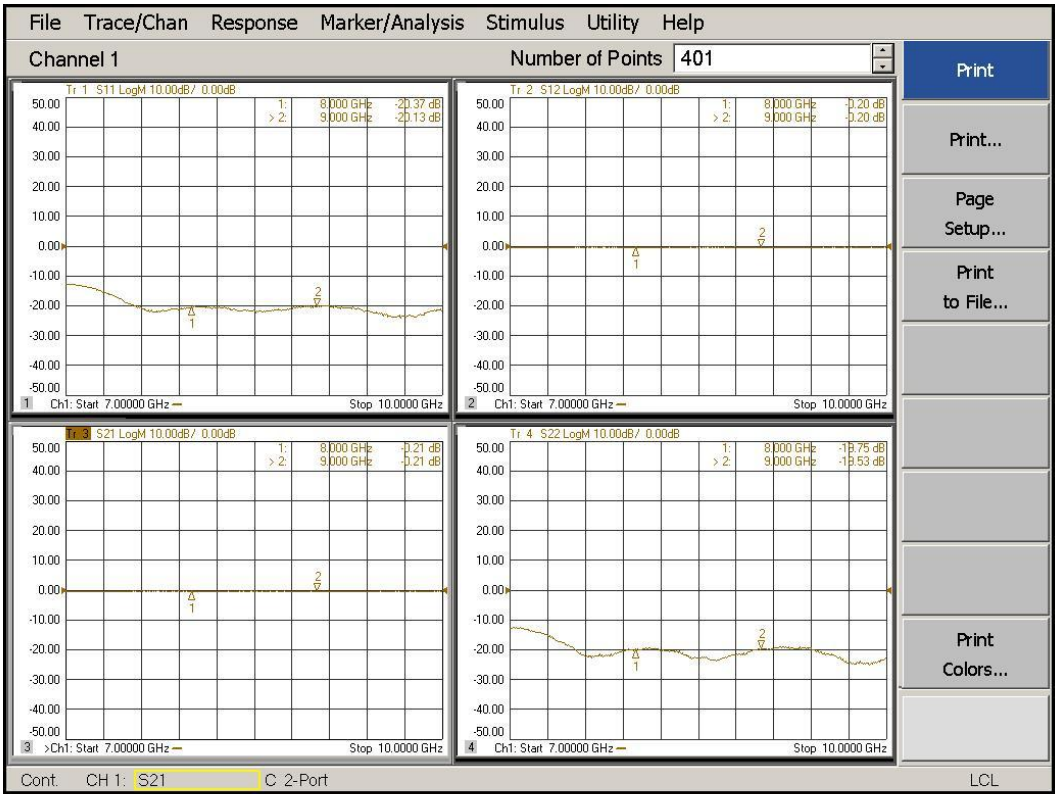
S band calibration signal input (UT-85B-SS).



S band LNA input (UT-141C-LL), + $K_{f\text{-}f}$ transition to airline.



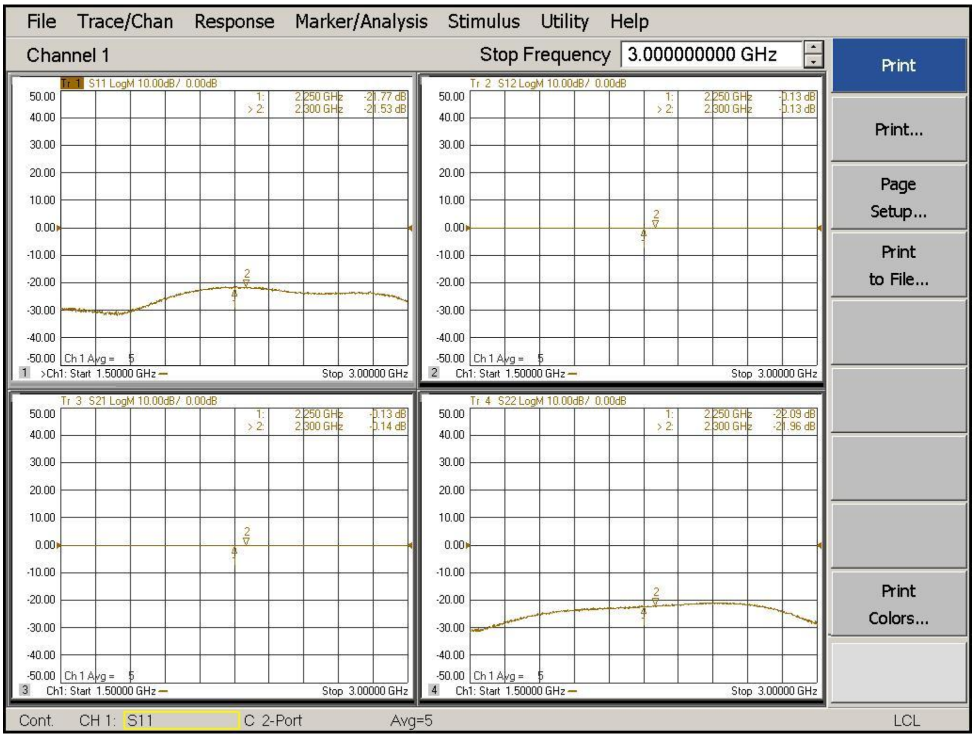
X band LNA input (UT-141C-LL).



X band waveguide/coaxial transition.

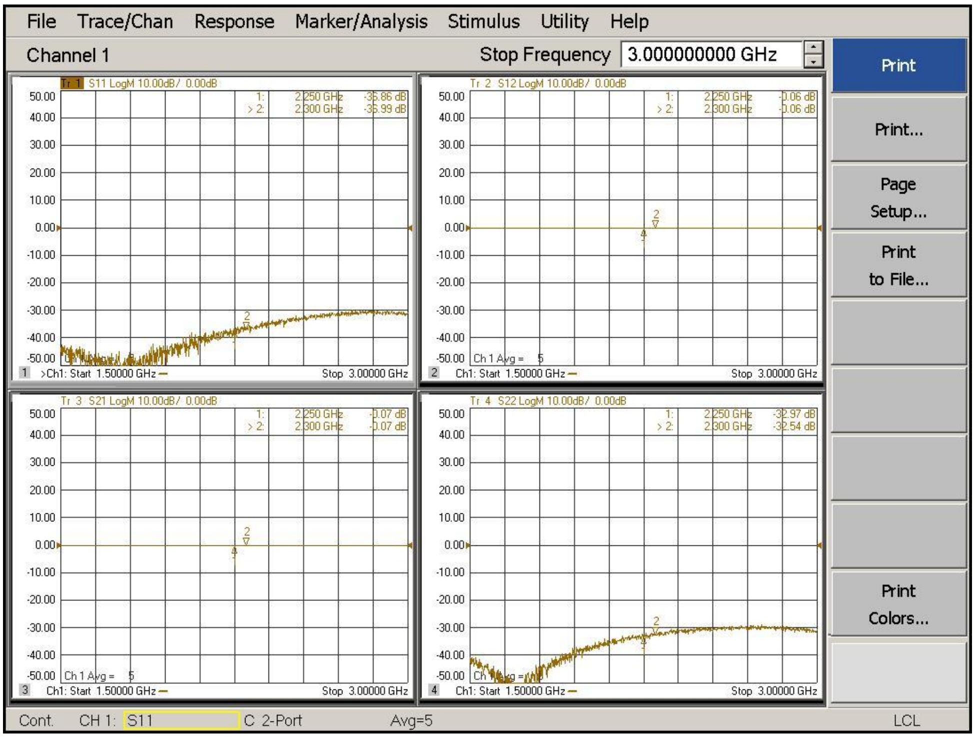
11.6. Airline (S band) measurement

Airline measurement setup.



Airline measurement result (airline + N_f/N_f + N_m/SMA_f) (m = male, f= female).

N transitions measurement setup.



N transitions (Nf/Nf + 2*Nm/SMAf)measurement result.

RESULTS:

- The airline is in good condition.
- The Nf-Nf hermetic transition is in good condition.

- Measurement frequency band (**1.5-3GHz**)
- Airline+N transition losses <**0.14dB**
- Airline+N transition adaptation <**-20dB**
- N transition loses <**0.07dB** ($N_f/N_f + 2*N_m/SMA_f$)

If we consider that the N_f/N_f hermetic transition losses are 0dB, then it is possible to affirm that the N_m/SMA_f transition losses are 0.07/2 = 0.035dB.

Therefore it is concluded that the Airline losses are 0.14dB - 0.035dB ≈ 0.1dB