O´Higgins S/X Bands Cryogenic Receiver

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Revision history

Version	Date	Updates
1.0	October 2013	First Version
1.1	April 2014	Update Gain and Coupling measurements

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1. Introduction

This report summarizes the new design and characteristics of the S and X bands cryogenic receiver for the Geodetic Antartic Station O´Higgins 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	> 25 dB at S band > 30 dB at X band
Noise Temperature	S band: < 20 K X band: < 20 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. Cryostat geometry

Next figures show the cryostat design:

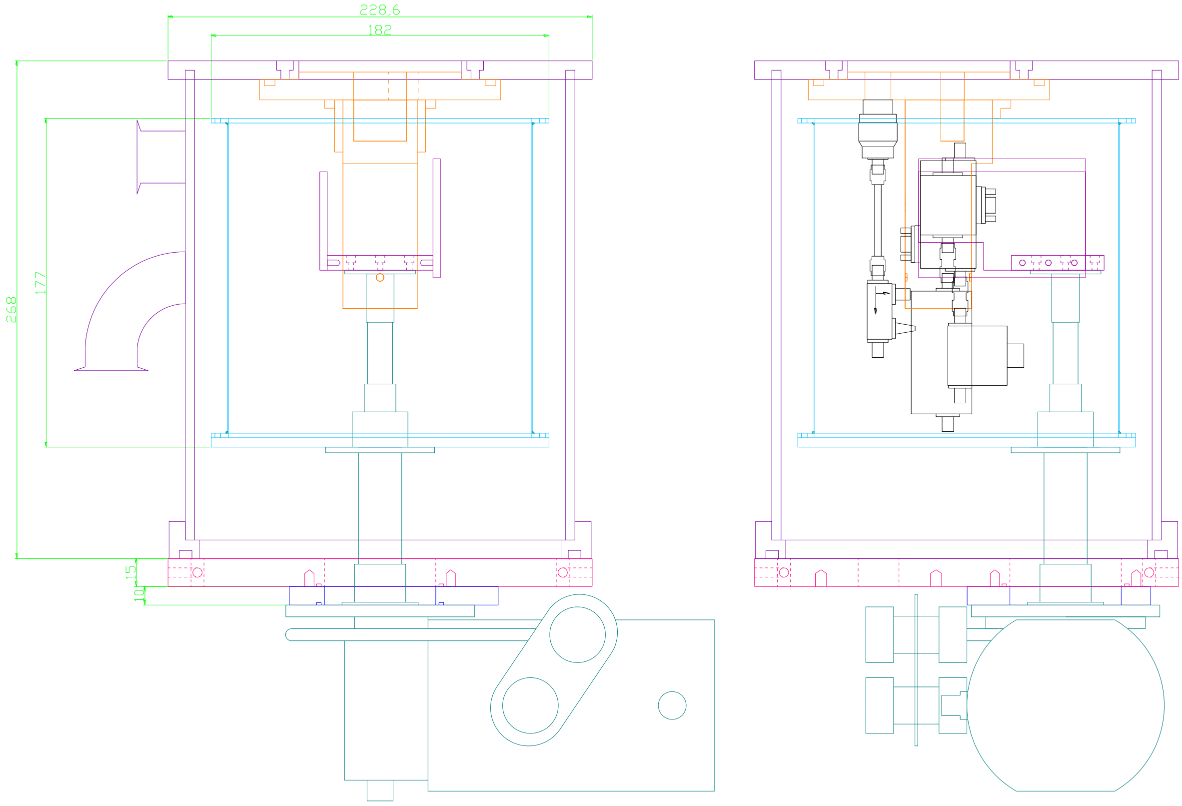


Figure 1. Cryostat overview (cold head (green), vacuum case (pink and violet), radiation shield (blue), cold stage (violet) and thermal transition (orange)).

The cryostat design is based on the previous cryostat installed at O´Higgins Station. 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.

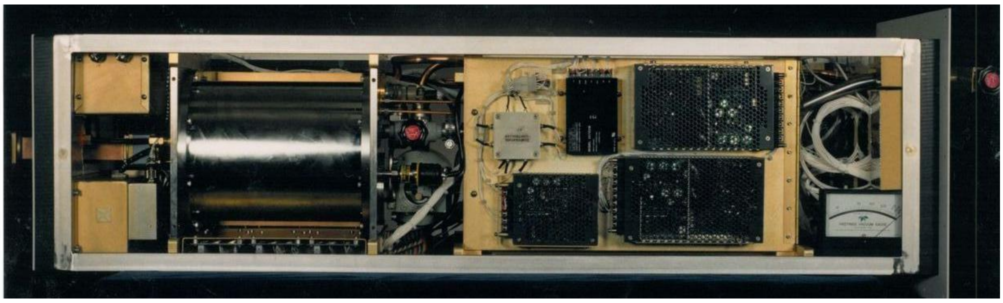


Figure 2. Previous dewar design inside the receiver box.

The cryostat is built over a Model-22 CTI cold head in a steel made cylindrical dewar. At the top cover, a vacuum window (Wettzell Observatory supplied) lets the X band radiation go through, for the S band a hermetic N connector feedthrough is used. At the bottom cover there are all the RF connectors for S and X bands, the flange for the pressure sensor, DC cabling and housekeeping connectors.

Inside the cryostat, attached to the intermediate stage, there is an aluminum made cylindrical radiation shield covered with multilayer isolator (MLI). The temperature of this stage is less than 70 K. Removing the radiation shield, the entire receiver can be easily reached. It is the coldest part of the receiver at, approximately, 18 K. Both amplifiers and the directional coupler are thermally attached to the copper made cold stage.

The RF cables that connect the cold stage (amplifiers and couplers) with the room temperature stage (SMA connectors and N connector) are coaxial semi-rigid steel cables, UT-085B-SS.

Figure 3. Cryostat overview (current design).

2.1. Vacuum case

The dewar consists of two main parts: stainless steel cylinder with the top cover and the bottom cover. 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).

The dewar lower flange has several outputs for different uses:

- Cold head connection: to place the cold head in the right position, a second flange was placed between the lower flange and the cold head. To get the desire vacuum two viton seals have been used.
- One aperture with a transition for the vacuum control (pressure sensor).
- Three hermetic Fischer connectors for the housekeeping control and monitoring, and amplifiers biasing.
- Four SMA hermetic connectors for the RF input/output signals (calibration and RF).

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.

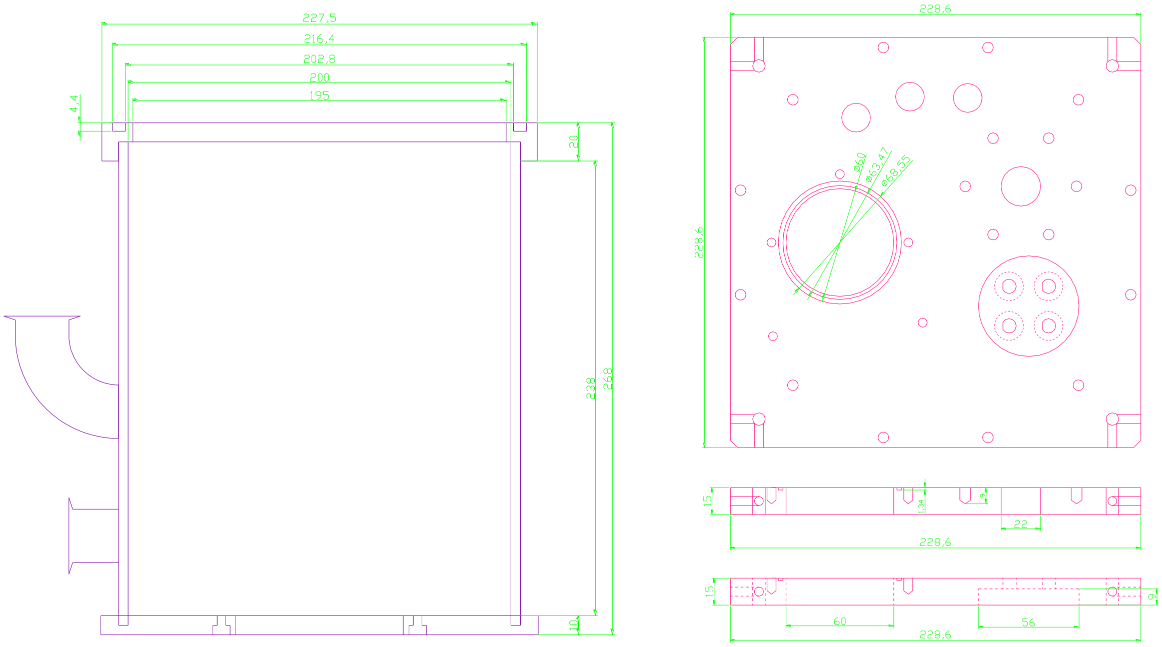


Figure 4. Dewar, vacuum seals and flange dimensions.

At the cylinder there are two flanges, one for the vacuum valve and the other one closed with a blind flange (the original safety vacuum valve has been removed because its use isn´t necessary and it could be a leakage source).

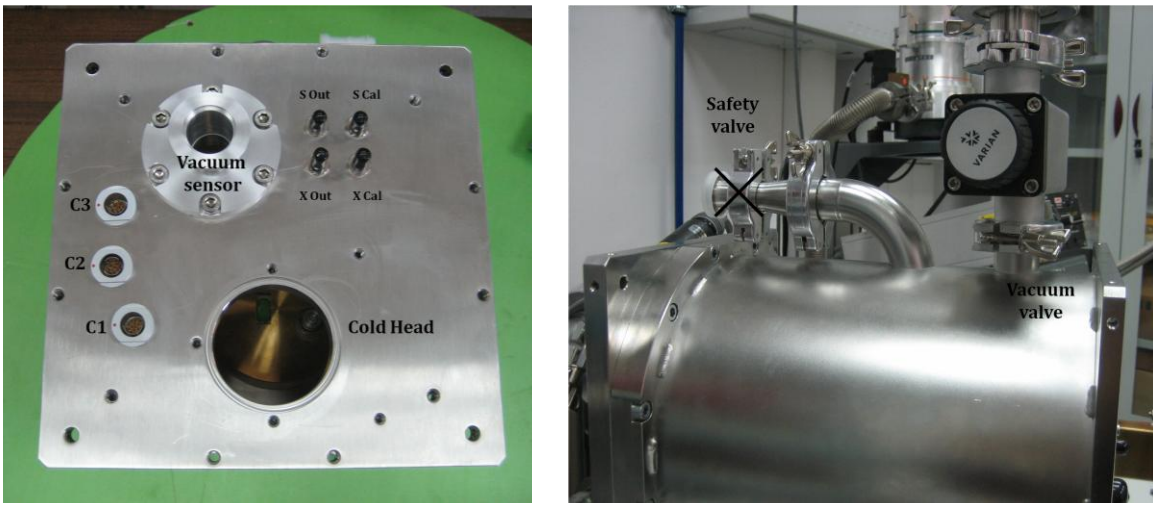


Figure 5. Bottom dewar cover and outer cylinder.

Figure 6. Cold head flange.

2.1.1. Vacuum window

The vacuum window goal is to allow transition (physical, electromagnetic and vacuum) between the X band horn, that it is out of the cryostat, and the directional coupler.

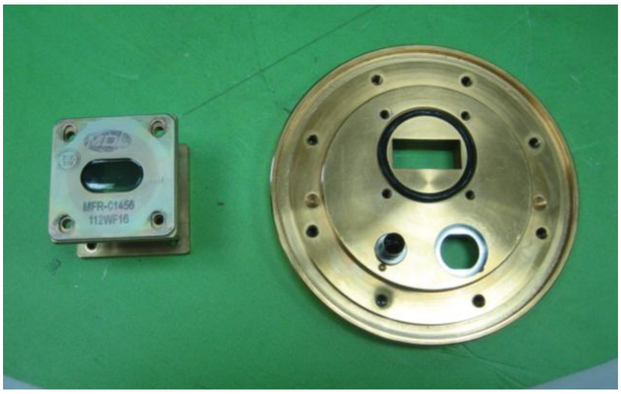


Figure 7. Vacuum window and waveguide transition.

2.1.2. Vacuum seals

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

Viton Seals	**Type**	**d_1 (mm)**	**d_2 (mm)**	**Reference**	**Qty**
Cold Head – ancillary flange – lower flange	OR VI	63.22	1.78	435.803	2
* Vacuum case – bottom flange	OR VI	202.57	5.33	346.631	1
* Vacuum window – golden transition	OR VI	34	3	462.291	1
* Golden transition – top flange	OR VI	116	4	425.319	1
* Vacuum sensor – lower flange	OR VI	40	4.5	346.768	1
Helicoflex Seals	**Type**	**d_1 x d_{ext} x d_2 (mm)**		**Reference**	**Qty**
Vacuum case – bottom flange	Garlock Helicoflex	-		128584	1
Golden transition – top flange	Garlock Helicoflex	114.5 x 123.5 x 4.5		125820	1
Vacuum sensor – lower flange	Garlock Helicoflex	41.5 x 50.5 x 4.5		-	1

Table 1: Viton vacuum seals (Epidor [5]) and Helicoflex seals.
* Viton seals supplied by Wettzell. The reference belongs to an Epidor catalog compatible gasket.

2.2. Intermediate stage and radiation shield

The intermediate stage is an aluminum plate of 5 mm thickness and 182 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 isolator, MLI (8 layers).

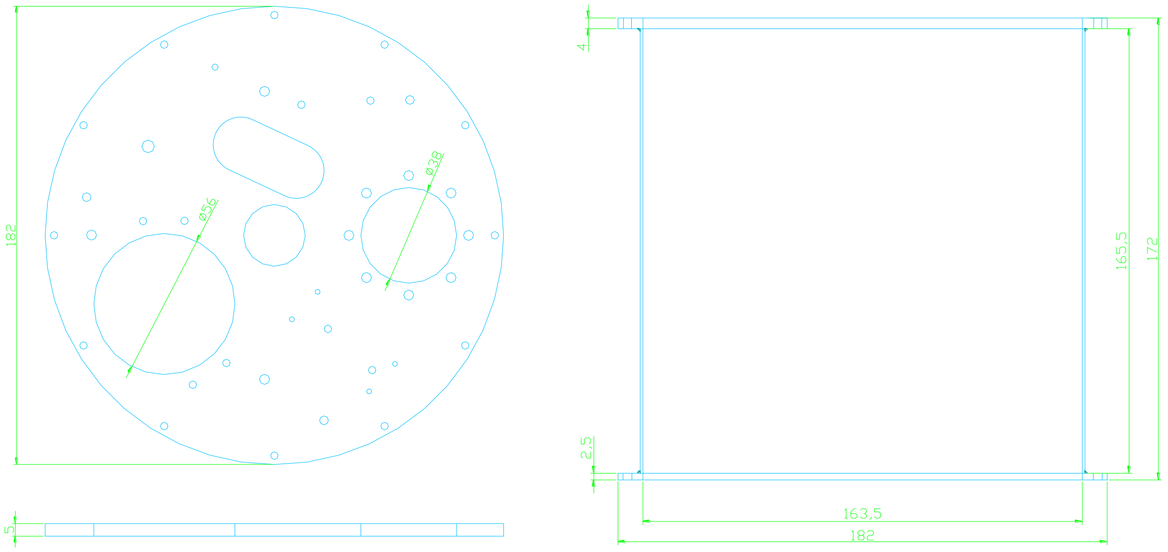


Figure 8. Intermediate stage design and radiation shield.

On the intermediate stage, a temperature sensor, a heating resistor, a thermostat and a zeolites based vacuum trap are installed. 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°.

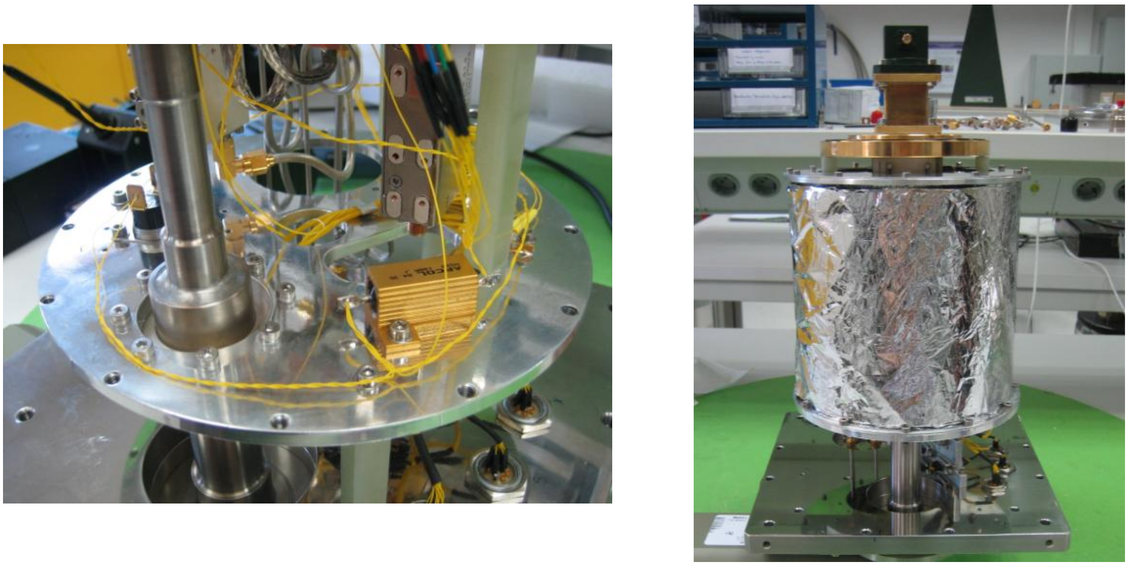


Figure 9. Intermediate stage installed in the cryostat and radiation shield with MLI.

2.3. Cold stage

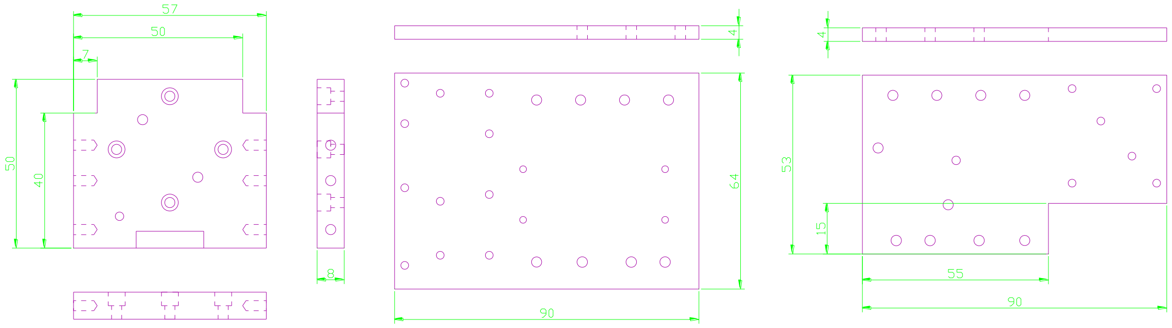


Figure 10. Cold stage design.

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 the X band directional coupler are attached to the lateral plates.

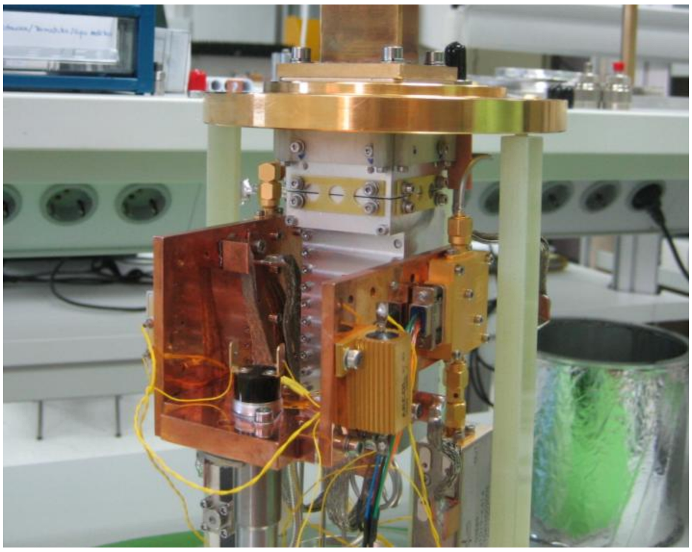


Figure 11. Cold stage with LNAs and housekeeping elements.

2.4. Amplifier setting-up

The cryostat contains two low noise amplifiers:

- S Band LNA: TTI-LNA-S-2248-CRYO.
- X Band LNA: 4-12 GHz Cryogenic LNA, YXA 1197

Detailed specifications and biasing information can be found in the appendix.

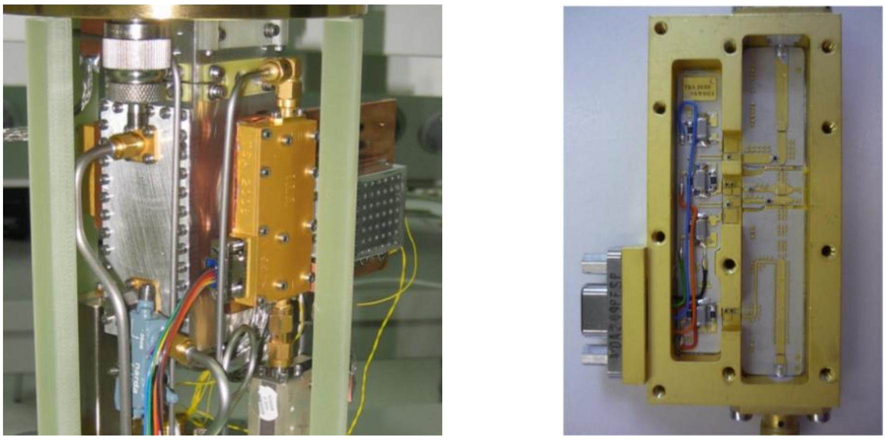


Figure 12. S band low noise amplifier.

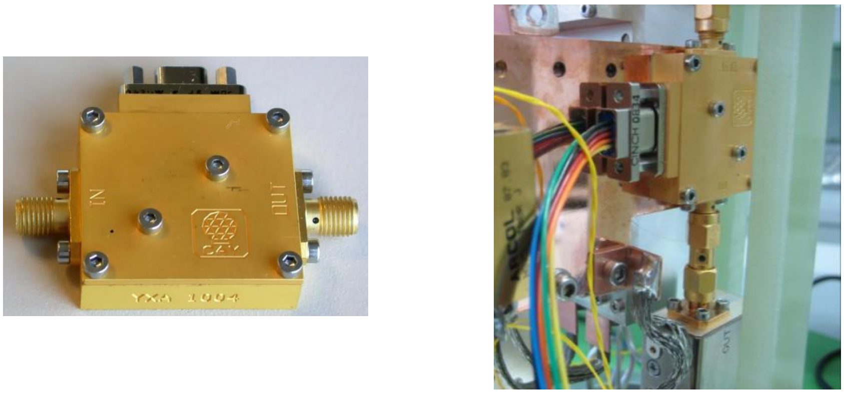


Figure 13. X band low noise amplifier.

2.5. Internal DC wiring

There are 3 hermetic Fischer connectors at the dewar bottom flange (figure 5):

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

Hermetic Fischer Connector	Function
C1	Housekeeping
C2	S band LNA
C3	X band LNA

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

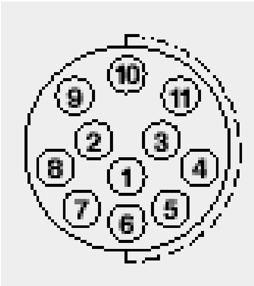


Figure 14: 11 pin Fischer
(connector view, red point up).

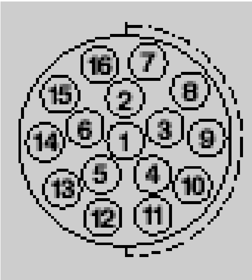


Figure 15: 16 pin Fischer
(connector view, red point up).

The DC wiring has been done using small section long cables to reduce the conduction load. Next tables indicate the pin-out association between connectors.

O´Higgins S/X receiver DC connections pin-out:

Fischer Pin	DB15 Pin	Signal
1	1	Tc_+
2	2	Tc_-
3	3	Ti_+
4	4	Ti_-
5	5	Calef_on
6	6	Regen_on
7	7	GND_res
8	8	Calef_mon
9	9	Regen_mon
10	10	(free)
11	11	(free)

Table 2: Fischer Connector (C1) 16 pin (housekeeping) correspondence with the DB15 connector.

Fischer Pin	DB9 Pin	Signal
1	1	Gnd
2	2	Vd1
3	3	Vg1
4	4	Vd2
5	5	Vg2
6	6	(free)
7	7	(free)

Table 3: Fischer Connector (C2) 11 pin (S band LNA) correspondence with the DB9 connector.

Fischer Pin	DB9 Pin	Signal
1	1	Gnd
2	2	Vd1
3	3	Vg1
4	4	Vd2
5	5	Vg2
6	6	Vd3
7	7	Vg3

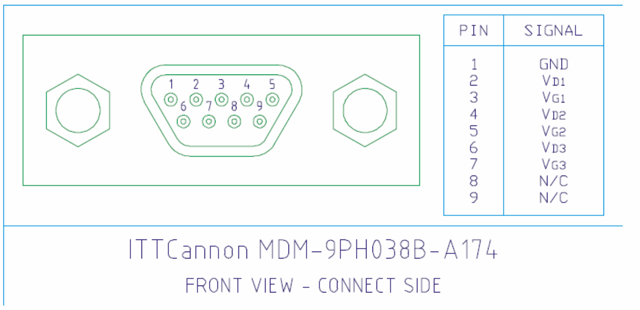
Table 4: Fischer Connector (C3) 11 pin (X band LNA) correspondence with the DB9 connector.

Figure 16: DC wiring (room temperature stage).

2.5.1. Low Noise Amplifiers biasing wiring

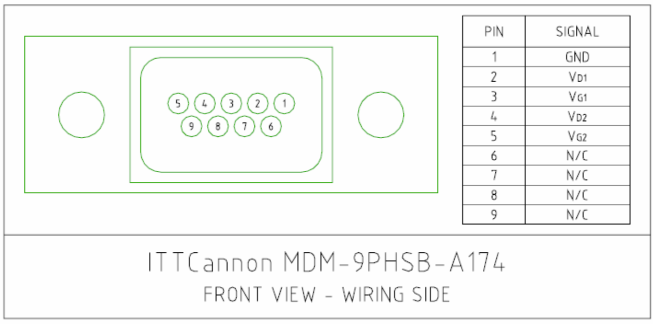
Band	Amplifier frequency range (GHz)	IVS Frequencies (GHz)	Purpose
S	2.2- 2.7	2.2 - 2.37	Geodetic VLBI
X	4 - 12	8.15 - 9.0	Geodetic VLBI

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



PIN	SIGNAL
1	GND
2	V_{D1}
3	V_{G1}
4	V_{D2}
5	V_{G2}
6	V_{D3}
7	V_{G3}
8	N/C
9	N/C

Figure 17. X band amplifier biasing connector pin-out.



PIN	SIGNAL
1	GND
2	V_{D1}
3	V_{G1}
4	V_{D2}
5	V_{G2}
6	N/C
7	N/C
8	N/C
9	N/C

Figure 18. S band amplifier biasing connector pin-out.

2.5.2. 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.

Fischer Pin	Signal	Description
1	Tc_+	Cold stage temperature sensor (+)
2	Tc_-	Cold stage temperature sensor (-)
3	Ti_+	Intermediate stage temperature sensor (+)
4	Ti_-	Intermediate stage temperature sensor (-)
5	Calef_on	Signal to activate the heaters after passing through the thermostat
6	Regen_on	Signal to activate the zeolites regeneration resistor after passing through the thermostat
7	GND_res	Ground
8	Calef_mon	Thermostat verification (heating resistors)
9	Regen_mon	Thermostat verification (regeneration resistors)

Table 5. Housekeeping signals description.

A 5-meters-lenght cable is supplied to connect 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:

Fischer Pin	Signal	Color	DB25 pin	Banana Connectors
1	Tc_+	Black	3, 4	
2	Tc_-	Grey	15, 16	
3	Ti_+	Violet	6, 7	
4	Ti_-	Green	18, 19	
5	Calef_on	Blue		**Red**
6	Regen_on	Brown		**Yellow**
7	GND_res	Orange		**Black**
8	Calef_mon	Red		**Red (test point)**
9	Regen_mon	White		**Black (test point)**

Table 6. Housekeeping 5 m cable description.

- DB25 connector: to Lakeshore 218 system (positions one and two), DT 670 sensors.
- Banana connectors: power supply for the receiver heating resistors and zeolites regeneration resistor.

2.6. Thermal waveguide transition

For the X band signal input, a thermal waveguide transition with a directional coupler have been designed, built and measured at Yebes Observatory laboratories. The transition optimization was carried out with the HFSS software and designed with Autocad.

The rectangular input waveguide undergoes to a high temperature gradient, from the room temperature stage to the cold stage. To avoid this sudden temperature change a thermal transition has been designed for the working frequency (8-9 GHz).

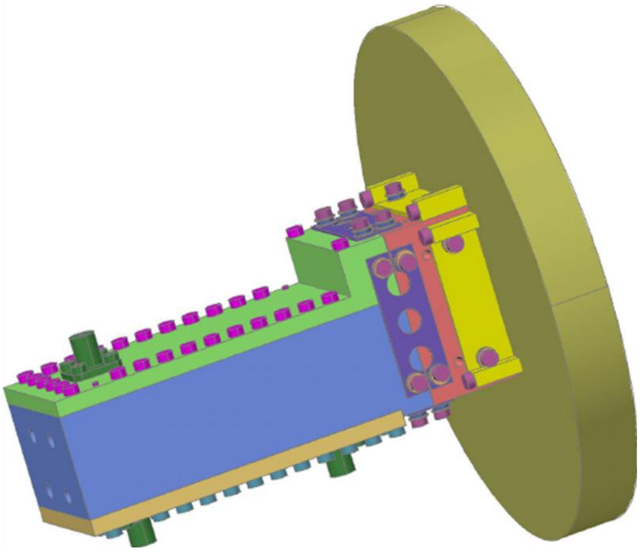


Figure 19: X band thermal transition and directional coupler.

The transition is made facing two rectangular waveguides, one with a smooth flange cover type and the other one is choke type, separated by a small gap. The choke depth is λ/4 to cancel the parallel components of the electric field flowing through the gap avoiding losses and resonances at the working frequency.

Besides the thermal transition, a directional coupler was designed. This coupler is attached to the transition through a second gap. With this design the thermal transition is double stage, since there are two temperature stages from 300 K to 70 K and from 70K to 20 K.

The gaps are achieved by means of fiber glass pieces. This material exhibits a very low thermal conductivity. Furthermore, a polystyrene IR filter has been placed within the guide to minimize the radiation load inside the guide.

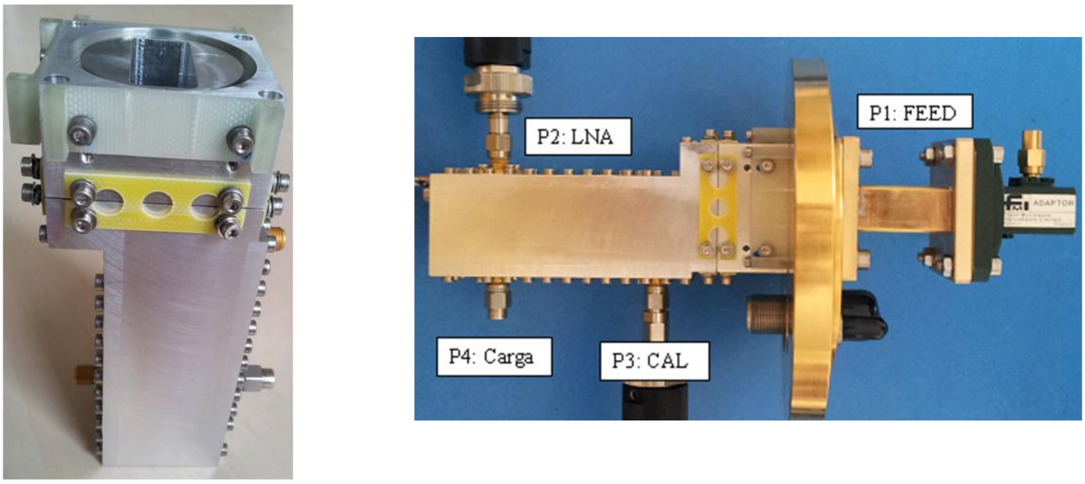


Figure 20: Thermal transition and directional coupler.

The previous structure was measured using the vector network analyzer. The relevant values of the measurements are presented in table 7.

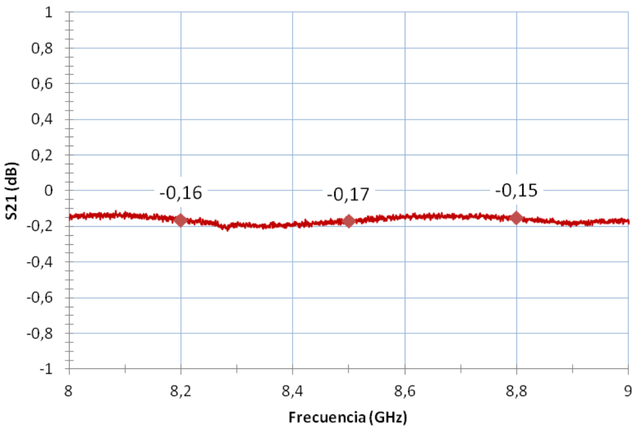


Figure 21. Chain insertion loss.

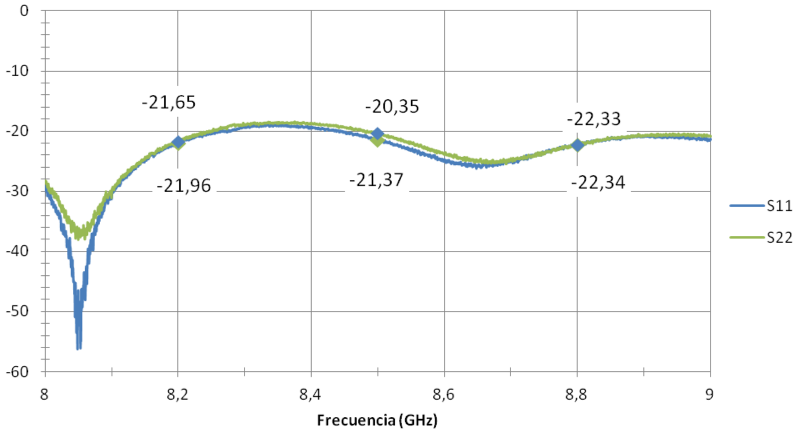


Figure 22: Return losses (ports 1 and 2).

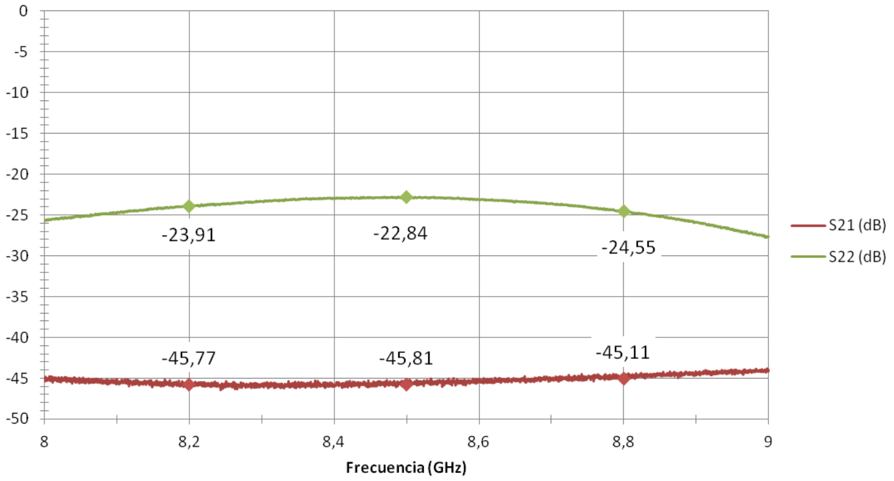


Figure 23. Isolation and return losses (port 3).

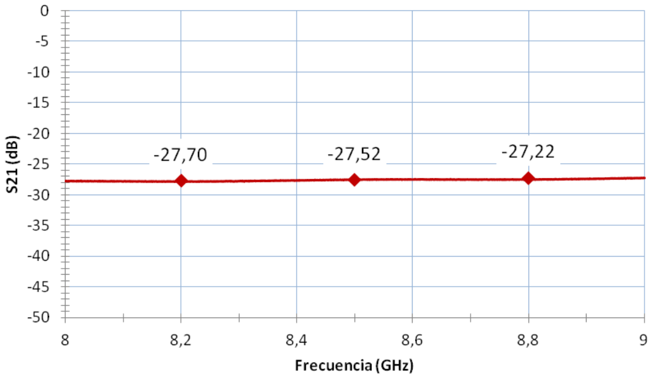


Figure 24. Coupling factor.

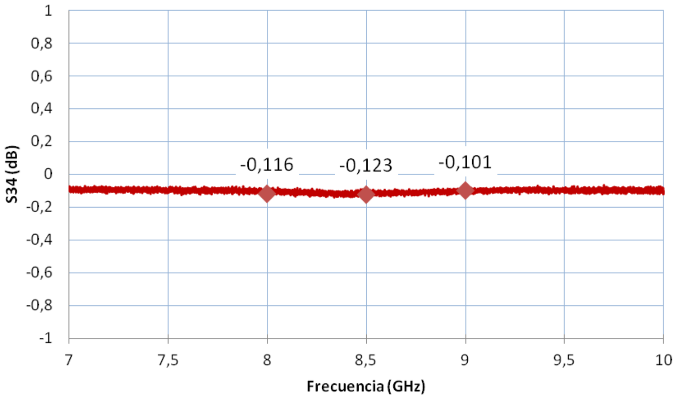


Figure 25. Waveguide losses.

Parameter	Value (dB)	Description	Figure
L	- 0.16	Insertion Loss	21
$RL_{1,2}$	< - 20	Return Losses Ports 1 and 2	22
RL_3	< - 22	Return Losses Port 3	23
C	- 27	Coupling Factor	24
ISO	< - 45	Isolation	23
Lg	- 0.1	Waveguide Losses	35

Table 7. Thermal transition with directional coupler final measurements.

3. Cryogenic system

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

Model 22 Cryodyne Refrigeration System

The Model 22 is available in both single and two stage configurations to suit a variety of applications that require a compact cryocooler.

The single stage M-22 is designed to provide up to 11 watts of heat lift at 77K for cooling of high temperature superconductors, detectors and optical devices.

The two stage M-22 is designed to provide useable heat lift under 10K and up to 1 watt at 20K and 8 watts at 77K simultaneously. Applications include spectroscopy, low temperature thermometry, amplifier cooling and LASER frequency tuning.

Model 22 Two Stage Cryodyne Refrigerator Typical Performance (60Hz)

Model 22 Single Stage Cryodyne Refrigerator Typical Performance (60Hz)

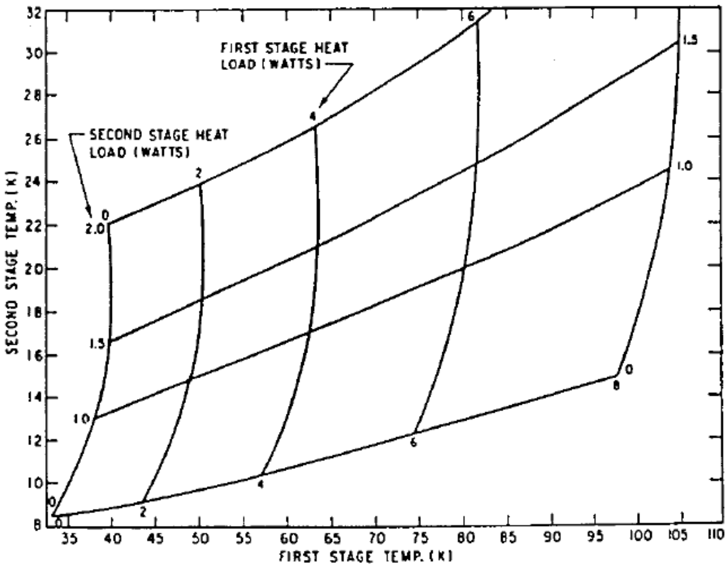


Figure 26. 22C cryodyne cryocooler typical refrigeration capacity (50 Hz).

4. 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: **≤ 68 K**.
- Cold stage temperature: **≤ 18 K**.
- Vacuum **<10^{-5} mbar** (cryogenic vacuum).
  - Leakage rate $1.3 \cdot 10^{-5}$ mbar·l/s ($1,6 \cdot 10^{-6}$ mbar/s).
- Cooling down time: **< 12 h.**
- Warming up time: < 30 h (or < 3.5 h with zeolites regeneration and heating resistors turned on).

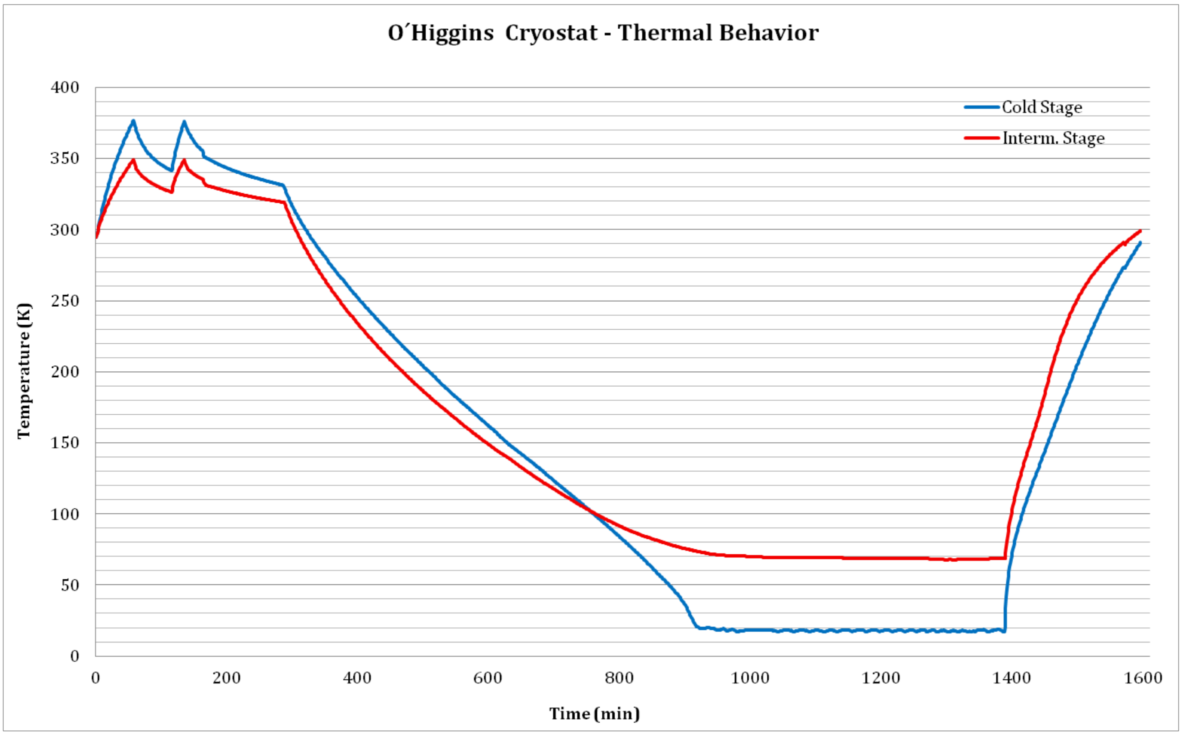


Figure 27. **Cooling test** (zeolites regeneration and heating resistors turned on to warm the cryostat).

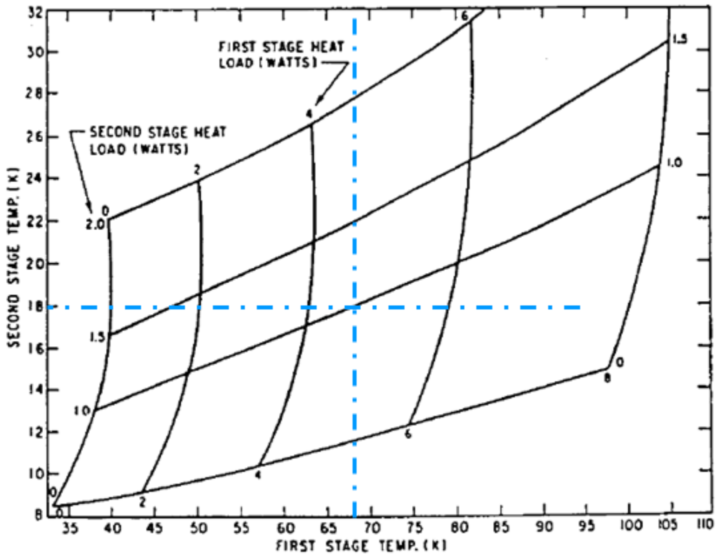


Figure 28. **Intermediate stage load ≈4.6 W, cold stage load ≈1 W**.

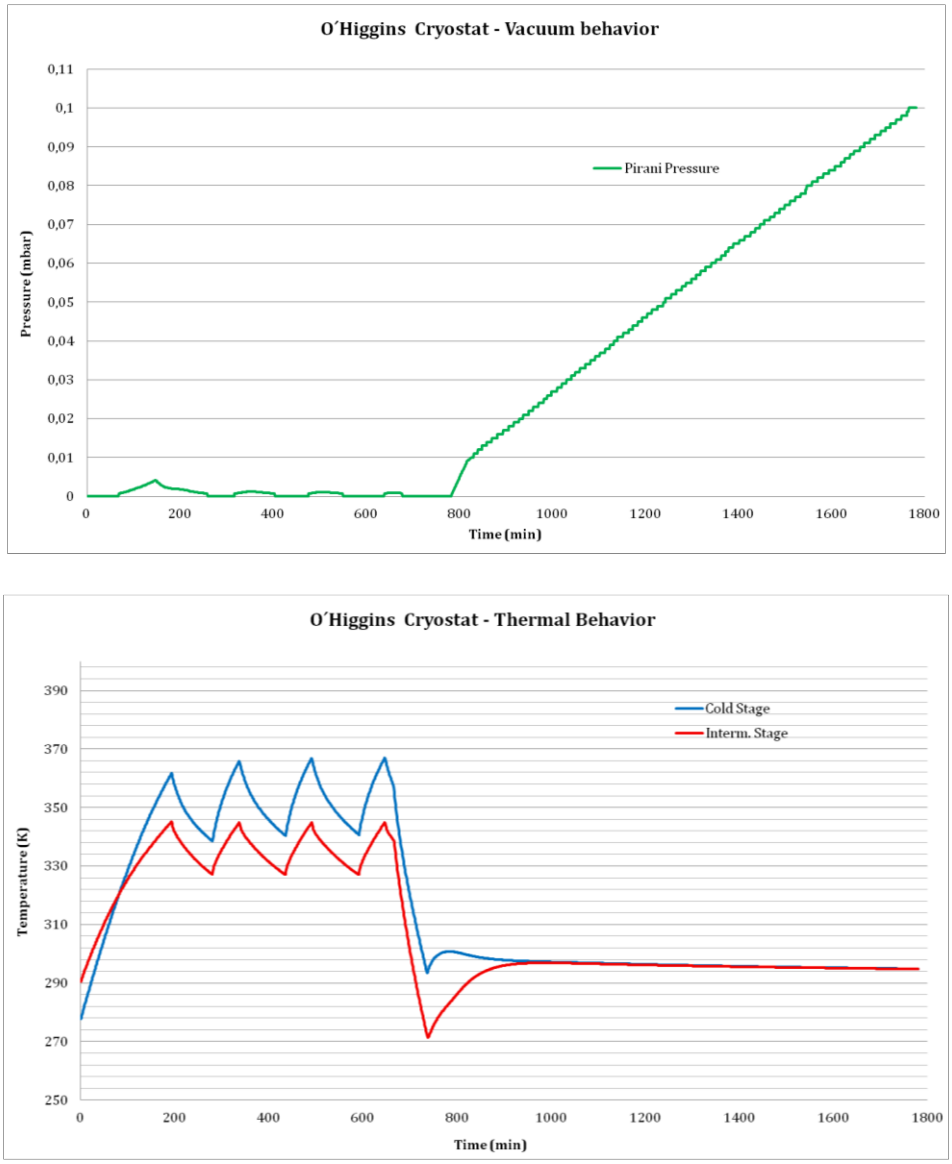


Figure 29. Vacuum test (Pirani sensor) and thermal behavior during the vacuum test, (zeolites regeneration and heating resistors turned on during the first 11 hours).

5. 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:

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

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 SMA 50 Ω load at room temperature, ≈ 297 K.
- Cold load: coaxial 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, N-N hermetic transition, waveguide transition, etc.

Figure 30. Receiver calibration.

LNAs Noise Temperature measured at room temperature

X band	
T_H= = 297 K	T_C = 77.3 K
Freq. (GHz)	**Noise Temp. (K)**
8	293.33
8.1	274.77
8.2	282.78
8.3	326.41
8.4	370.05
8.5	376.35
8.6	355.46
8.7	376.68
8.8	348.86
8.9	381.36
9	376.91

S band	
T_H= = 297 K	T_C = 77.3 K
Freq. (GHz)	**Noise Temp. (K)**
2	128.07
2.1	133.62
2.2	110.52
2.3	106.28
2.4	125.23
2.5	95.77
2.6	165.43

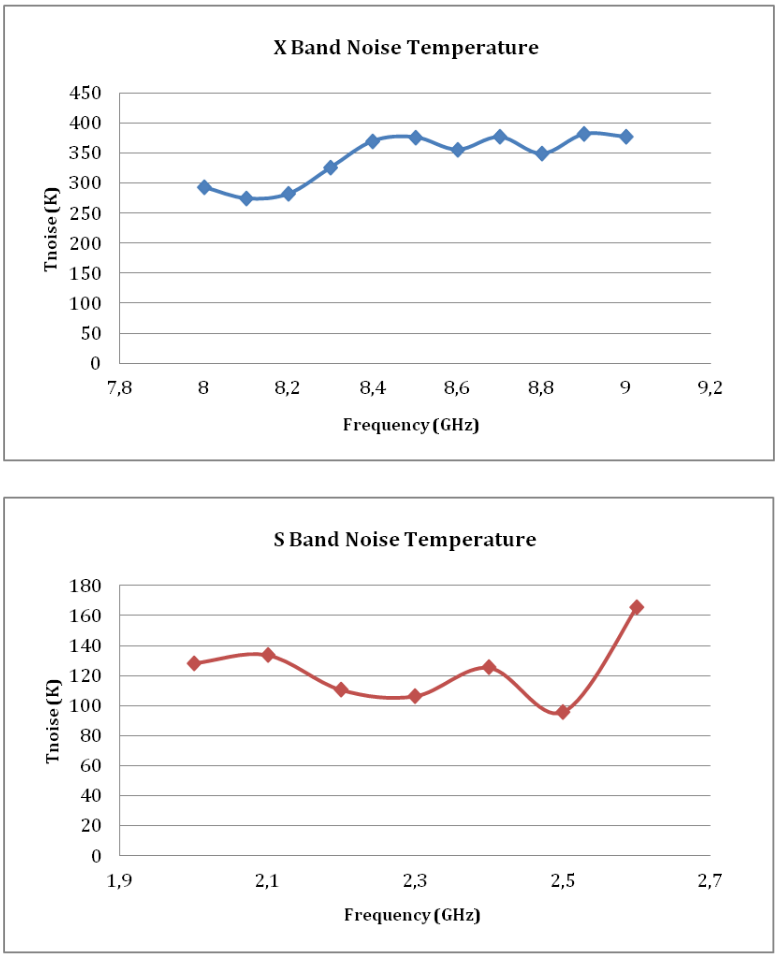
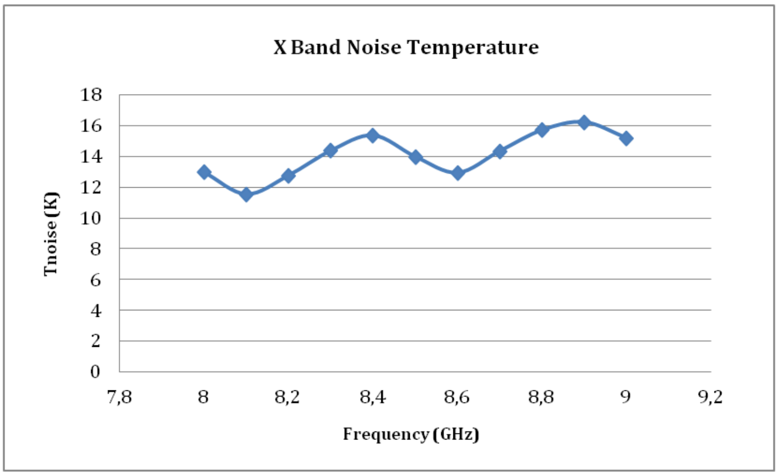


Figure 31. T_{RX} at room temperature (LNAs at ≈ 297 K).

LNAs Noise Temperature measured at cold temperature

X band	
T_H = 297 K	T_C = 77.3 K
Freq. (GHz)	**Noise Temp. (K)**
8	12.96
8.1	11.55
8.2	12.77
8.3	14.37
8.4	15.36
8.5	13.98
8.6	12.94
8.7	14.34
8.8	15.70
8.9	16.22
9	15.20

S band	
T_H= = 297 K	T_C = 77.3 K
Freq. (GHz)	**Noise Temp. (K)**
2	11.59
2.1	12.98
2.2	12.98
2.3	13.37
2.4	13.77
2.5	17.97
2.6	18.24



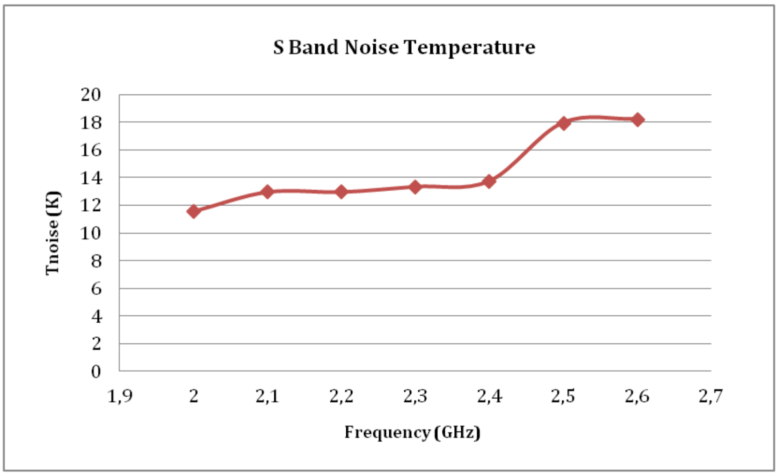
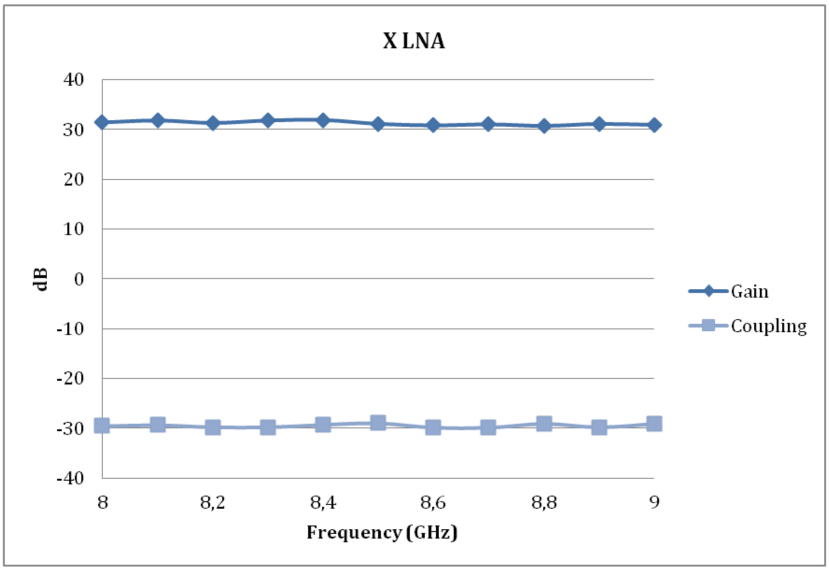


Figure 32. T_{RX} at cold temperature (LNAs at ≈ 18 K).

LNAs Gain and Coupling measured at cold temperature

X Band		
Freq. (Ghz)	**Gain (dB)**	**Coupling (dB)**
8	**31.4**	-29.6
8.1	**31.8**	-29.4
8.2	**31.3**	-29.8
8.3	**31.8**	-29.8
8.4	**31.9**	-29.3
8.5	**31.1**	-29
8.6	**30.8**	-29.9
8.7	**31**	-29.9
8.8	**30.7**	-29.1
8.9	**31.1**	-29.8
9	**30.9**	-29.1

S Band		
Freq. (Ghz)	**Gain (dB)**	**Coupling (dB)**
2	**25.3**	-21.2
2.1	**25.6**	-21
2.2	**26**	-20.8
2.3	**26.1**	-20.7
2.4	**25.5**	-20.4
2.5	**25.2**	-20.4
2.6	**24.8**	-20.3



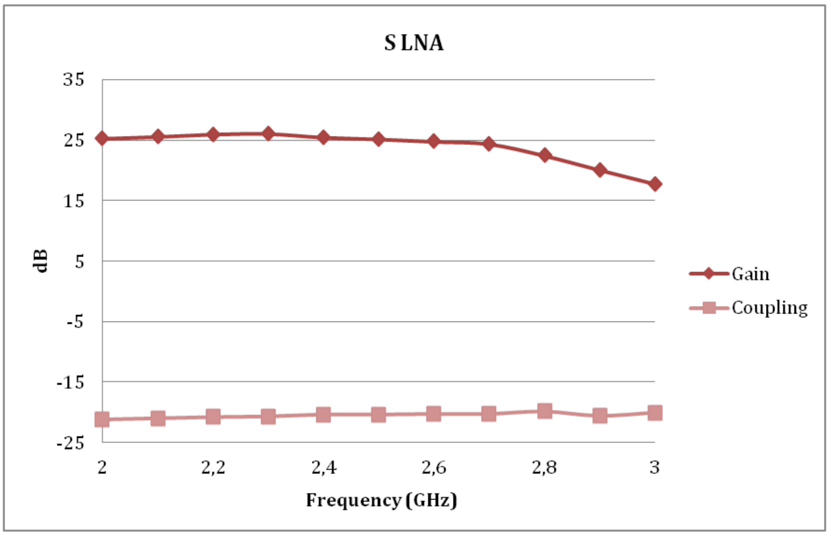


Figure 33. Gain and coupling at cold temperature (LNAs at ≈ 18 K).

6. Low Noise Amplifiers biasing module

With the receiver, a biasing module for the low noise amplifiers is supplied.

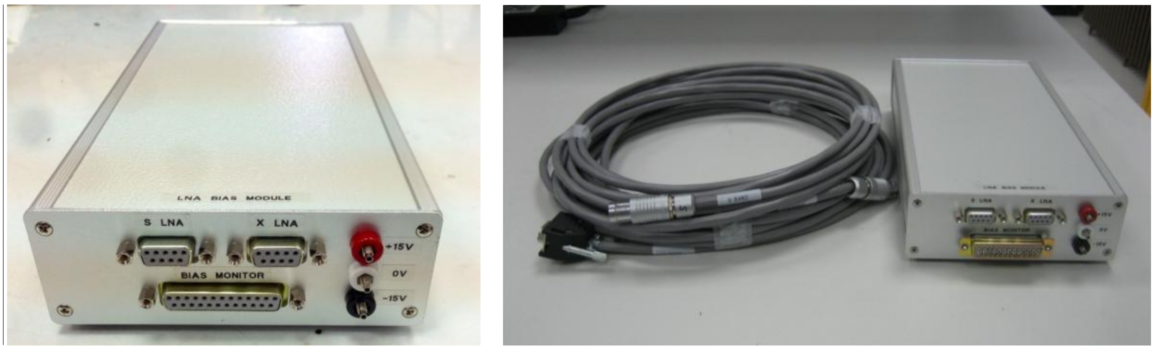


Figure 34. LNAs biasing module and 5 m cables for X and S band amplifiers.

The biasing module is already adjusted for the indicated S and X LNAs biasing points. However, the back cover of the biasing module can be removed for accessing to the biasing power supply cards (the schematics of the cards are shown in figure 35). The card, used for the S LNA, allows the adjustment of two stages and the card for the X LNA three stages. V_d and I_d can be adjusted for each stage by means of the corresponding potentiometer.

S LNA	
V_{d1}	1.2 V
I_{d1}	7 mA
V_{g1}	-2.01 V
V_{d2}	0.8 V
I_{d2}	5 mA
V_{g2}	-2.6 V

LNAs Biasing Module Consume	
+15 V	-15 V
≈ 107 mA	≈ 70 mA

X LNA	
V_{d1}	0.95 V
I_{d1}	4.5 mA
V_{g1}	-1.57 V
V_{d2}	0.75 V
I_{d2}	3.5 mA
V_{g2}	-1.02 V
V_{d3}	0.75 V
I_{d3}	3.5 mA
V_{g3}	-0.94 V

Table 8. LNAs biasing (cold temperature 15K).

The biasing values can be monitored through a DB25 female connector placed at the module front panel. Read values could be slightly different to the real ones due to cable ohmic losses. When adjusting (only if necessary), read the values directly through the pins in the card.

Low Noise Amplifiers biasing procedure:

- Connect Fischer connectors to the corresponding connectors (S and X) on the dewar.
- Connect DB9 connectors to the S and X inputs.
- Connect a power supply to the +15 V and -15 V inputs.
- Turn on power supply and verify electric current values.

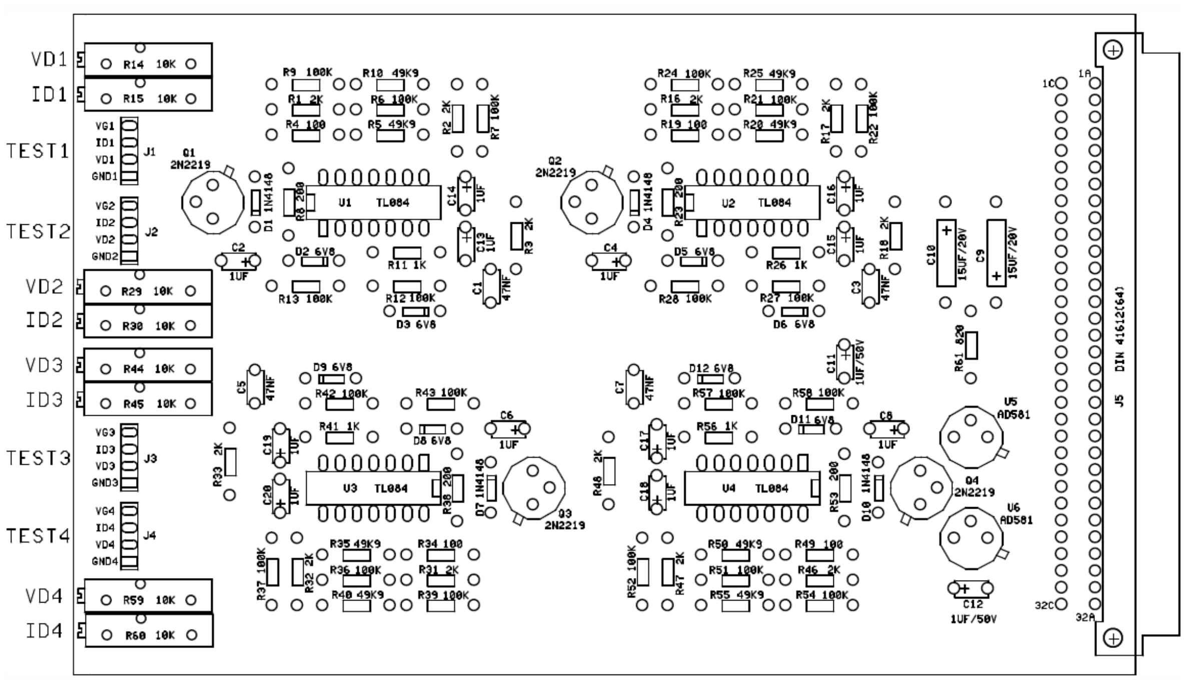


Figure 35. PC Board Components.

LNAs Biasing Monitor DB25 Connector Pin-out

DB25 pin	Signal	Wire color
1	GND	Brown
2	V_{g1} - S	Pink, blue dots
3	I_{d1} - S	Yellow, blue dots
4	V_{d1} - S	Red, blue dots
5	V_{g2} - S	Yellow, pink dots
6	I_{d2} - S	Brown, blue dots
7	V_{d2} - S	Brown, dark blue dots
8	V_{g1} - X	Green, blue dots
9	I_{d1} - X	White, pink dots
10	V_{d1} - X	Yellow, red dots
11	V_{g2} - X	White, yellow dots
12	I_{d2} - X	Brown, green dots
13	V_{d2} - X	Green, blue dots
14	V_{g3} - X	Grey, green dots
15	I_{d3} - X	Grey, brown dots
16	V_{d3} - X	White, blue dots

Table 9. LNAs Biasing Monitor DB25 Connector pin-out.

Biasing cables pin-out

Fischer Pin (F)	DB9 Pin	Wire color	Signal
1	1	Black	Gnd
2	2	Blue	Vd1
3	3	Yellow	Vg1
4	4	Orange	Vd2
5	5	Red	Vg2
6	6	Brown	(free)
7	7	Grey	(free)

Table 10. S band, 5 m cable description.

Fischer Pin (F)	DB9 Pin	Wire color	Signal
1	1	Black	Gnd
2	2	Brown	Vd1
3	3	Yellow	Vg1
4	4	Orange	Vd2
5	5	Green	Vg2
6	6	Blue	Vd3
7	7	Violet	Vg3

Table 11. X band, 5 m cable description.

7. 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 (C1) (figure 5).
    - 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 DB25 connector for the 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 banana connector to a power supply.
        - Black: GND
        - Yellow:+6.17 V, ≈112 mA
    - Connect the heating resistor banana connectors to a power supply.
        - Black: GND
        - Red: +25.7 V, ≈498 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.

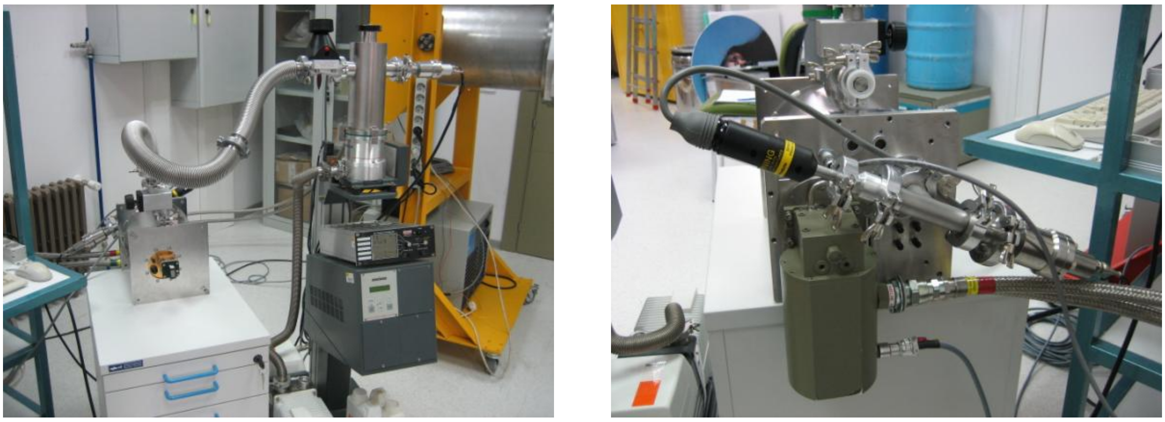


Figure 36. O´Higgins cryostat vacuum and cooling test.

- **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 (figure 5).

Cryostat Connector	LNA Biasing Module
C2	S band LNA
C3	X band LNA

  - 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, table 8).

- **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, 120 K. 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.

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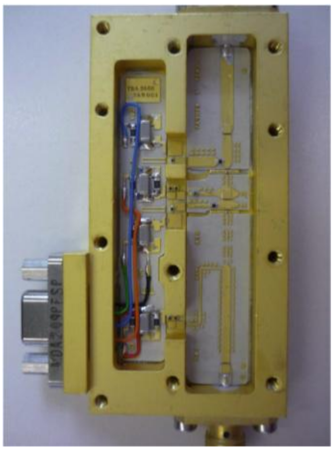
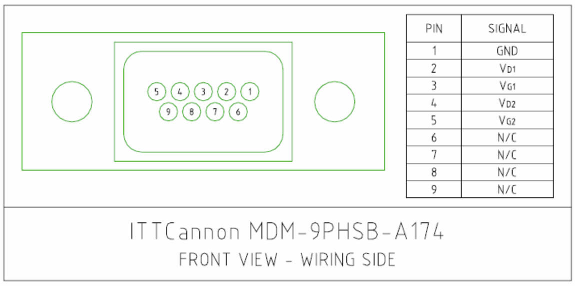
9. Appendix

9.1. S band amplifier specifications



Amplifier external view.



PIN	SIGNAL
1	GND
2	V_{D1}
3	V_{G1}
4	V_{D2}
5	V_{G2}
6	N/C
7	N/C
8	N/C
9	N/C

ITTCannon MDM-9PHSB-A174
FRONT VIEW - WIRING SIDE

DC connector pin-out.

Customer	OAN	**Manufacturer**	TTI
Product Description	S band Cryogenic LNA	**Test Operator**	Francisco Díaz
Part Number	TTI-LNA-S-2248-Cryo	**Band**	2.2 GHz – 2.7 GHz
Serial Number	**TSA 2008**	**Test Date / Time**	March 2013

ROOM TEMPERATURE DATA (292K)				
Nominal Bias	First Stage: Mitsubishi MGFC4419	$V_{D1} = 2.00V$	$I_{D1} = 10mA$	$V_{G1} = -4.26$ V
	Second Stage: Mitsubishi MGFC4419	$V_{D2} = 2.00V$	$I_{D2} = 10mA$	$V_{G2} = -4.41$ V
Maximum/Average Noise Temperature: 57.81K/ 47.8 K		Average Gain, Ripple (VNA): 25.8, 0.85dB		
Minimum Input Return Loss: 6.6 dB		Minimum Output Return Loss: 25.1 dB		

CRYOGENIC TEMPERATURE DATA (15K)			
Optimum Bias (P_{DIS} < 12.4mW)	$V_{D1} = 1.20V$	$I_{D1} = 7mA$	$V_{G1} = -2.01V$
	$V_{D2} = 0.80V$	$I_{D2} = 5mA$	$V_{G2} = -2.06V$

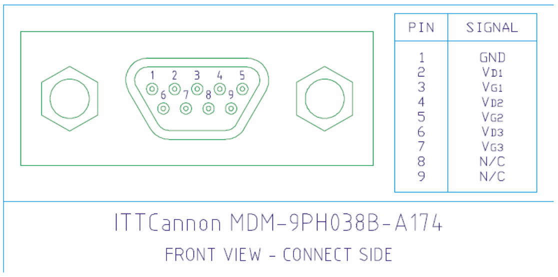
Technical Specification	**Requirement**	**Test**	**Equipment**	**Result**	**Compliance**
Frequency Range	2.2 – 2.7 GHz	-	-	2.2-2.7 GHz	Yes
Noise Temperature	< 10K	Noise	N8975A	< 5.90 K	Yes
Average Gain	> 26 dB	Scattering Parameters based on VNA	N5230A	> 27 dB	Yes
Gain Flatness	2dB p-p		N5230A	< 1.1 dB p-p	Yes
Input VSWR	< 3 dB		N5230A	< 6.0 dB	Yes
Output VSWR	< 10 dB		N5230A	< 26.3 dB	Yes
Power Consumption	< 10mW	-	34970A	< 12.4 mW	Yes
Amplifier Stability	Unconditionally Stable	Sliding Shorts	U2002A 1909D2	Note 1	Yes
Mass	< 50 grams	-	Scale	42 grams	Yes

Note 1

Amplifier stability was tested at cryogenic temperature changing V_D from 0 to 1.75V for each stage

9.2. X band amplifier specifications

Amplifier external view.

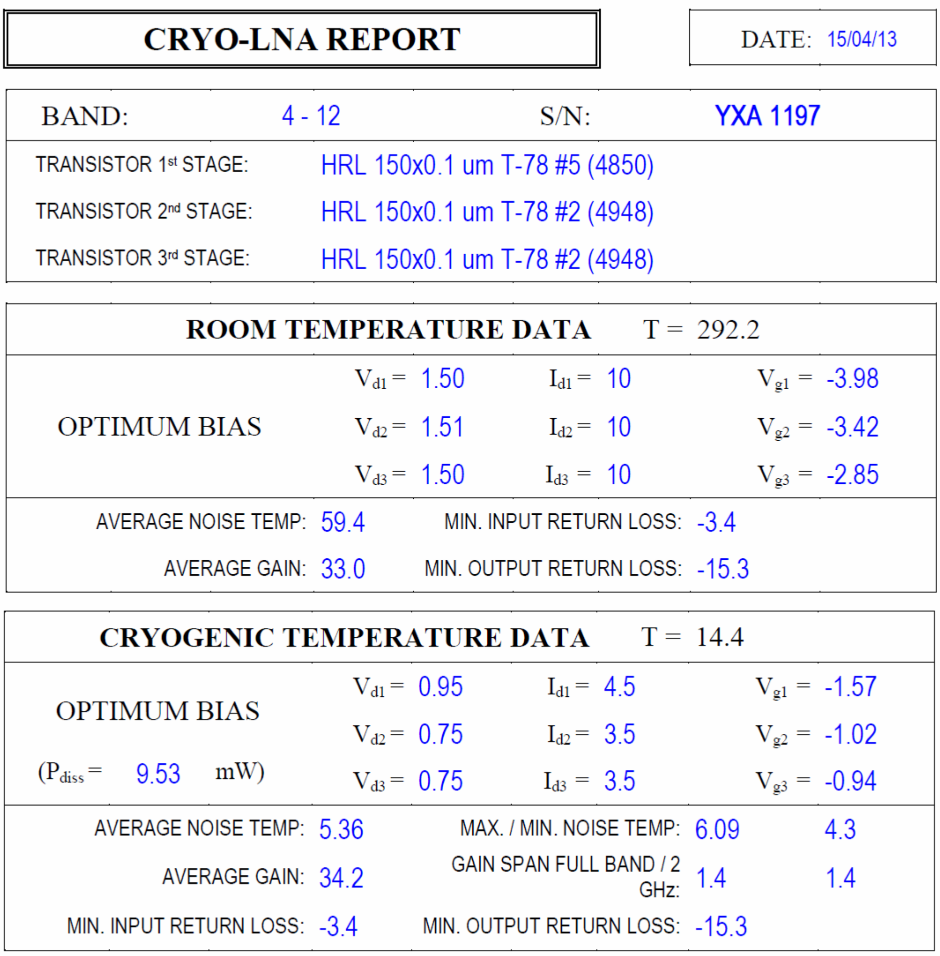


PIN	SIGNAL
1	GND
2	V_{D1}
3	V_{G1}
4	V_{D2}
5	V_{G2}
6	V_{D3}
7	V_{G3}
8	N/C
9	N/C

ITTCannon MDM-9PH038B-A174

FRONT VIEW - CONNECT SIDE

DC connector pin-out.



CRYO-LNA REPORT

DATE: 15/04/13

BAND:	4 - 12	S/N:	YXA 1197
TRANSISTOR 1st STAGE:	HRL 150x0.1 um T-78 #5 (4850)		
TRANSISTOR 2nd STAGE:	HRL 150x0.1 um T-78 #2 (4948)		
TRANSISTOR 3rd STAGE:	HRL 150x0.1 um T-78 #2 (4948)		

ROOM TEMPERATURE DATA T = 292.2

OPTIMUM BIAS	V_{d1} = 1.50	I_{d1} = 10	V_{g1} = -3.98
	V_{d2} = 1.51	I_{d2} = 10	V_{g2} = -3.42
	V_{d3} = 1.50	I_{d3} = 10	V_{g3} = -2.85

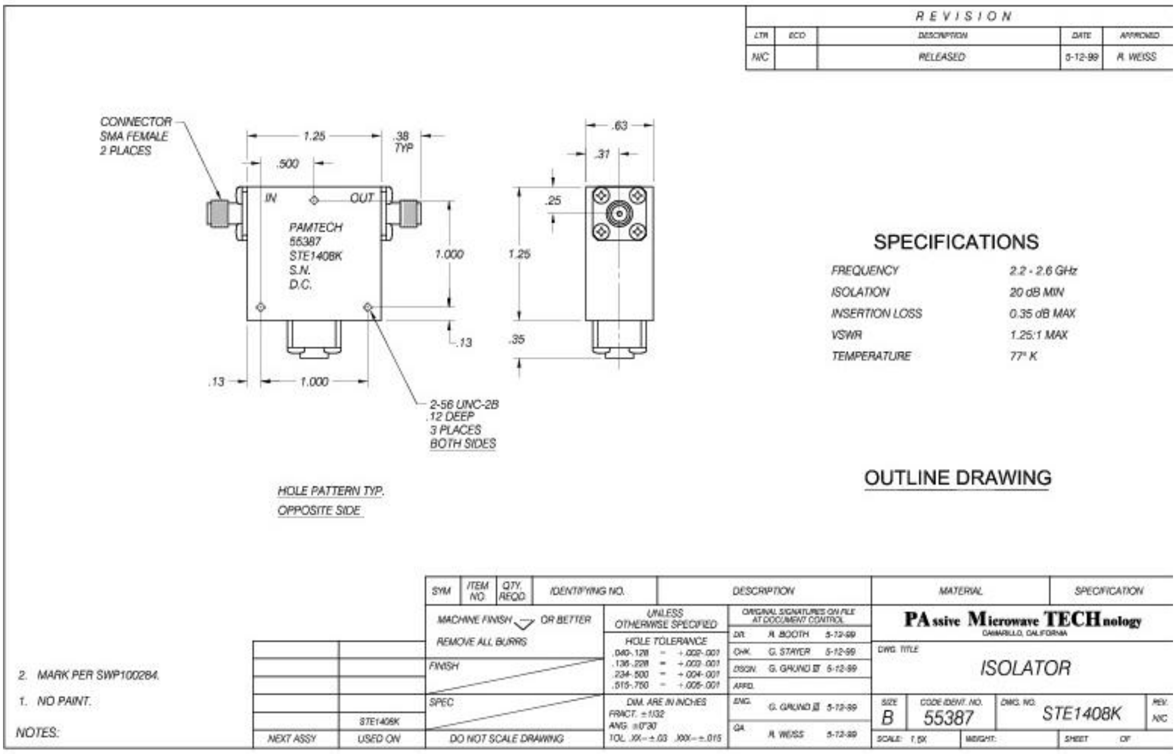
AVERAGE NOISE TEMP:	59.4	MIN. INPUT RETURN LOSS:	-3.4
AVERAGE GAIN:	33.0	MIN. OUTPUT RETURN LOSS:	-15.3

CRYOGENIC TEMPERATURE DATA T = 14.4

OPTIMUM BIAS	V_{d1} = 0.95	I_{d1} = 4.5	V_{g1} = -1.57
	V_{d2} = 0.75	I_{d2} = 3.5	V_{g2} = -1.02
(P_{diss} = 9.53 mW)	V_{d3} = 0.75	I_{d3} = 3.5	V_{g3} = -0.94

AVERAGE NOISE TEMP:	5.36	MAX. / MIN. NOISE TEMP:	6.09	4.3
AVERAGE GAIN:	34.2	GAIN SPAN FULL BAND / 2 GHz:	1.4	1.4
MIN. INPUT RETURN LOSS:	-3.4	MIN. OUTPUT RETURN LOSS:	-15.3	

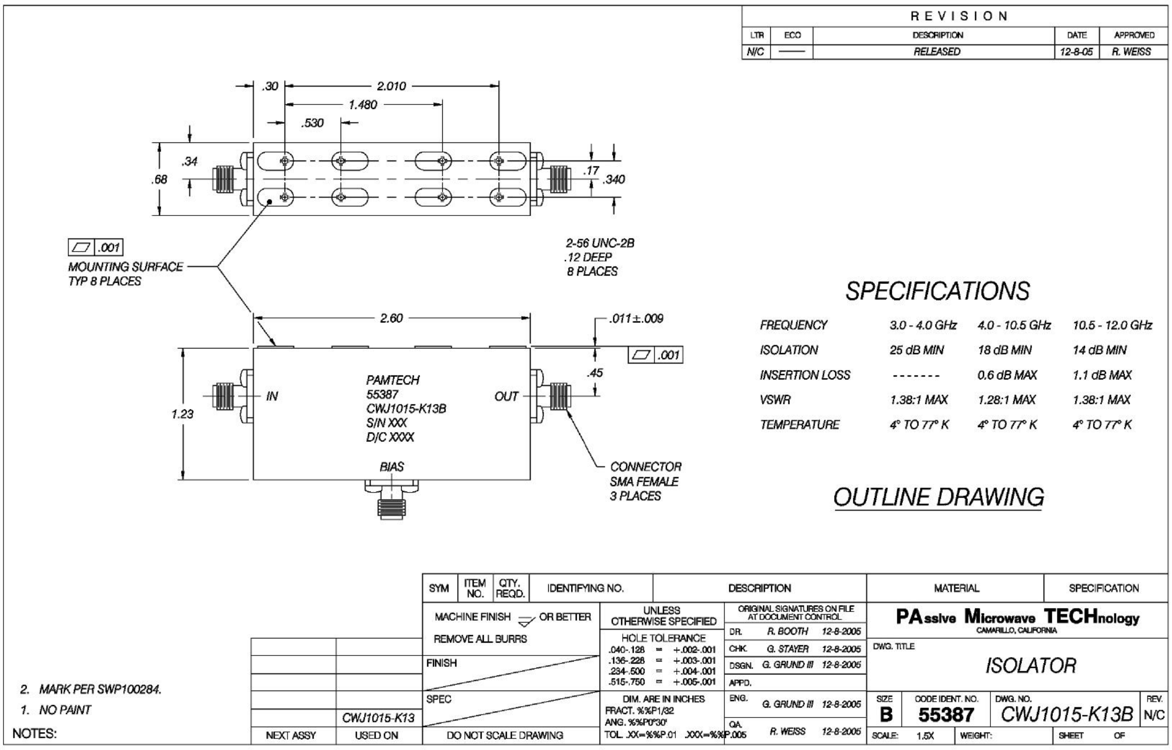
9.3. S band isolator specifications



SPECIFICATIONS

FREQUENCY	2.2 - 2.6 GHz
ISOLATION	20 dB MIN
INSERTION LOSS	0.35 dB MAX
VSWR	1.25:1 MAX
TEMPERATURE	77° K

9.4. X band isolator specifications



SPECIFICATIONS

FREQUENCY	3.0 - 4.0 GHz	4.0 - 10.5 GHz	10.5 - 12.0 GHz
ISOLATION	25 dB MIN	18 dB MIN	14 dB MIN
INSERTION LOSS	- - - - - - -	0.6 dB MAX	1.1 dB MAX
VSWR	1.38:1 MAX	1.28:1 MAX	1.38:1 MAX
TEMPERATURE	4° TO 77° K	4° TO 77° K	4° TO 77° K

9.5. 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

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.

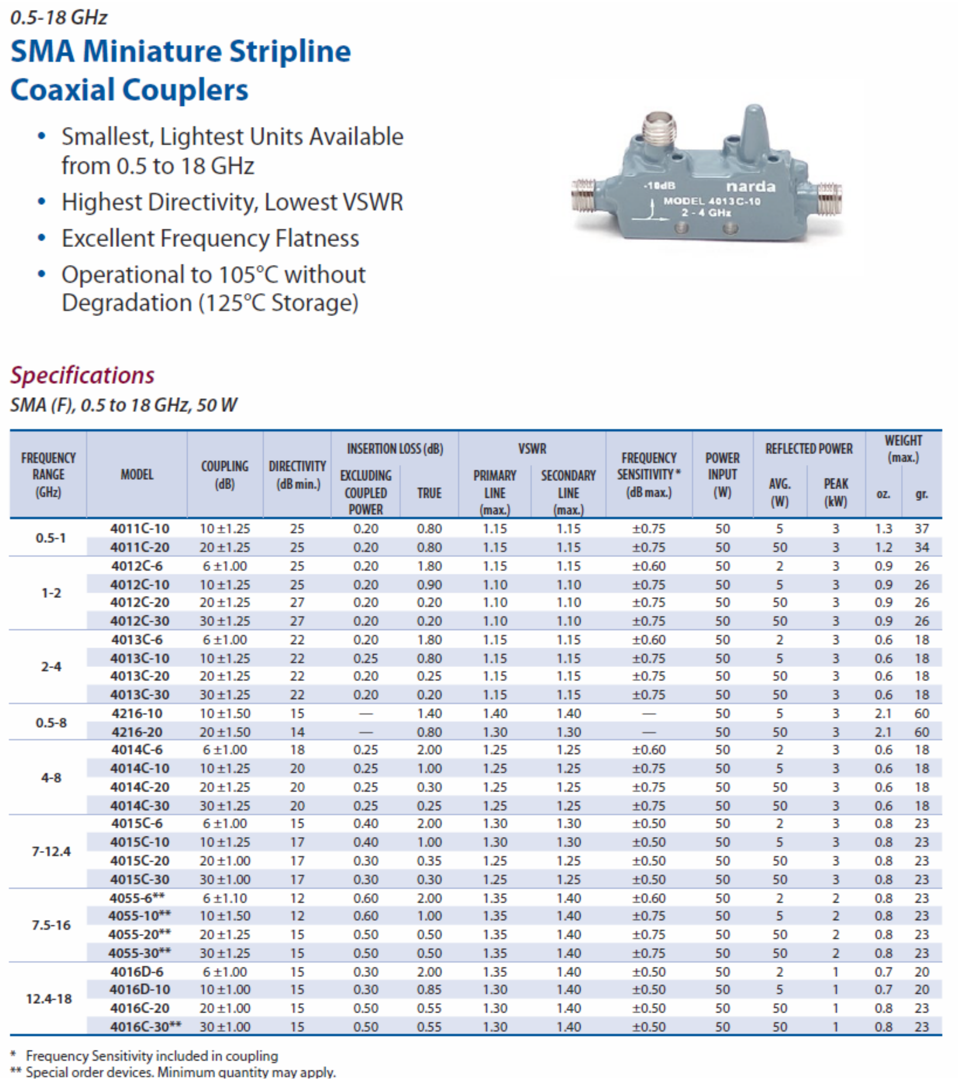
DT-621-HR Miniature Silicon Diode

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.

Typical DT-670 Diode Voltage Values

Typical DT-670 Diode Sensitivity Values

9.6. S band coupler (narda 4013C-20) specifications



0.5-18 GHz

SMA Miniature Stripline Coaxial Couplers

- Smallest, Lightest Units Available from 0.5 to 18 GHz
- Highest Directivity, Lowest VSWR
- Excellent Frequency Flatness
- Operational to 105°C without Degradation (125°C Storage)

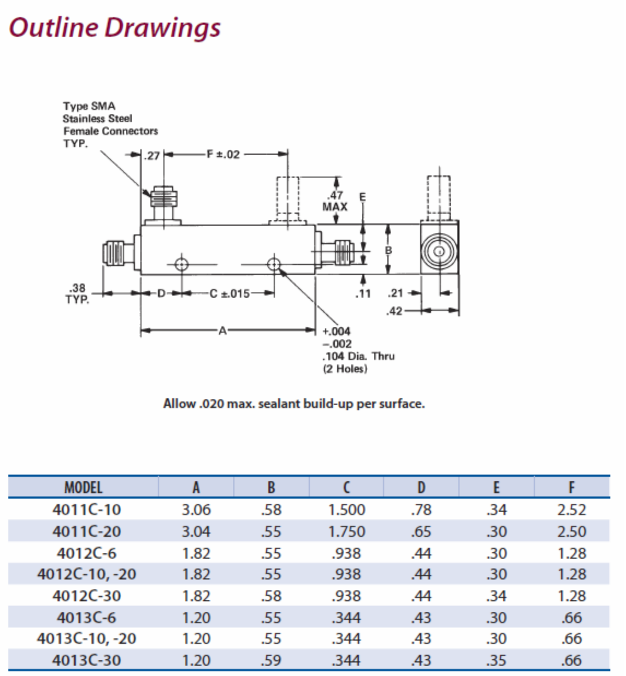
Specifications

SMA (F), 0.5 to 18 GHz, 50 W

FREQUENCY RANGE (GHz)	MODEL	COUPLING (dB)	DIRECTIVITY (dB min.)	INSERTION LOSS (dB)		VSWR		FREQUENCY SENSITIVITY * (dB max.)	POWER INPUT (W)	REFLECTED POWER		WEIGHT (max.)	
				EXCLUDING COUPLED POWER	TRUE	PRIMARY LINE (max.)	SECONDARY LINE (max.)			AVG. (W)	PEAK (kW)	oz.	gr.
0.5-1	4011C-10	10 ±1.25	25	0.20	0.80	1.15	1.15	±0.75	50	5	3	1.3	37
	4011C-20	20 ±1.25	25	0.20	0.80	1.15	1.15	±0.75	50	50	3	1.2	34
1-2	4012C-6	6 ±1.00	25	0.20	1.80	1.15	1.15	±0.60	50	2	3	0.9	26
	4012C-10	10 ±1.25	25	0.20	0.90	1.10	1.10	±0.75	50	5	3	0.9	26
	4012C-20	20 ±1.25	27	0.20	0.20	1.10	1.10	±0.75	50	50	3	0.9	26
	4012C-30	30 ±1.25	27	0.20	0.20	1.10	1.10	±0.75	50	50	3	0.9	26
2-4	4013C-6	6 ±1.00	22	0.20	1.80	1.15	1.15	±0.60	50	2	3	0.6	18
	4013C-10	10 ±1.25	22	0.25	0.80	1.15	1.15	±0.75	50	5	3	0.6	18
	4013C-20	20 ±1.25	22	0.20	0.25	1.15	1.15	±0.75	50	50	3	0.6	18
	4013C-30	30 ±1.25	22	0.20	0.20	1.15	1.15	±0.75	50	50	3	0.6	18
0.5-8	4216-10	10 ±1.50	15	—	1.40	1.40	1.40	—	50	5	3	2.1	60
	4216-20	20 ±1.50	14	—	0.80	1.30	1.30	—	50	50	3	2.1	60
4-8	4014C-6	6 ±1.00	18	0.25	2.00	1.25	1.25	±0.60	50	2	3	0.6	18
	4014C-10	10 ±1.25	20	0.25	1.00	1.25	1.25	±0.75	50	5	3	0.6	18
	4014C-20	20 ±1.25	20	0.25	0.30	1.25	1.25	±0.75	50	50	3	0.6	18
	4014C-30	30 ±1.25	20	0.25	0.25	1.25	1.25	±0.75	50	50	3	0.6	18
7-12.4	4015C-6	6 ±1.00	15	0.40	2.00	1.30	1.30	±0.50	50	2	3	0.8	23
	4015C-10	10 ±1.25	17	0.40	1.00	1.30	1.30	±0.50	50	5	3	0.8	23
	4015C-20	20 ±1.00	17	0.30	0.35	1.25	1.25	±0.50	50	50	3	0.8	23
	4015C-30	30 ±1.00	17	0.30	0.30	1.25	1.25	±0.50	50	50	3	0.8	23
7.5-16	4055-6**	6 ±1.10	12	0.60	2.00	1.35	1.40	±0.60	50	2	2	0.8	23
	4055-10**	10 ±1.50	12	0.60	1.00	1.35	1.40	±0.75	50	5	2	0.8	23
	4055-20**	20 ±1.25	15	0.50	0.50	1.35	1.40	±0.75	50	50	2	0.8	23
	4055-30**	30 ±1.25	15	0.50	0.50	1.35	1.40	±0.75	50	50	2	0.8	23
12.4-18	4016D-6	6 ±1.00	15	0.30	2.00	1.35	1.40	±0.50	50	2	1	0.7	20
	4016D-10	10 ±1.00	15	0.30	0.85	1.30	1.40	±0.50	50	5	1	0.7	20
	4016C-20	20 ±1.00	15	0.50	0.55	1.30	1.40	±0.50	50	50	1	0.8	23
	4016C-30**	30 ±1.00	15	0.50	0.55	1.30	1.40	±0.50	50	50	1	0.8	23

* Frequency Sensitivity included in coupling

** Special order devices. Minimum quantity may apply.

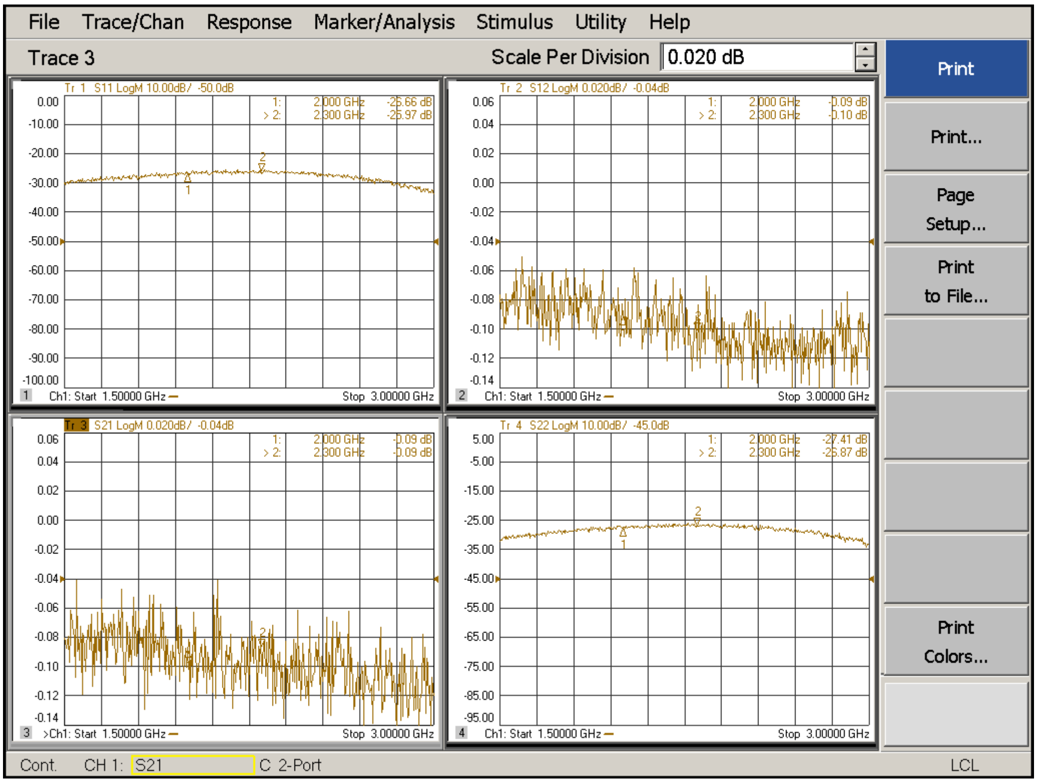


Outline Drawings

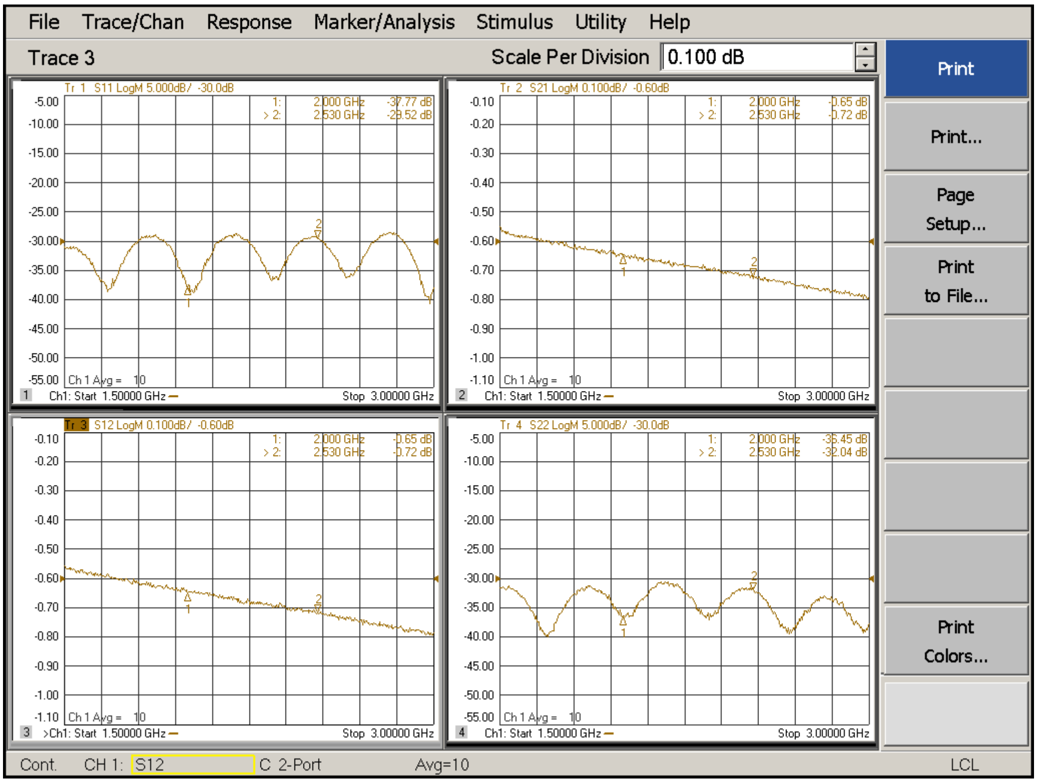
Allow .020 max. sealant build-up per surface.

MODEL	A	B	C	D	E	F
4011C-10	3.06	.58	1.500	.78	.34	2.52
4011C-20	3.04	.55	1.750	.65	.30	2.50
4012C-6	1.82	.55	.938	.44	.30	1.28
4012C-10, -20	1.82	.55	.938	.44	.30	1.28
4012C-30	1.82	.58	.938	.44	.34	1.28
4013C-6	1.20	.55	.344	.43	.30	.66
4013C-10, -20	1.20	.55	.344	.43	.30	.66
4013C-30	1.20	.59	.344	.43	.35	.66

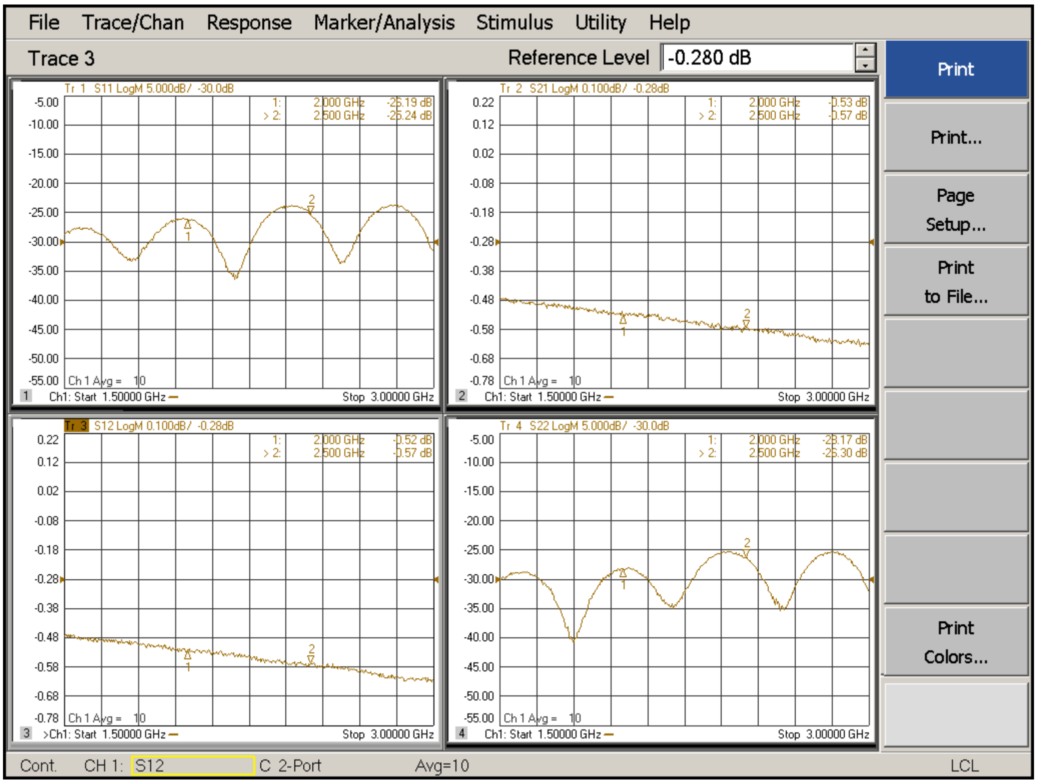
9.7. RF Measurements



S band input cable, UT-85B-SS, 5 cm length.



S band output cable, UT-85B-SS.

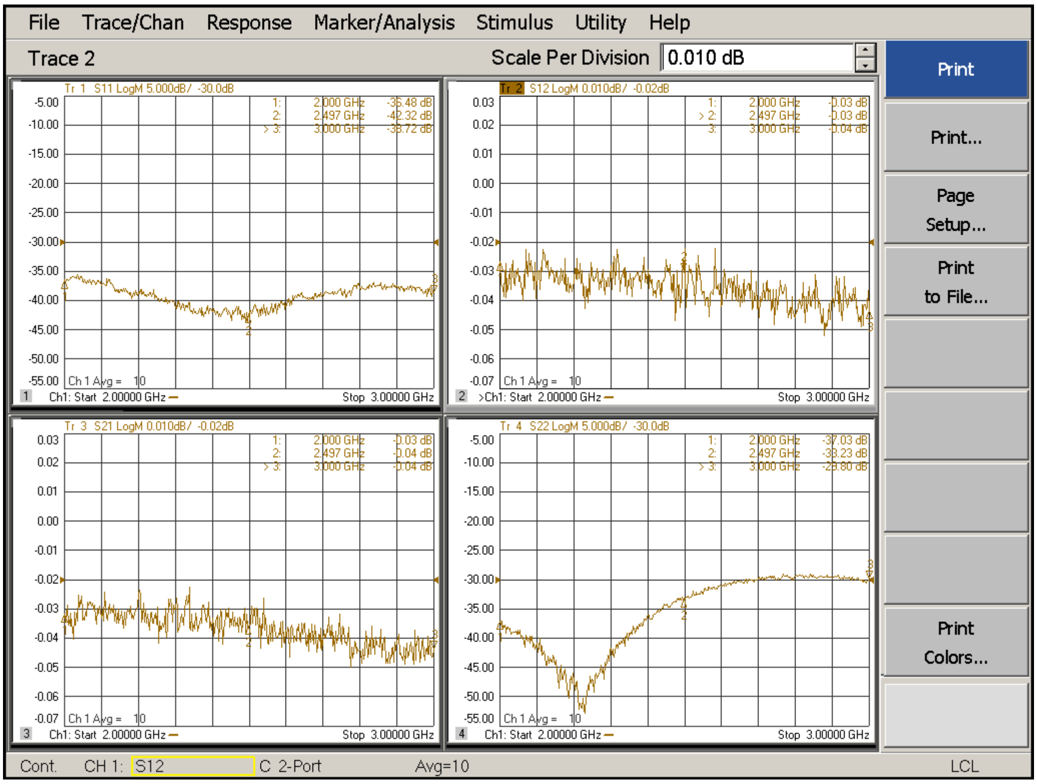


Trace 3

Reference Level -0.280 dB

CH 1: S12 C 2-Port Avg=10

S band calibration input cable, UT-85B-SS.

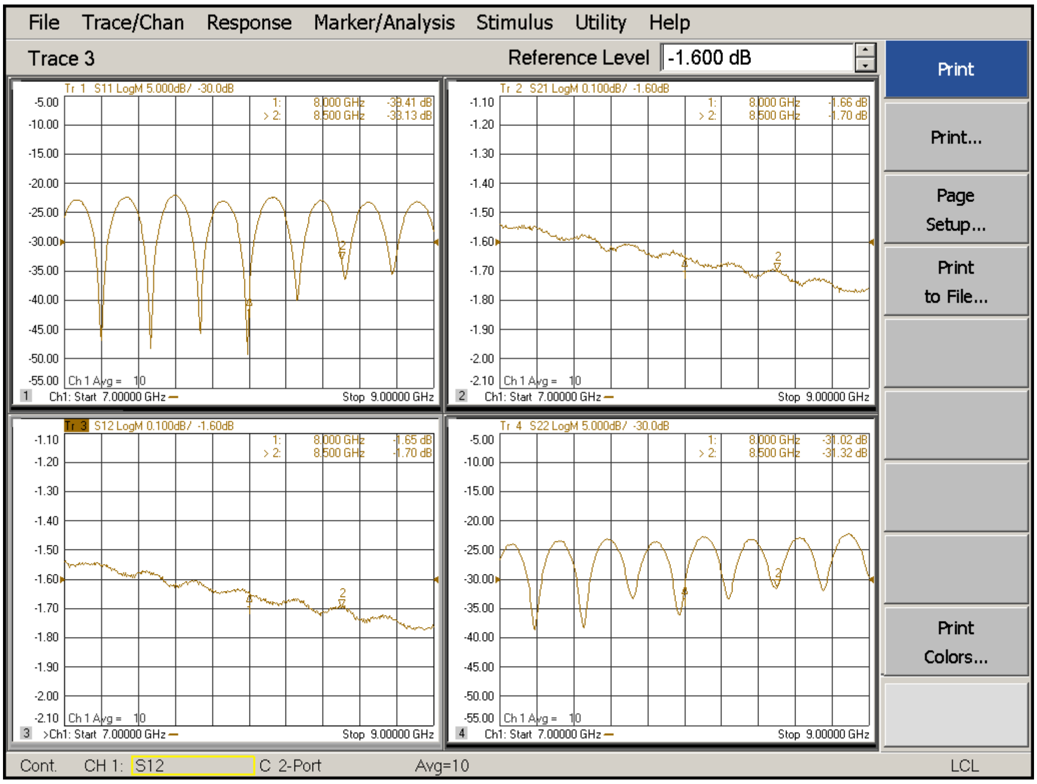


Trace 2

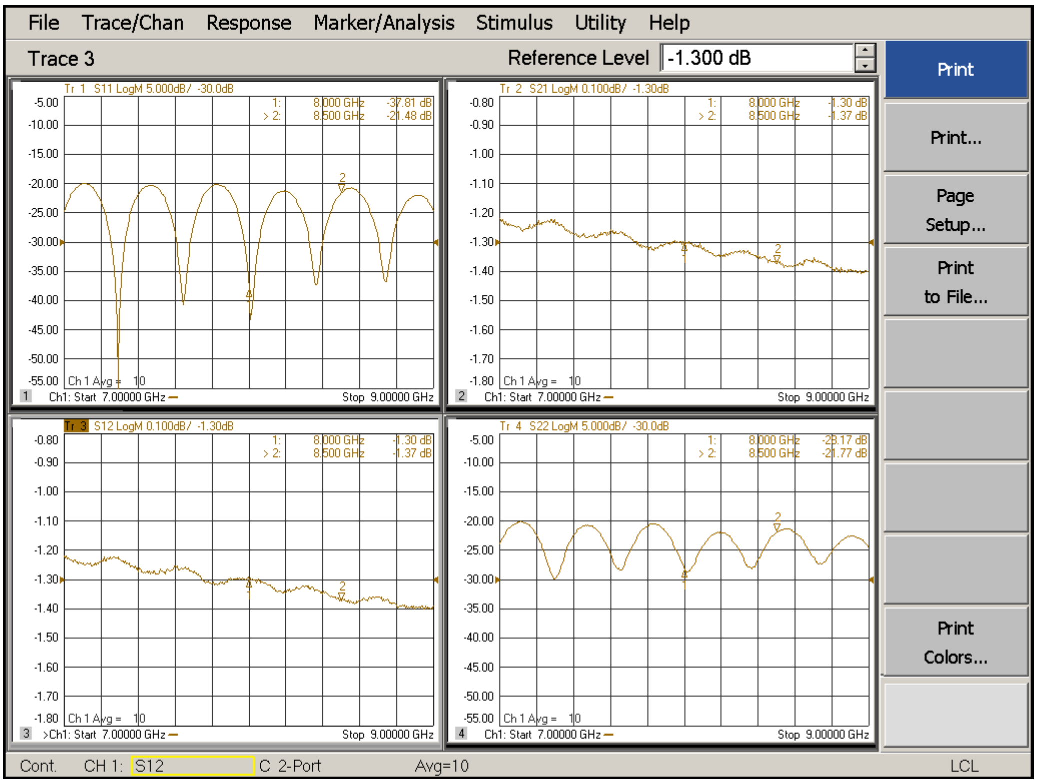
Scale Per Division 0.010 dB

CH 1: S12 C 2-Port Avg=10

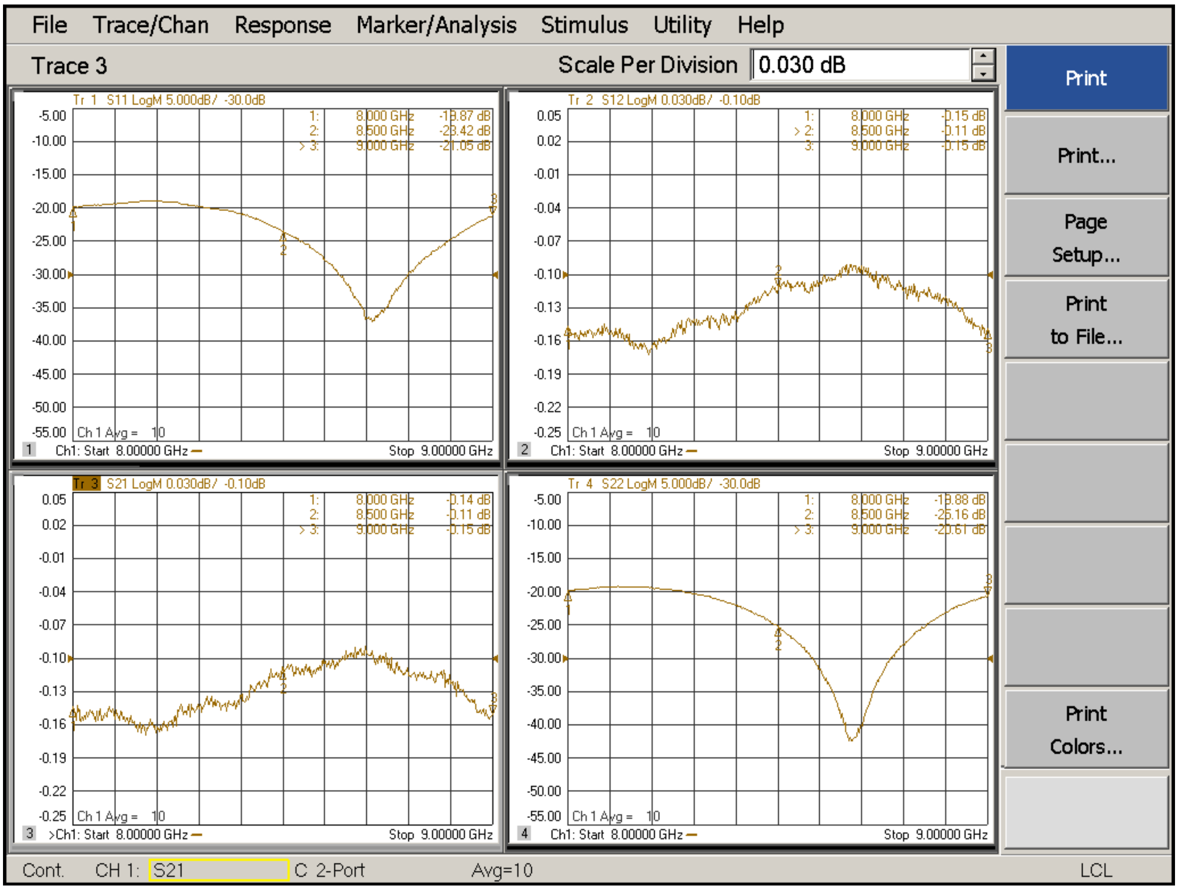
S band hand-formable cable (directional coupler - isolator).



X band output cable, UT-85B-SS.



X band calibration input cable, UT-85B-SS.



Scale Per Division 0.030 dB

Tr 1 S11 LogM 5.000dB/ -30.0dB

```
  1:   8.000 GHz   -19.87 dB
  2:   8.500 GHz   -23.42 dB
> 3:   9.000 GHz   -21.05 dB
```

Ch 1 Avg = 10

Ch1: Start 8.00000 GHz — Stop 9.00000 GHz

Tr 2 S12 LogM 0.030dB/ -0.10dB

```
  1:   8.000 GHz   -0.15 dB
> 2:   8.500 GHz   -0.11 dB
  3:   9.000 GHz   -0.15 dB
```

Ch 1 Avg = 10

Ch1: Start 8.00000 GHz — Stop 9.00000 GHz

Tr 3 S21 LogM 0.030dB/ -0.10dB

```
  1:   8.000 GHz   -0.14 dB
  2:   8.500 GHz   -0.11 dB
> 3:   9.000 GHz   -0.15 dB
```

Ch 1 Avg = 10

>Ch1: Start 8.00000 GHz — Stop 9.00000 GHz

Tr 4 S22 LogM 5.000dB/ -30.0dB

```
  1:   8.000 GHz   -19.88 dB
  2:   8.500 GHz   -25.16 dB
> 3:   9.000 GHz   -20.61 dB
```

Ch 1 Avg = 10

Ch1: Start 8.00000 GHz — Stop 9.00000 GHz

Cont. CH 1: S21 C 2-Port Avg=10 LCL

X band hand-formable cable (thermal transition - isolator).