New K Band Receiver
for Multifrequency VLBI

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1. Introduction

This report summarizes the new design and characteristics of the K band cryogenic receiver developed at Yebes Observatory. The goal of this receiver is to be part of the new multifrequency VLBI system implemented in the 40 m radio telescope (observations in K and Q bands, future 3 mm upgrade).

The receiver is based on a two stage closed cycle cryocooler (CTI-350), the cold stage below 20 K and the intermediate stage, below 70 K. The K band receiver chain is composed by a corrugated feed horn (frequency band 21.75-24.45 GHz), polarizer and two low noise amplifiers (RHCP and LHCP). These devices have been designed, built, and measured at Yebes Observatory laboratories.

1.1. Specifications

Frequency bands	K Band: 20.5 – 24.5 GHz
Physical Temperature	< 65 K radiation shield < 15 K cold stage
Pressure	< 10^{-6} mbar
Pressure Leaks at room temperature (mainly outgassing)	< $3.5 \cdot 10^{-5}$ mbar·l/s < $8.3 \cdot 10^{-7}$ mbar/s
Gain LNAs	27.7dB RCP 25.95 dB LCP
Noise Temperature	RCP band: < 20 K LCP band: < 20 K
Input	K band: feed RCP calibration: SMA LCP calibration: SMA
Output	RCP: K connector LCP: K connector
Output impedance	50 Ω

2. Cryostat geometry

Next figures show the cryostat design overview:

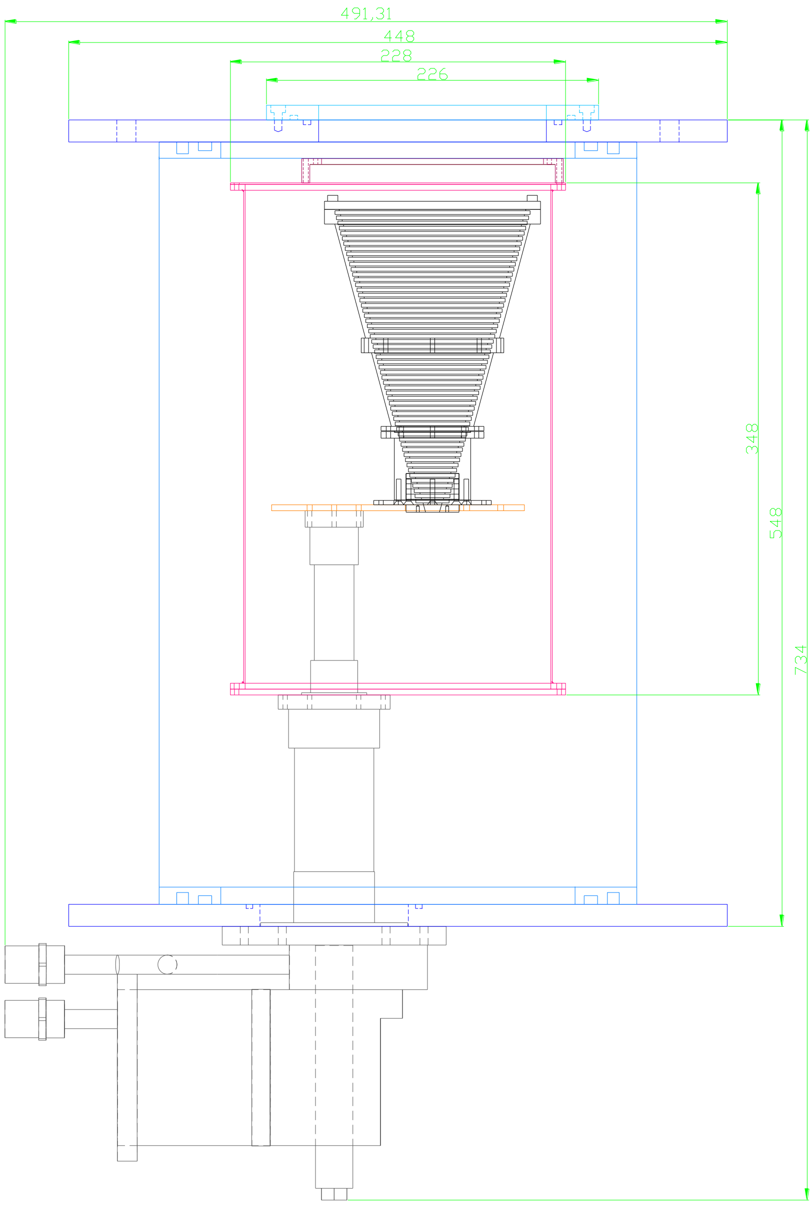


Figure 1. Cryostat overview (cold head (grey), vacuum case (blue), radiation shield (pink), cold stage (orange), feed (black) and vacuum window (light blue)).

The cryostat is built over a Model-350 CTI cold head in a steel made cylindrical dewar. At the top cover, a vacuum window lets the K band radiation go through. At the bottom cover there are all the RF connectors for K band, the flanges for the pressure sensor and vacuum valve, 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 61 K. Removing the radiation shield, the entire receiver can be easily reached. It is the coldest part of the receiver at, approximately, 13 K. Amplifiers, polarizer and the feed are thermally attached to the copper made cold stage.

The RF cables that connect the amplifiers and the polarizer with the room temperature stage (SMA connectors), are coaxial semi-rigid steel cables, UT-085B-SS. The cables that connect the LNAs with the polarizer are coaxial semi-rigid copper cables, UT-141C-LL.

2.1. Vacuum case

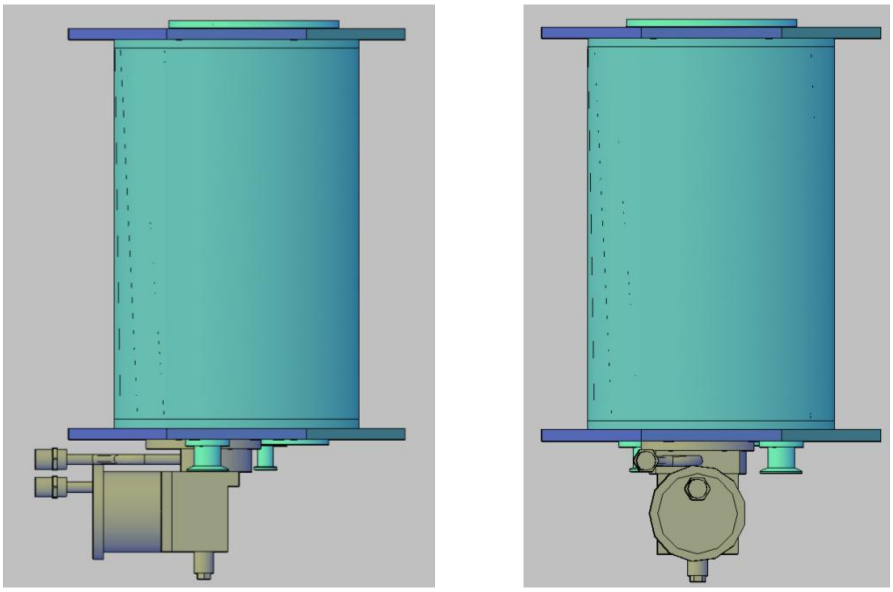


Figure 2. Vacuum case and cold head 3D view.

The dewar consists of three main parts: stainless steel cylinder, aluminum bottom flange and top flange. The vacuum window (made of Mylar) for the signal input, is located at the top flange. 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.
- Four SMA hermetic connectors for the RF input/output signals (calibration and RF).

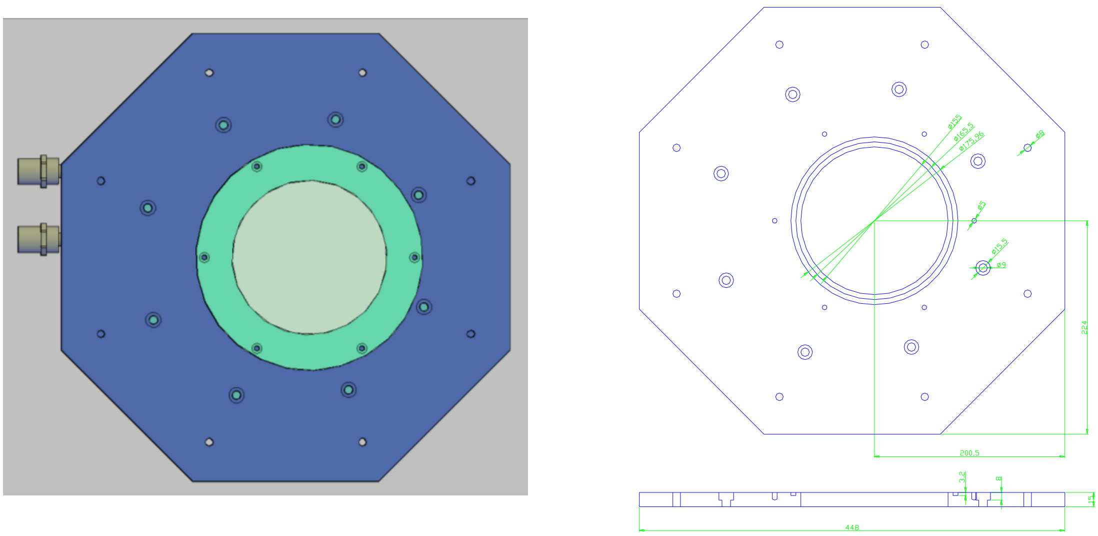


Figure 3. Dewar top flange and vacuum window.

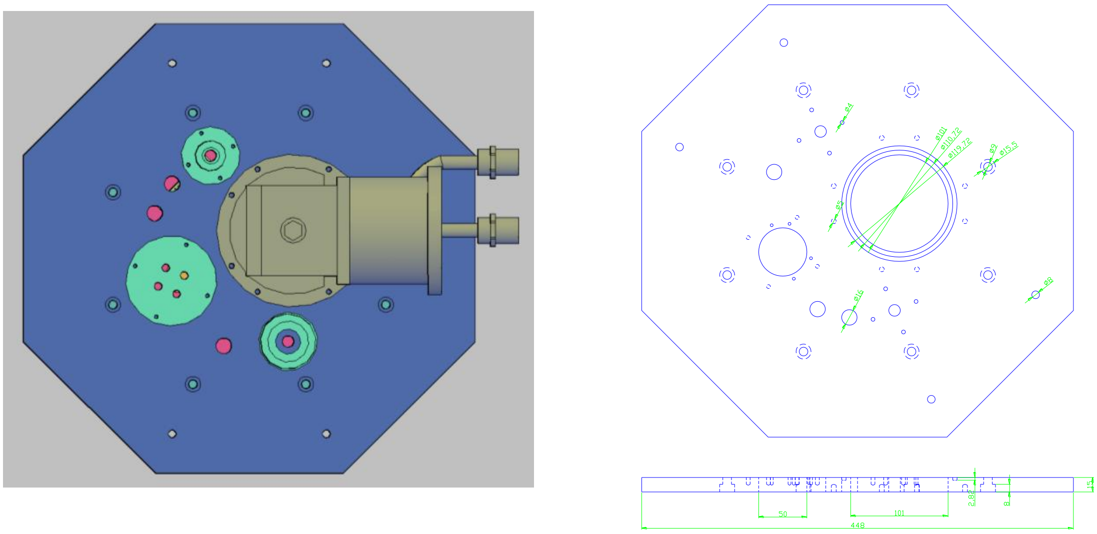


Figure 4. Dewar bottom flange.

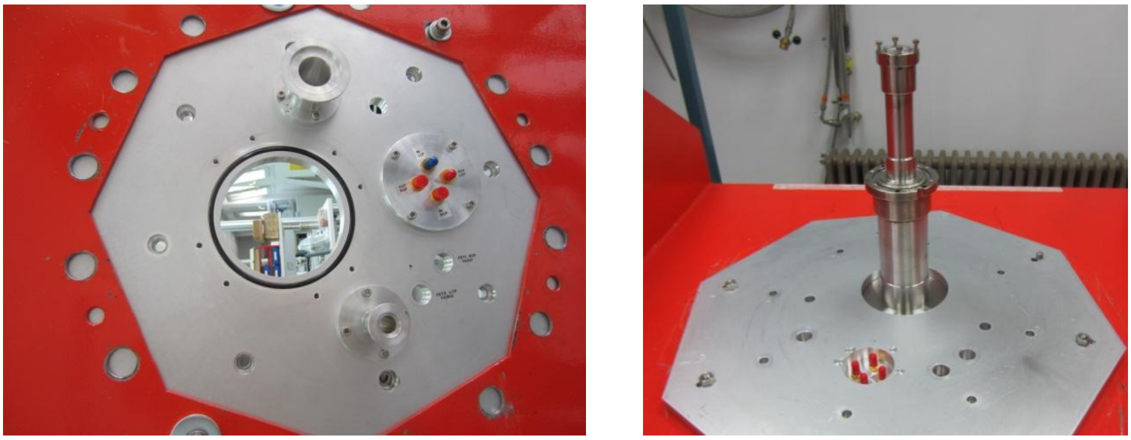


Figure 5. Bottom dewar flange, both sides.

2.1.1. Vacuum window

The vacuum window goal is to allow transition (physical, electromagnetic and vacuum) between the signal and the K band feed. For this receiver, a vacuum window made of Mylar (Polyethylene terephthalate film, thickness 0.5 mm) was selected.

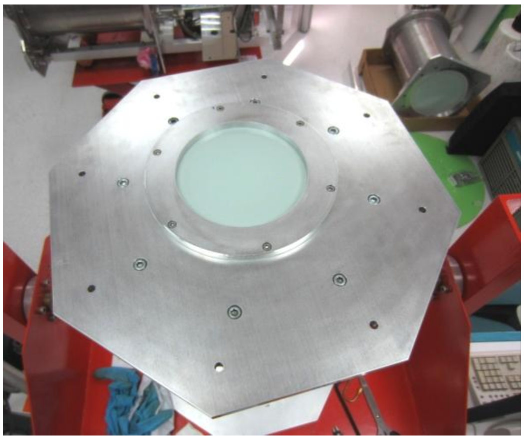


Figure 6. Top dewar flange and vacuum window.

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 - bottom flange	OR VI	110.72	3.53	305.643	1
Vacuum case - bottom and top flanges	OR VI	253.37	6.99	305.578	2
Vacuum window - Mylar	OR VI	165	4	436.963	1
Top flange - Mylar	OR VI	183	4	593.269	1
Vacuum valve and vacuum sensor - bottom flange	OR VI	28	4	670.265	2
SMAs flange - bottom flange	OR VI	58.42	2.62	305.517	1

Table 1: Viton vacuum seals (Epidor [5]).

2.2. Intermediate stage and radiation shield

The intermediate stage is an aluminum plate of 4 mm thickness and 228 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 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.

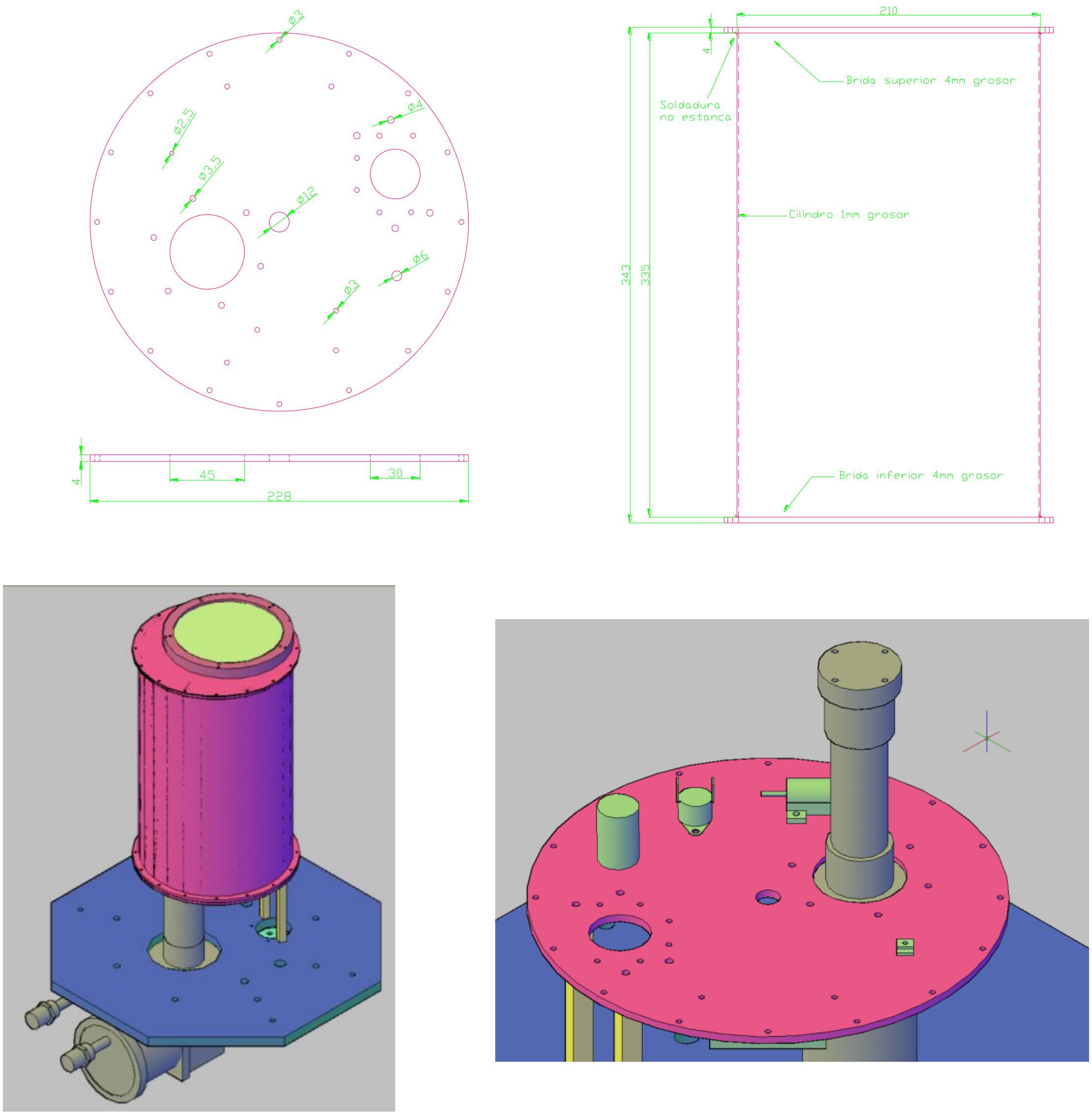


Figure 7. Intermediate stage and radiation shield design.

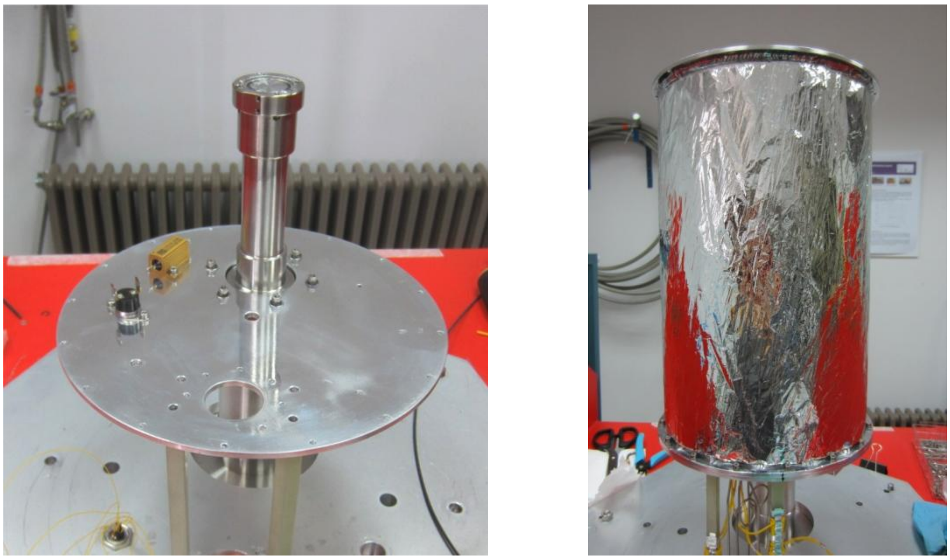


Figure 8. Intermediate stage and radiation shield with multilayer isolator.

Another important element, at the intermediate stage, is the infrared filter. It is located on the top cover of the radiation shield. The infrared filter is used to decrease the thermal load to the cold stage (infrared radiation that goes into the cryostat through the window of the vacuum case). It is made of extruded polystyrene foam (3 ± 0.3 mm thickness, 0.033 W/mK thermal conductivity at 40°C, 35 kg/m^3 density). The filter consists of three foam layers separated by nylon washers 0.8 mm.

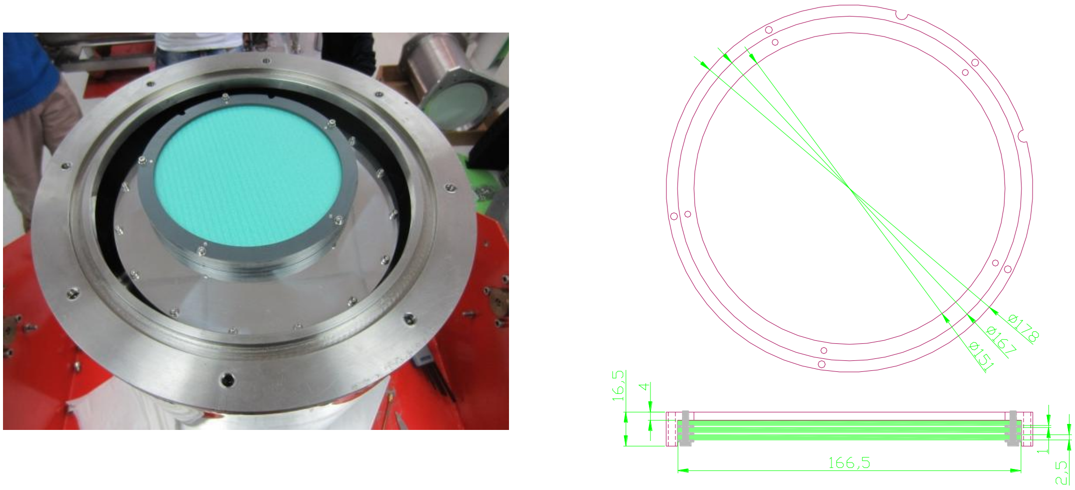


Figure 9. IR filter.

2.3. Cold stage

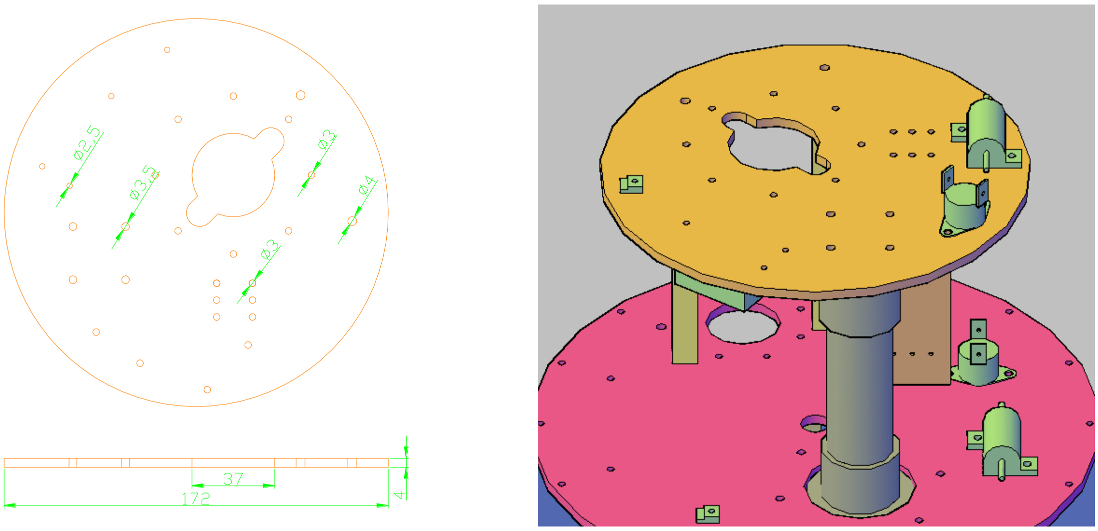


Figure 10. Cold stage design and 3D view with the housekeeping devices.

The cold stage consists of a copper plate of 4 mm thickness and 172 mm diameter, screwed onto the second stage of the cold head. Attached to this plate are placed one vacuum trap, thermostat, heating resistor and a temperature sensor (same specifications than the used for the intermediate stage). The K band LNAs, the feed horn and the polarizer are also attached to this stage.

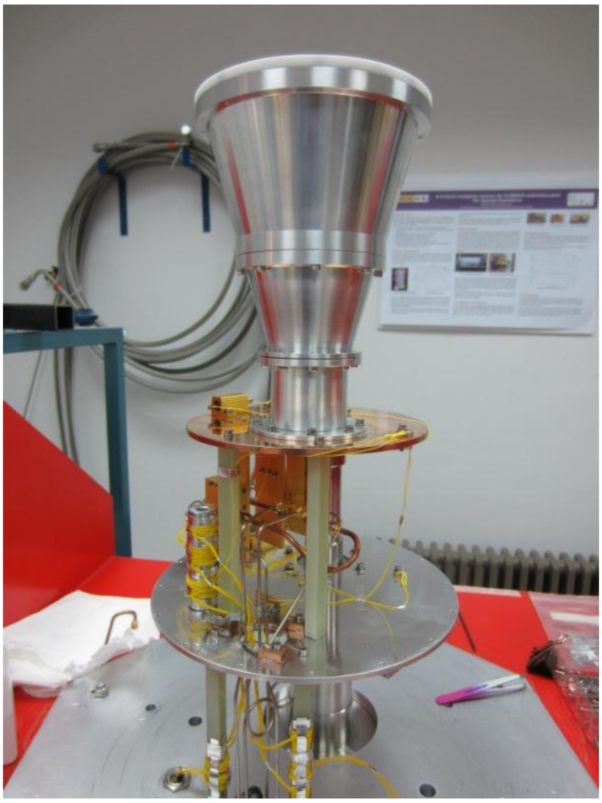


Figure 11. Intermediate and cold stages, feed horn, polarizer and LNAs.

3. Amplifier setting-up

The cryostat contains two low noise amplifiers, designed and built at Yebes Observatory:

LNA/Band	YK22 002 K band LCP	YK22 003 K band RCP
Nominal Band	20.5 – 24.5 GHz	20.5 – 24.5 GHz
Average noise temperature @15K	8.48 K	12.69 K
Average gain @15K	25.95 dB	27.7 dB
This LNA should be operated with	LED OFF	LED OFF
Stages	3	3
Transistors		InP 0.1×200 µm CRYO3 TRW

Table 2. LNAs main specifications (detailed specifications and biasing information can be found in the appendix).

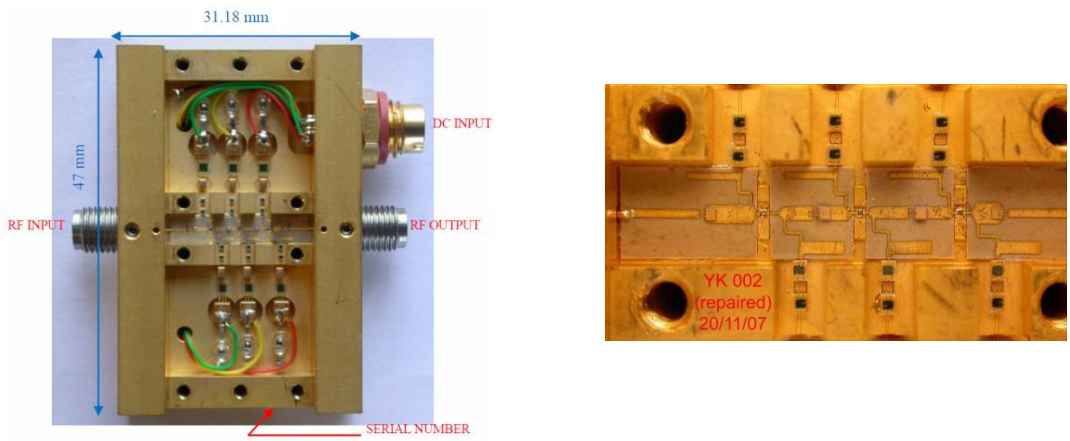


Figure 12. YK22 003 – RCP and YK22 002 – LCP.

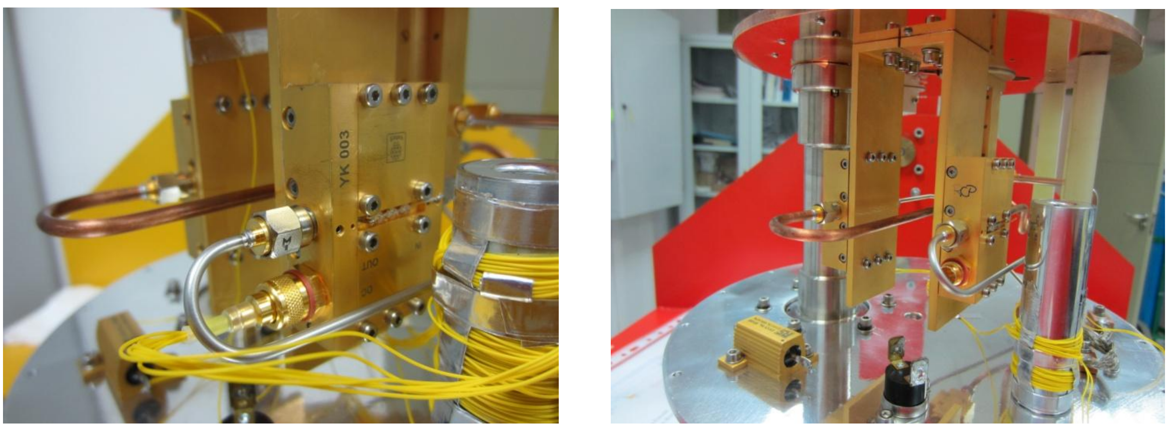


Figure 13. Amplifiers attached to the cold stage.

3.1. Low Noise Amplifiers biasing module

Figure 14. LNAs biasing module.

The LNAs biasing module (K Band Down Converter) is already adjusted for the indicated K LNAs biasing points. However, the bottom cover of the down converter can be removed for accessing to the biasing power supply cards (the schematics of the cards are shown in figure below). The cards, used for the LNAs, allow the adjustment of three stages. V_d and I_d can be adjusted for each stage by means of the corresponding potentiometer.

YK22 002 K band LCP			
Optimum bias values @14K		Measured values	
		@12K	@297K
V_{d1}	**1.4 V**	1.4 V	1.398 V
I_{d1}	**5 mA**	4.9 mA	5 mA
V_{g1}		0.16 V	0.018 V
V_{d2}	**1.4 V**	1.4 V	1.403 V
I_{d2}	**7 mA**	7 mA	7.04 mA
V_{g2}		0.226 V	0.086 V
V_{d3}	**1.4 V**	1.4 V	1.403 V
I_{d3}	**7 mA**	7 mA	6.97 mA
V_{g3}		0.08 V	-0.082 V

YK22 003 K band RCP			
Optimum bias values @14K		Measured values	
		@12K	@297K
V_{d1}	**1.5 V**	1.5 V	1.5 V
I_{d1}	**5.44 mA**	5.46 mA	5.46 mA
V_{g1}	**0.16 V**	0.17 V	0.057 V
V_{d2}	**1.4 V**	1.4 V	1.4 V
I_{d2}	**6.45 mA**	6.40 mA	6.44 mA
V_{g2}	**0.02 V**	0.02 V	-0.095 V
V_{d3}	**1.4 V**	1.4 V	1.401 V
I_{d3}	**7 mA**	6.97 mA	6.98 mA
V_{g3}	**0.15 V**	0.16 V	0.024 V

Table 3. Optimum LNAs biasing at cold temperature and module set values.

YK22 003 K band RCP	
Optimum bias values @290K	
V_{d1}	**1.4 V**
I_{d1}	**7 mA**
V_{g1}	**0.09 V**
V_{d2}	**1.4 V**
I_{d2}	**7 mA**
V_{g2}	**-0.09 V**
V_{d3}	**1.4 V**
I_{d3}	**7 mA**
V_{g3}	**0 V**

Table 4. Optimum LNAs biasing at room temperature. (NO data for LNA YK22 002).

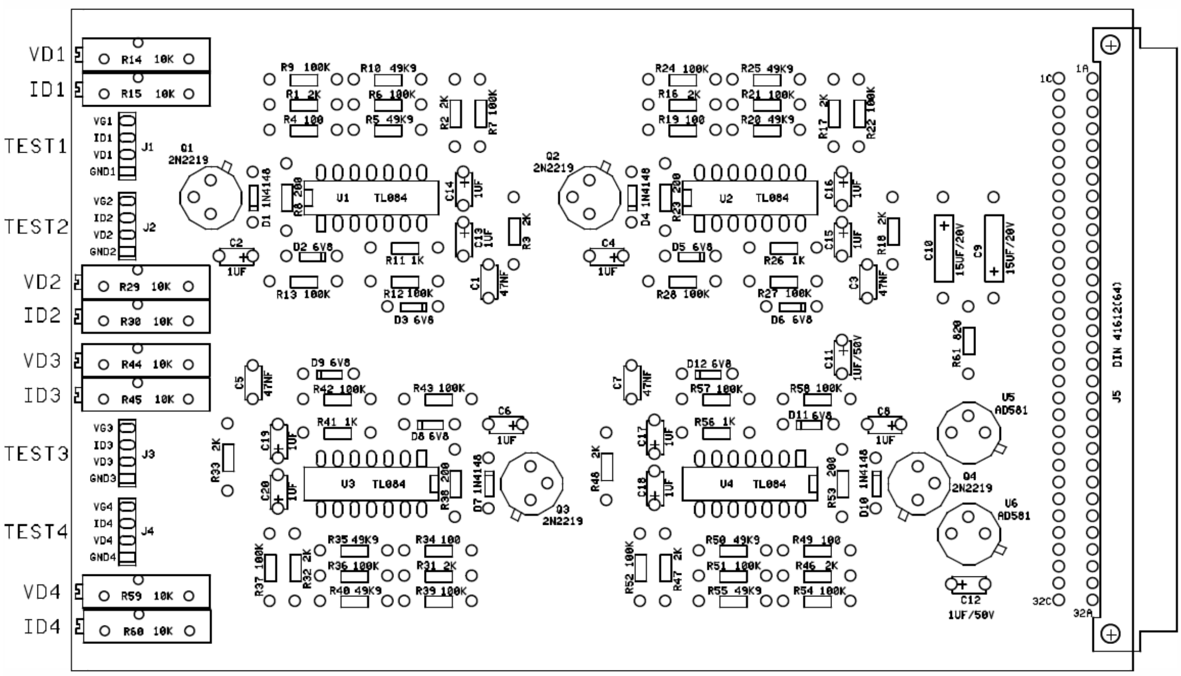


Figure 15. PC Board Components.

Low Noise Amplifiers biasing procedure:

- Connect Fischer connectors to the corresponding connectors (FET1 and FET2) on the dewar.
- Connect DB15 connectors to the LNAs biasing module.
- Connect a power supply to the +15 V and -15 V inputs.
- **Warning!** Verify correct ground connection between dewar and biasing module.
- Turn on power supply and verify electric current values.

4. K band corrugated feed horn

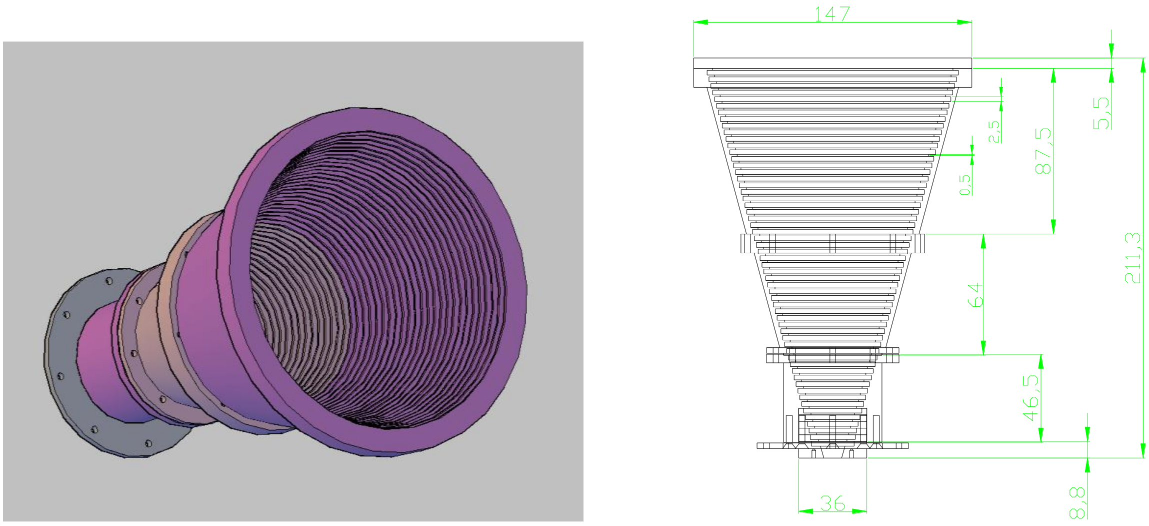


Figure 16. K band corrugated feed horn design.

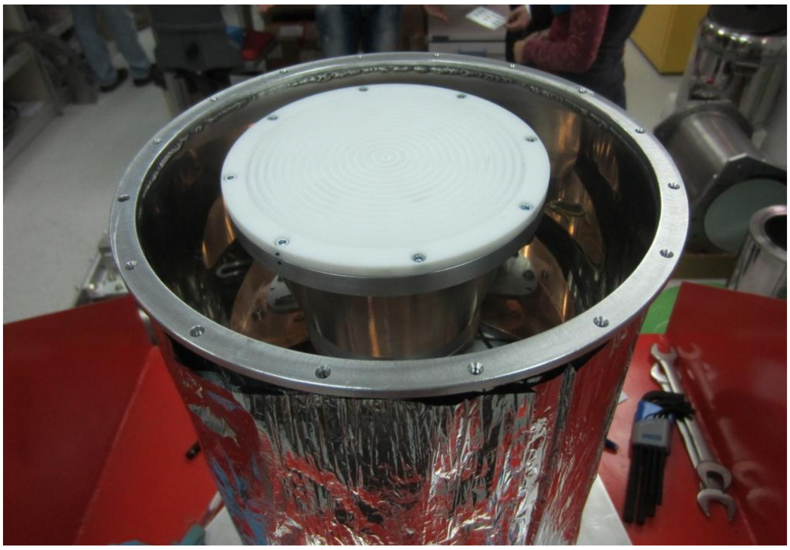


Figure 17. Feed, lens and radiation shield.

4.1. K band feed measurements

The measurements have been carried out in the Yebes Observatory Anechoic Chamber (CDTAC), Planar Near-Field scanner. The device under test is composed by the K band conical corrugated horn (with lens) attached to the polarizer/coupler.

Measurements: LHCP and RHCP. Radiation patterns (both copolar and crosspolar), axial ratio and directivity. Frequency range from 20 to 25 GHz, Δf=1 GHz.

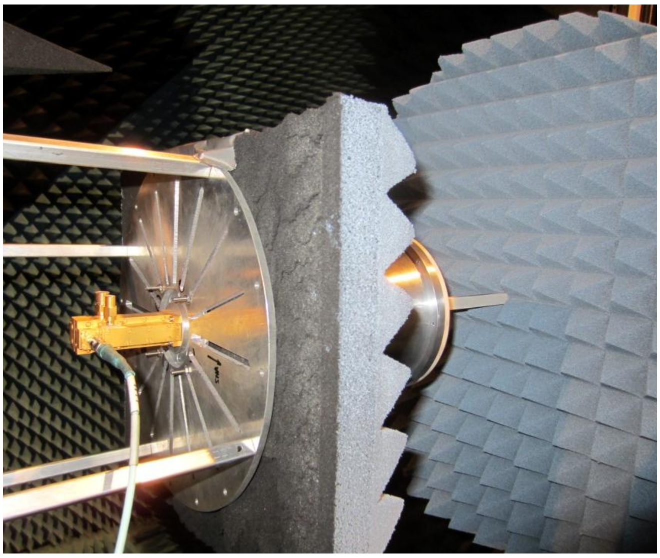
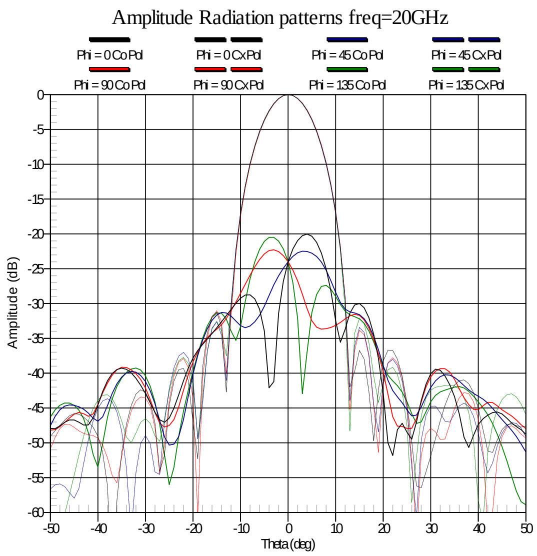


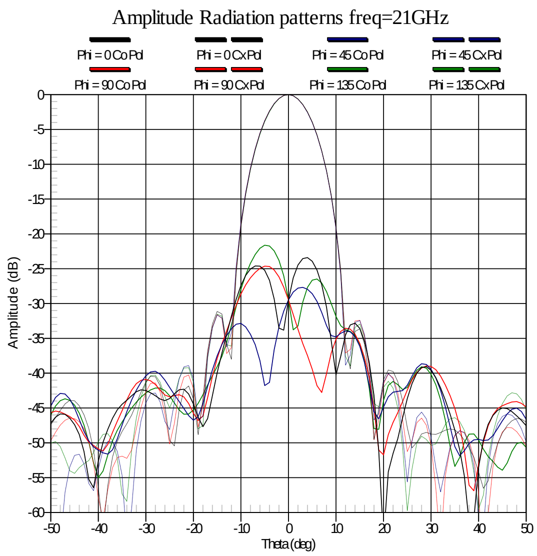
Figure 18. K band feed in the anechoic chamber.

LHCP

Frequency (GHz)	Directivity (dB)	Axial Ratio (dB)	BW(-3dB)
20	26.5	1.1	9
20.5	26.7	1.1	9
21	26.9	0.58	9
21.5	27.2	0.55	9
22	27.4	0.43	9
22.5	27.5	0.35	9
23	27.6	0.45	9
23.5	28	0.36	7
24	28.2	0.56	7
24.5	28.3	0.79	7
25	28.4	1.23	7

Table 5. K band feed: directivity and axial ratio, 20-25 GHz - LCP.





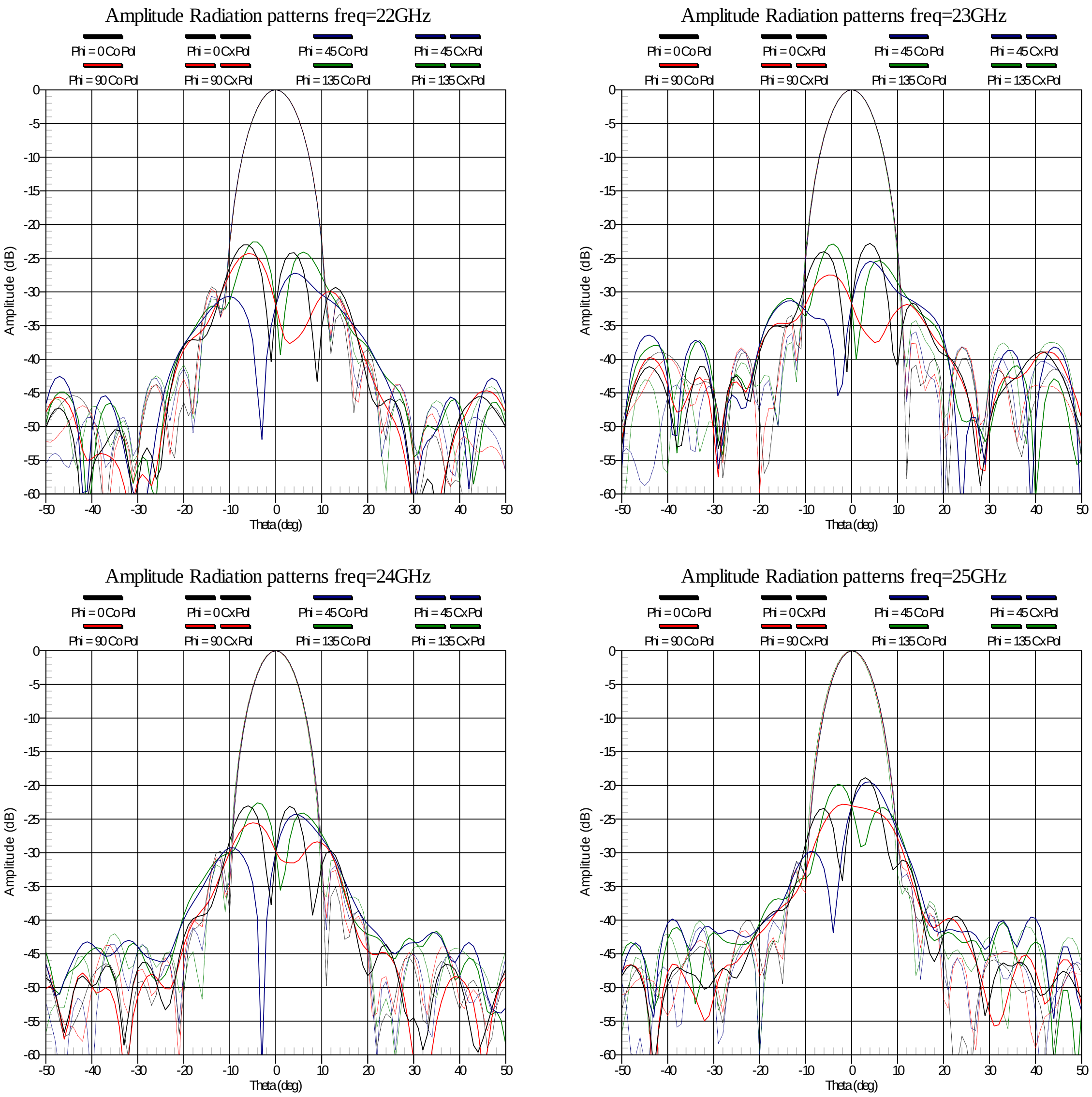


Figure 19. Amplitude radiation pattern 20-25 GHz - LCP.

RHCP

Frequency (GHz)	Directivity (dB)	Axial Ratio (dB)	BW(-3dB)
20	26.5	1.2	9
20.5	26.7	1.2	9
21	26.9	0.49	9
21.5	27.2	0.59	9
22	27.4	0.38	9
22.5	27.5	0.35	9
23	27.6	0.47	8
23.5	28	0.39	7
24	28.2	0.53	7
24.5	28.2	0.76	7
25	28.4	1.23	7

Table 6. K band feed: directivity and axial ratio, 20-25 GHz - RCP.

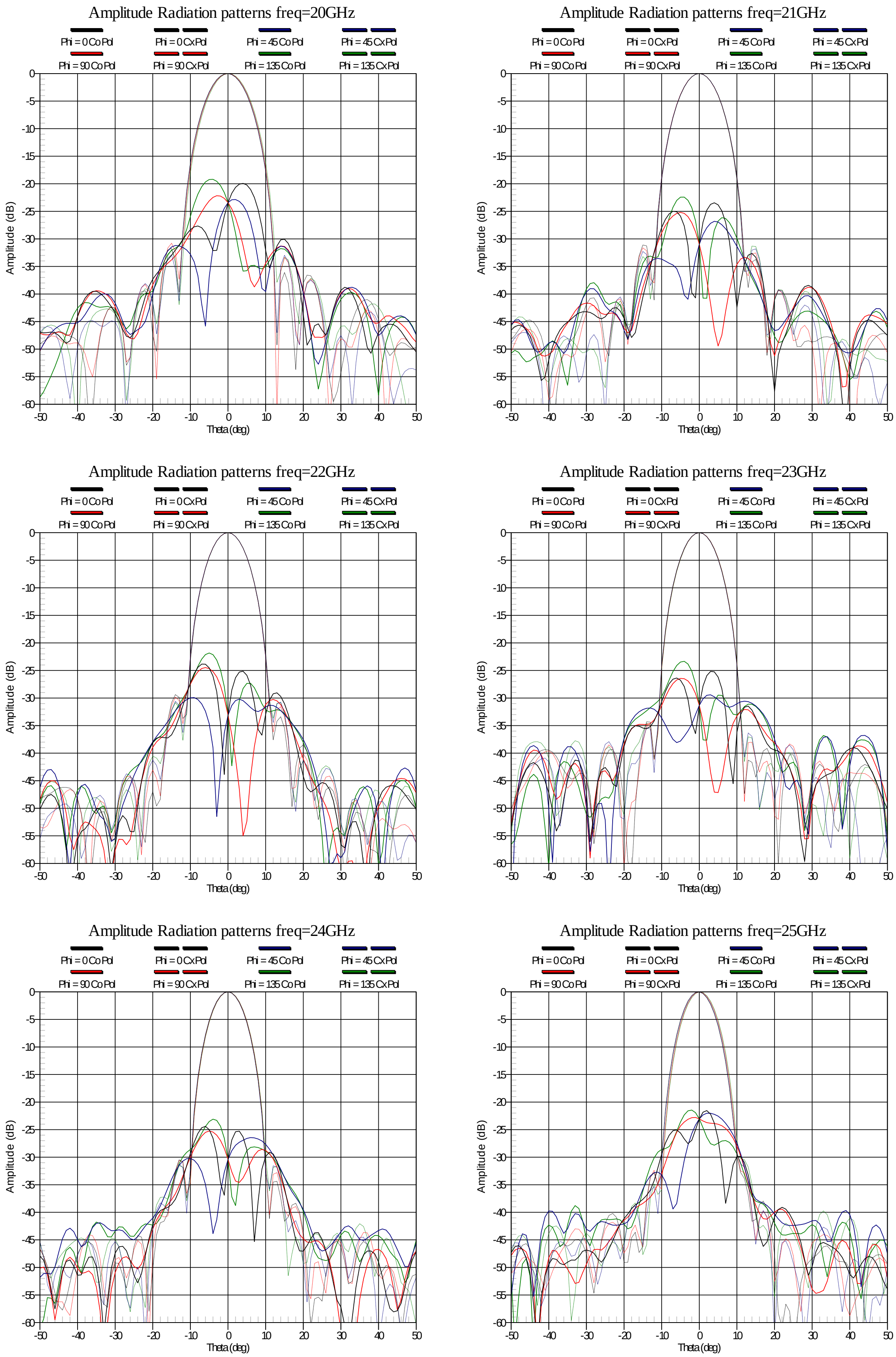


Figure 20. Amplitude radiation pattern 20-25 GHz - RCP.

5. Internal and external DC wiring

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

- One Fischer connector 16 pin, for monitoring signals and housekeeping.
- Two Fischer connectors 11 pin, for the amplifiers biasing signals.

Hermetic Fischer Connector	Function
Housekeeping	Housekeeping
FET1 RCP YK003	YK003 biasing signal
FET2 LCP YK002	YK002 biasing signal

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

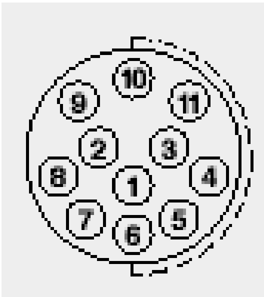
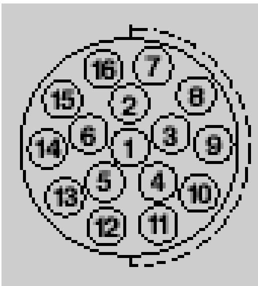


Figure 21. 11 pin Fischer ("wire" connector view (female), red point up).



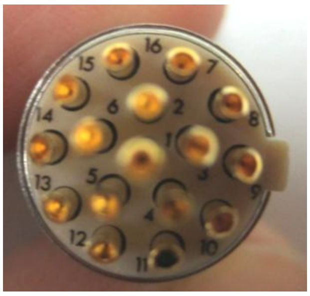


Figure 22. 16 pin Fischer ("wire" connector view (female), red point up).

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

5.1. Low Noise Amplifiers biasing wiring

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

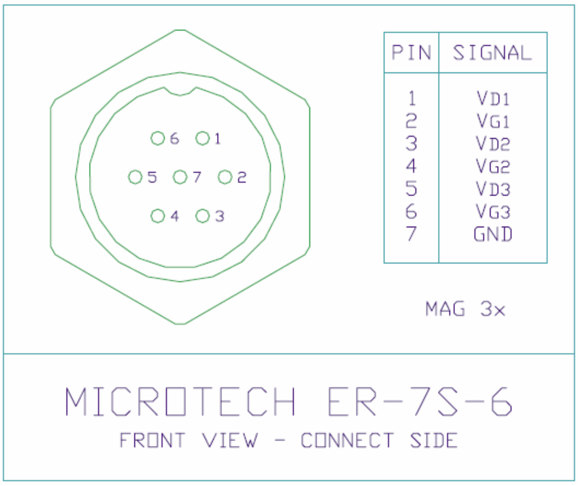


Figure 23. DC connector pin-out, YK 003 and YK 002.

External and internal biasing cables pin-out

Signal	DB15 Pin	Fischer Pin	Microtech	Notes
(free)		1		
(free)		2		
LED		3		External cable black color
GND	1	4	7	
V_{g3}	7	5	6	
V_{d3}	6	6	5	
V_{g2}	5	7	4	
(free)		8		
V_{d2}	4	9	3	
V_{g1}	3	10	2	
V_{d1}	2	11	1	

Table 7. YK002 LCP biasing pin-out. Fischer connector (FET2) correspondence with Microtech connector, YK002.

Signal	DB15 Pin	Fischer Pin	Microtech	Notes
(free)		1		
(free)		2		
LED		3		External cable black color
GND	1	4	7	
V_{g3}	7	5	6	
V_{d3}	6	6	5	
V_{g2}	5	7	4	
(free)		8		
V_{d2}	4	9	3	
V_{g1}	3	10	2	
V_{d1}	2	11	1	

Table 8. YK003 RCP biasing pin-out. Fischer connector (FET1) correspondence with Microtech connector, YK003.

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.

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 after passing through the thermostat
GND_res	Ground
Calef_mon	Thermostat verification (heating resistors)
Regen_mon	Thermostat verification (regeneration resistors)

Table 9. Housekeeping signals description.

A 3-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:

Fischer Pin	Signal	Color	DB25 pin	Banana Connectors
1	Ti_+	Black	3, 4	
2	Ti_-	Brown	15, 16	
3	Tc_+	Red	6, 7	
4	Tc_-	Orange	18, 19	
5	(free)	Yellow	9,10	
6	(free)	Green	21, 22	
7	(free)	Grey	12, 13	
8	(free)	White	24, 25	
9	Calef_on	White/black		**Red**
10	Regen_on	White/brown		**Yellow**
11	GND_res	White/red		**Black**
12	Calef_mon	White/orange		**Red (test point)**
13	Regen_mon	White/yellow		**Black (test point)**
14	(free)			
15	(free)			
16	(free)			

Table 10. Housekeeping cable pin-out.

- 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.

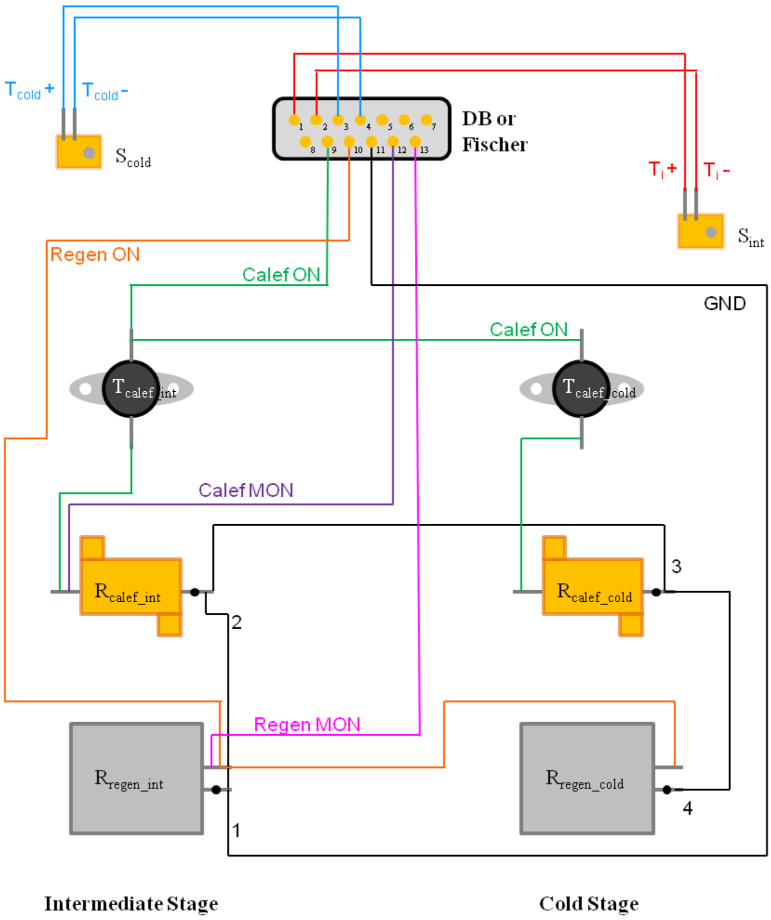


Figure 24. Housekeeping circuit scheme.

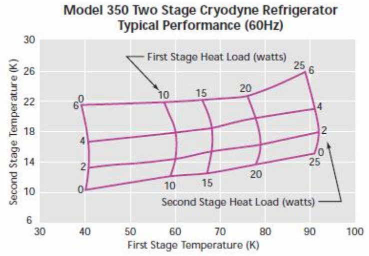
6. Cryogenic system

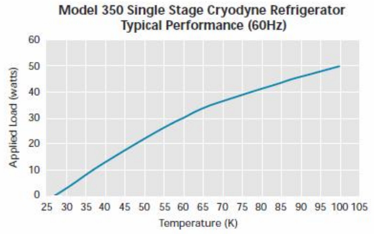
This receiver uses a Model 350 CTI-Cryogenics Cold Head, with the following characteristics:

Model 350 Cryodyne Refrigeration System

The Model 350 is available in both single and two stage configurations. The two stage M-350 was originally designed to cool amplifiers in satellite communication ground stations. The M-350 is the basic refrigerator that is used in the majority of cryopumps throughout the world.

The M-350 is used in many laboratory and commercial applications such as cooling low noise microwave amplifiers for radar and radio astronomy. The M-350 is used in basic materials research, matrix isolation spectroscopy and cooling of superconductors. The single stage M-350 will provide 40 watts of heat lift at 77K. The two stage M-350 will provide a heat lift of 4 watts at 20K and 20 watts at 77K simultaneously.





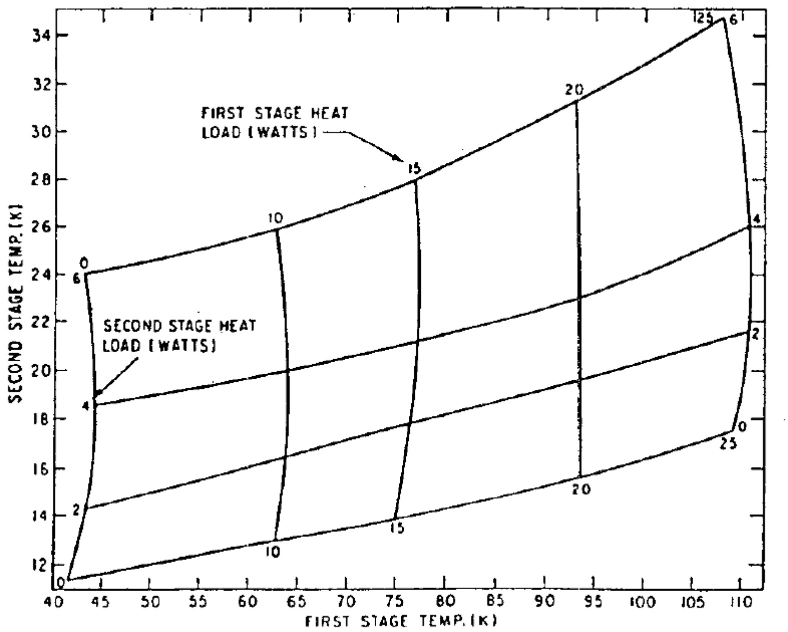


Figure 25. Typical refrigeration capacity of the Model 350C cryodyne cryocooler (50 Hz).

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 350.
- Compressor: CTI 8200, 220 V - 50Hz.
- Vacuum system:
  - Rotary pump and turbomolecular pump (Alcatel).
  - Vacuum sensors (MKS): Pirani sensor (pressure range: atmospheric to 10^{-4} mbar) and cold cathode (pressure range: 10^{-4} mbar to 10^{-8} mbar).

Measurement, **final results**:

- Intermediate stage temperature: **≤ 60 K**.
- Cold stage temperature: **≤ 13 K**.
- Vacuum **<10^{-6} mbar** (cryogenic vacuum).
  - Leakage rate $3.5 \cdot 10^{-5}$ mbar·l/s ($8.3 \cdot 10^{-7}$ mbar/s).
- Cooling down time: **< 6.5 h.**
- Warming up time: ≈ 24 h (or < 6.5 h with zeolites regeneration and heating resistors turned on).

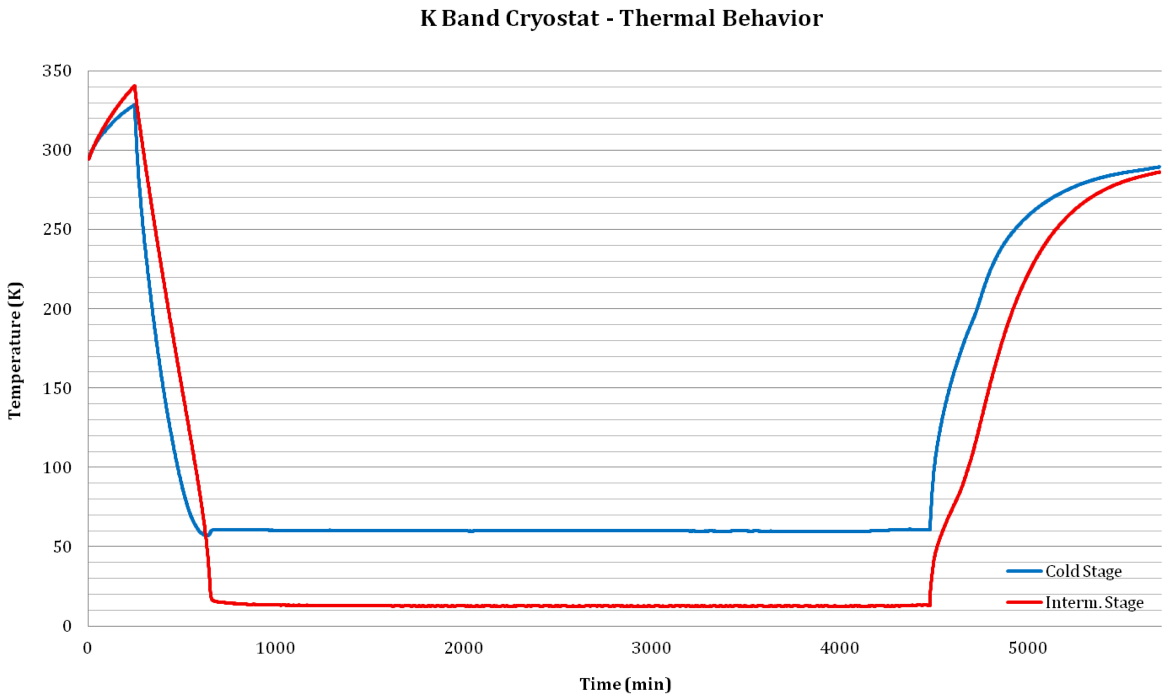


Figure 26. **Cooling test 1.**

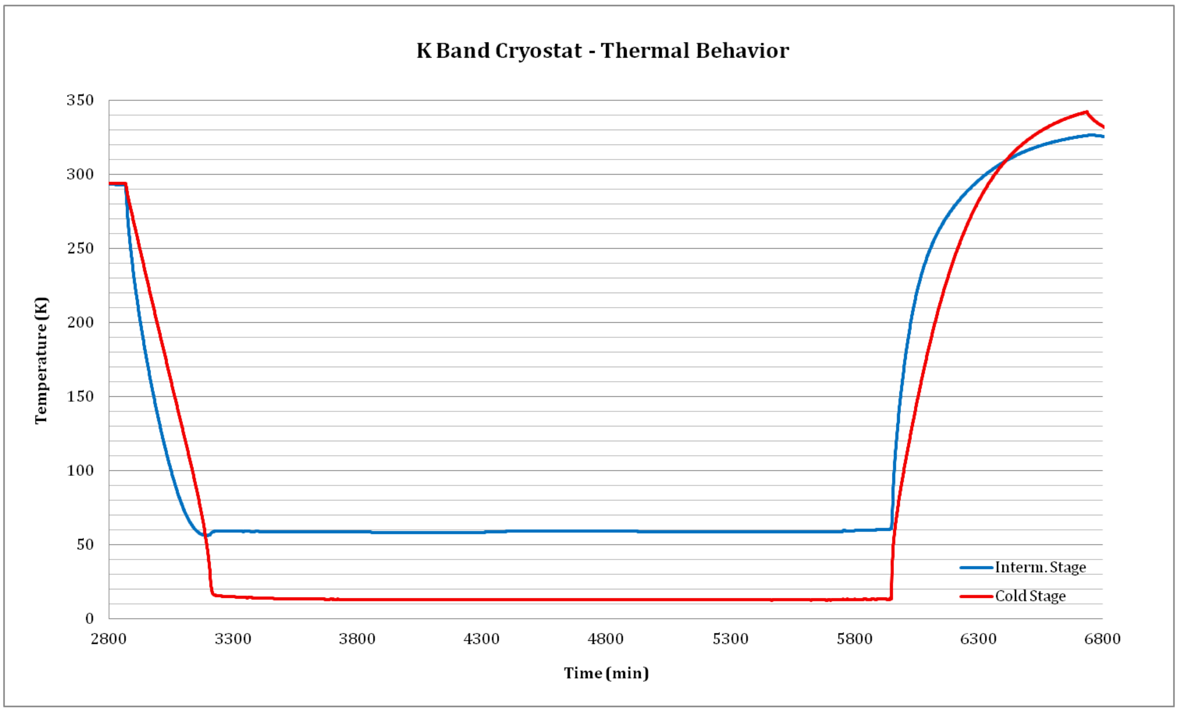


Figure 27. **Cooling test 2** (zeolites regeneration and heating resistors turned on to warm the cryostat).

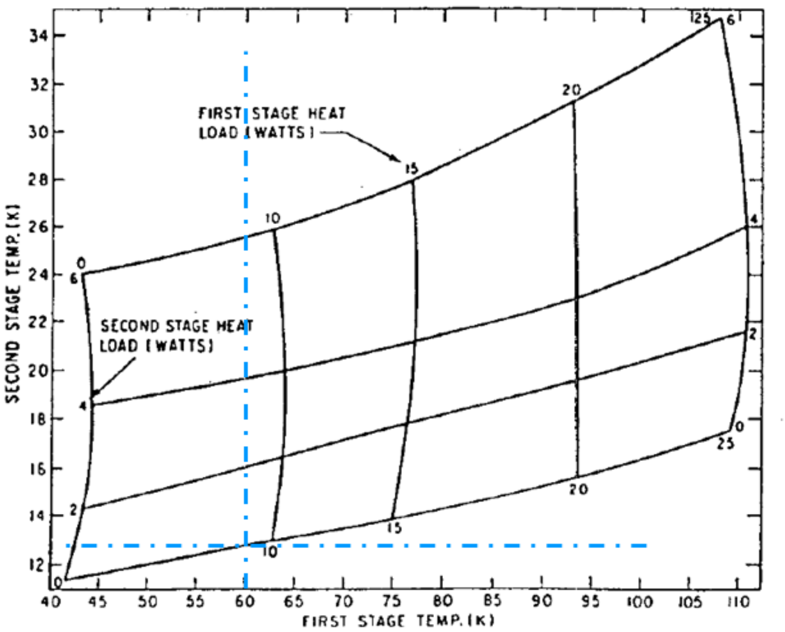
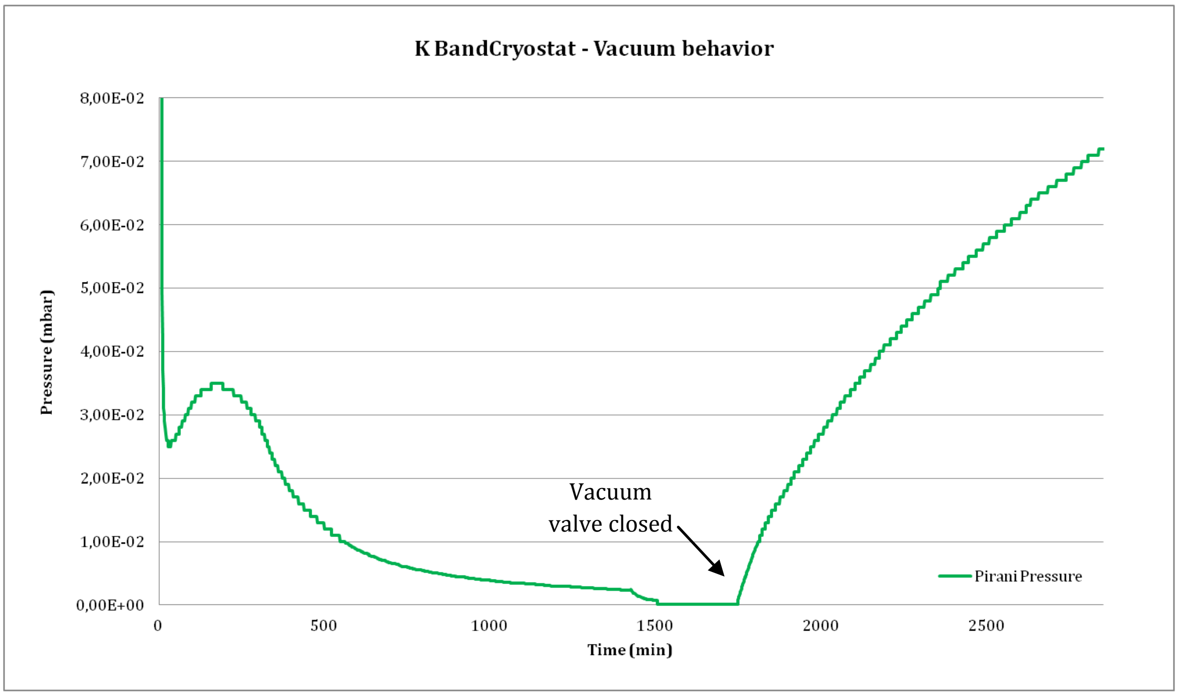


Figure 28. **Intermediate stage load ≈8.5 W, cold stage load ≈0 W**.



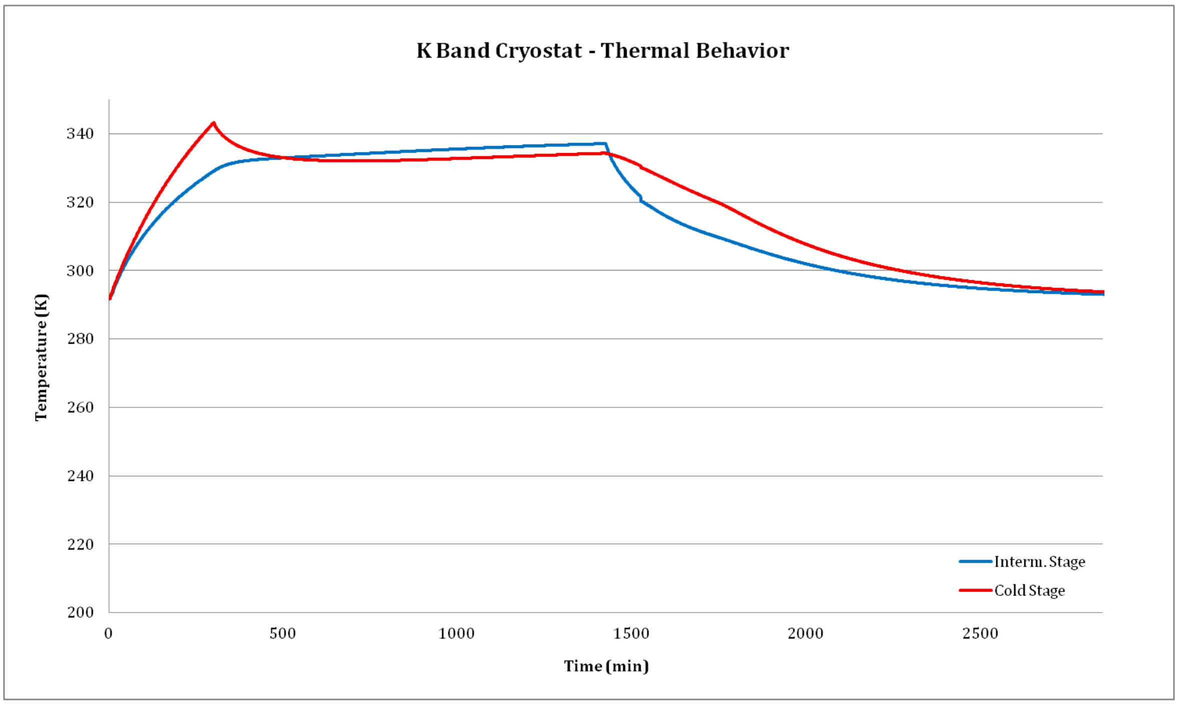


Figure 29. Vacuum test (Pirani sensor) and thermal behavior during the vacuum test, (zeolites regeneration and heating resistors turned on during the first 24 hours).

Figure 30. Receiver during vacuum and cold tests.

8. Receiver calibration: noise temperature

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: Absorber at room temperature, ≈ 293 K.
- Cold load: Absorber 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.

8.1. Laboratory measurements

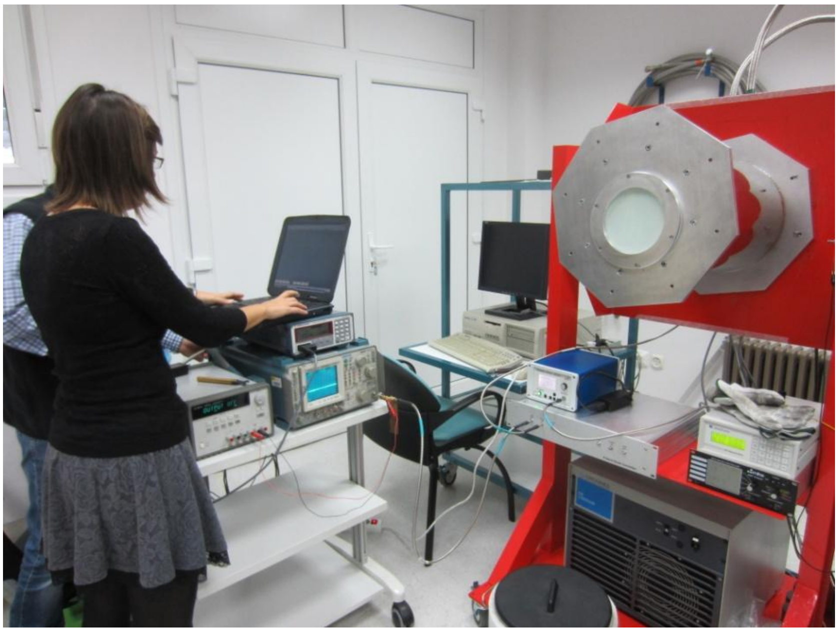


Figure 31. Receiver calibration.

Receiver Noise Temperature measured at cold temperature

T_{RX} LCP (YK002)	
T_H = 295 K	T_C = 77.3 K
Freq. (GHz)	**Noise Temp. (K)**
20	19,63
20,5	14,16
21	12,67
21,5	**13,39**
22	**14,85**
22,5	**15,41**
23	**15,96**
23,5	**19,76**
24	**18,28**
24,5	**18,00**
25	19,28
25,5	30,30
26	31,07

T_{RX} RCP (YK003)	
T_H = 295 K	T_C = 77.3 K
Freq. (GHz)	**Noise Temp. (K)**
20	20,87
20,5	19,34
21	16,40
21,5	**16,32**
22	**18,22**
22,5	**19,50**
23	**21,63**
23,5	**20,68**
24	**18,80**
24,5	**20,01**
25	20,21
25,5	23,90
26	24,55

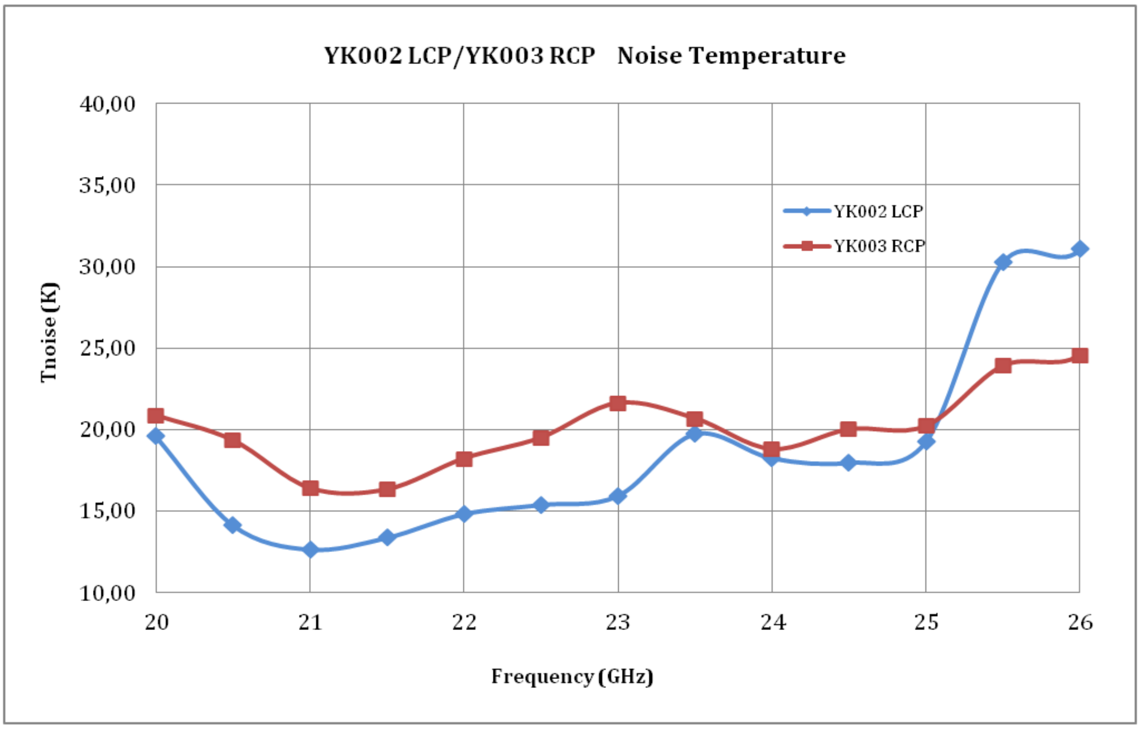


Figure 32. T_{RX} at cold temperature (**LNAs at ≈ 12.5 K**).

Note: several measurements, at different frequency range, have been carried out to estimate the receiver noise temperature. The above tables show the average noise temperature calculated with these measurements.

Receiver Noise Temperature measured at room temperature

T_{RX} LCP (YK002)	
T_H = 295 K	T_C = 77.3 K
Freq. (GHz)	**Noise Temp. (K)**
20	359,94
20,5	291,79
21	277,22
21,5	**288,64**
22	**252,09**
22,5	**243,90**
23	**246,88**
23,5	**260,30**
24	**286,79**
24,5	**292,89**
25	289,17
25,5	376,08
26	359,75

T_{RX} RCP (YK003)	
T_H = 295 K	T_C = 77.3 K
Freq. (GHz)	**Noise Temp. (K)**
20	584,20
20,5	294,17
21	328,34
21,5	**286,67**
22	**252,57**
22,5	**302,89**
23	**312,30**
23,5	**236,83**
24	**244,62**
24,5	**277,85**
25	258,19
25,5	285,40
26	301,08

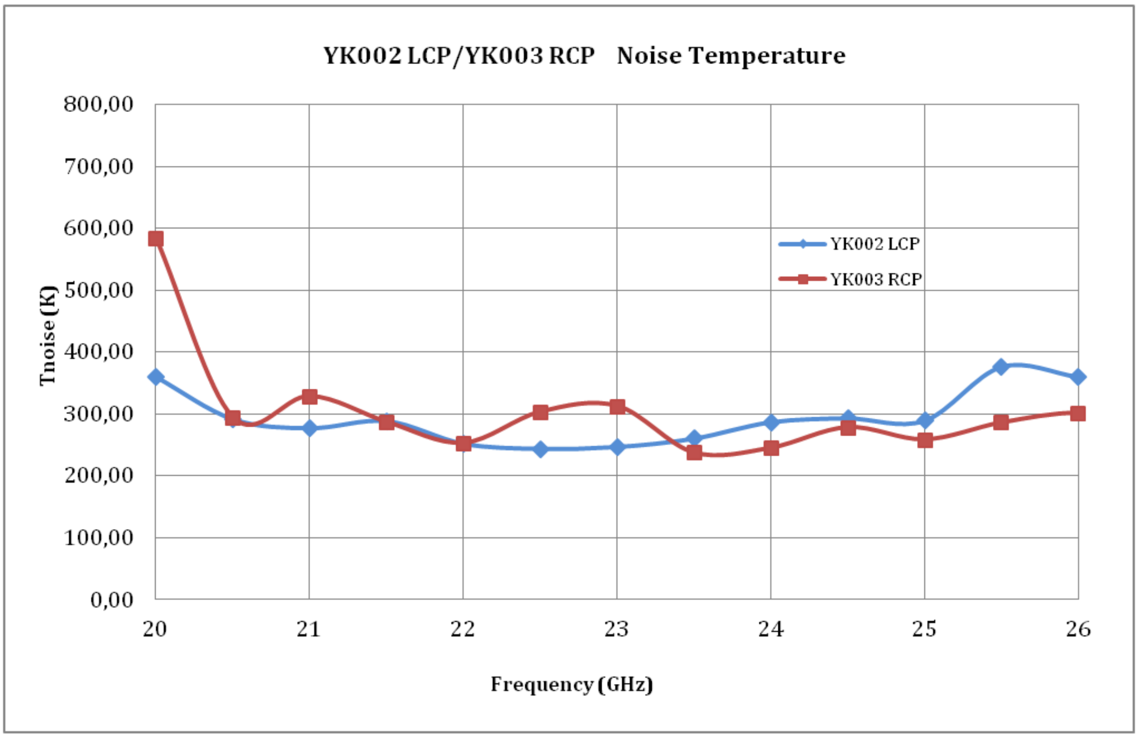


Figure 33. T_{RX} at room temperature (**LNAs at ≈ 300K).**

9. Receiver installed at the 40 m Radio Telescope

The new K band receiver is installed in the receiver cabin (left side) at the 40 m radio telescope. The receiver is placed on a table next to the Q band receiver. Using a dichroic mirror and several reflecting mirrors, it is possible to do observations with both receivers at the same time.

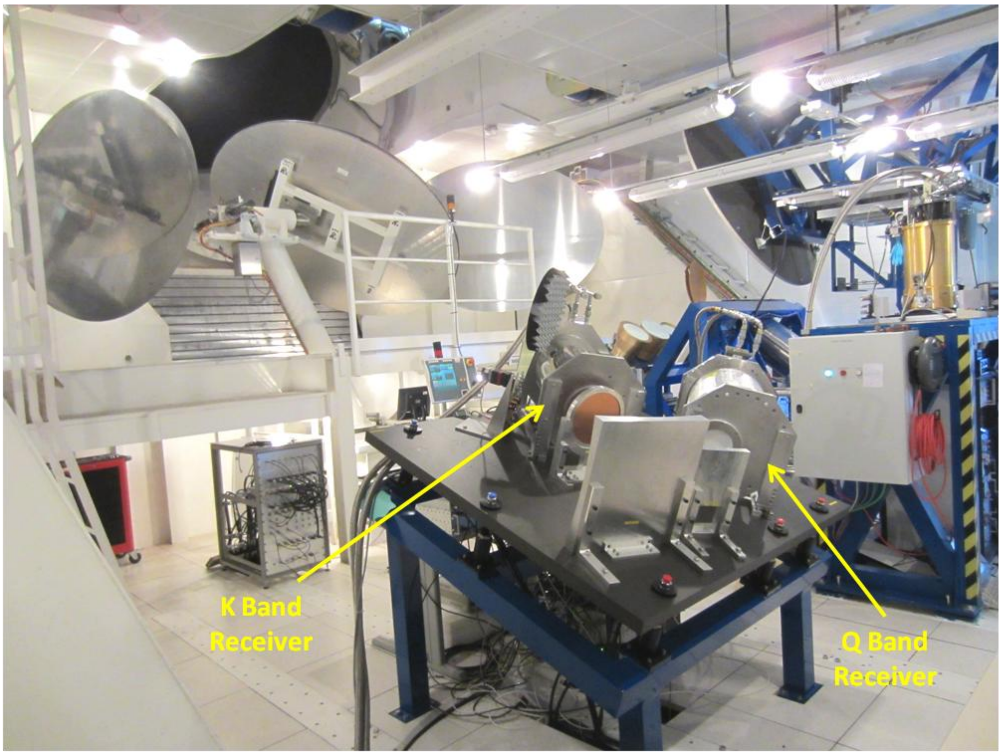


Figure 34. K and Q band receivers at the 40 m Radio Telescope.

Figure 35. K receiver with dichroic mirror in front of the vacuum window.

9.1. Noise temperature

Receiver noise temperature measured with the receiver final placement.

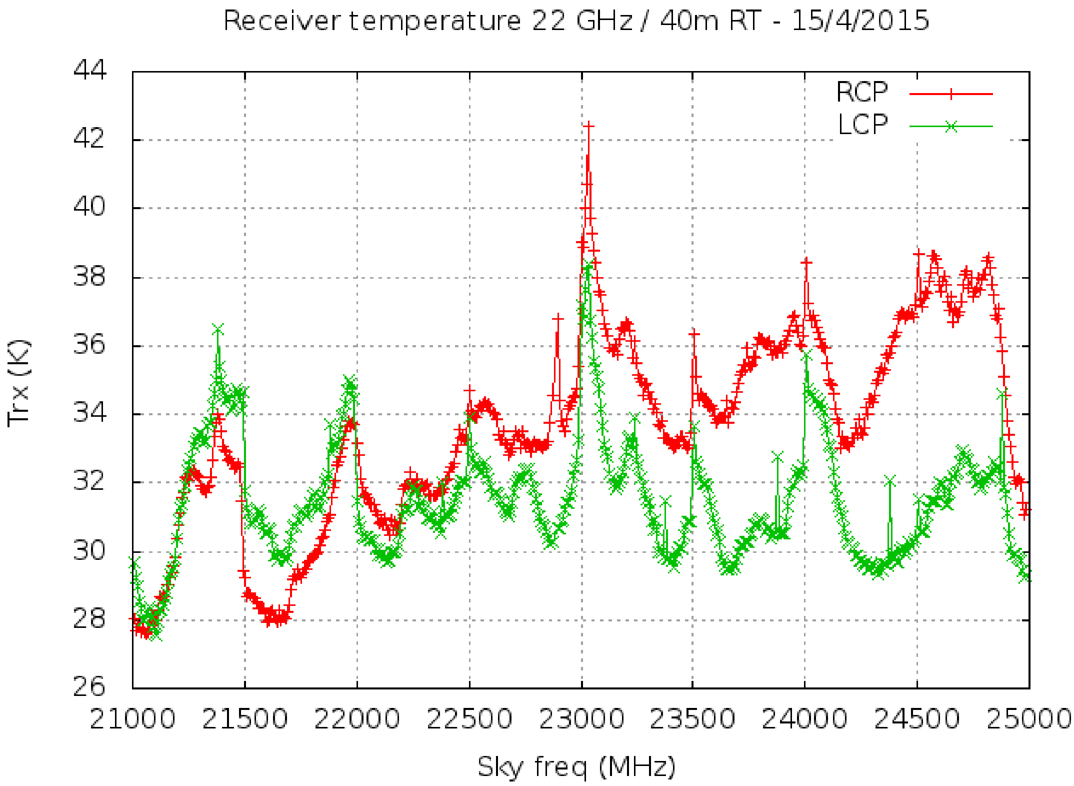


Figure 36. Noise temperature K band receiver, with Mylar window and dichroic mirror.

10. References

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[2] Behrens, G., Campbell, W., Williams, D., White, S.. *Guidelines for de Design of Cryogenic Systems*. National Radio Astronomy Observatory (NRAO), Green Bank, West Virginia. 1997.

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[4] *DT-670 Sensor Catalog.* Lakeshore. (http://www.lakeshore.com/Documents/LSTC_DT670_l.pdf)

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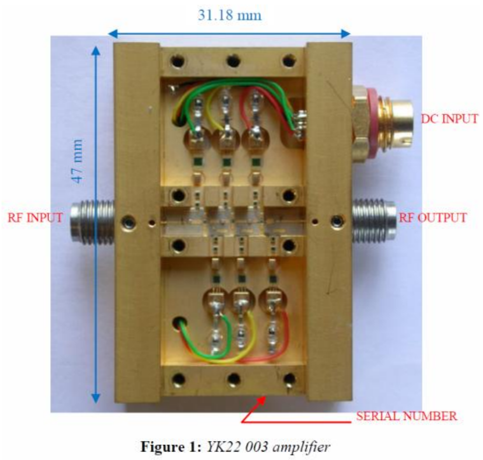
[12] Vaquero, B., Serna Puente, J. M., López Fernández, J. A., Tercero, F., López-Pérez, J.A., Patino, M., Vigil, L.. *O´Higgins S/X Bands Cryogenic Receiver*. Informe Técnico CDT 2013-11.

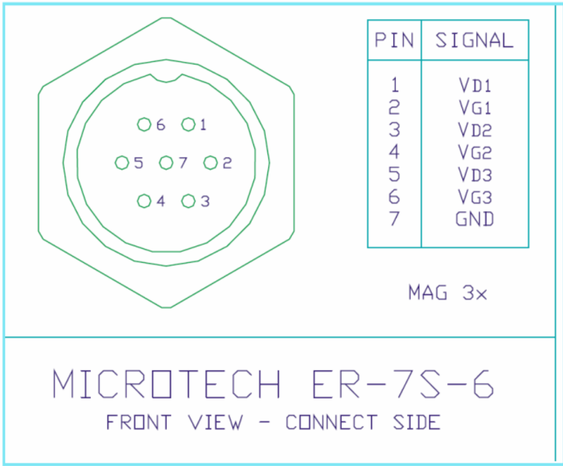
[13] Vaquero, B., Serna Puente, J. M., López Fernández, J. A., Almendros, C., Abad, J.A.. *Reparación cabeza refrigeradora: CTI 350***.** Informe Técnico CDT 2014-2.

11. Appendix

11.1. YK22 003 amplifier specifications



Amplifier internal view.



DC connector pin-out.

K-BAND CRYOGENIC AMPLIFIER REPORT DATE: December 2010

BAND:	20.5 – 24.5	S/N:	YK22 003
TRANSISTOR 1st STAGE:	TRW 200x0.1 um T-42		
TRANSISTOR 2nd STAGE:	TRW 160x0.1 um T-30		
TRANSISTOR 3rd STAGE:	TRW 160x0.1 um T-30		

ROOM TEMPERATURE DATA (T=290 K)

OPTIMUM BIAS	V_{d1} =	1.40	I_{d1} =	7	V_{g1} =	0.09
	V_{d2} =	1.40	I_{d2} =	7	V_{g2} =	-0.09
	V_{d3} =	1.40	I_{d3} =	7	V_{g3} =	0
AVERAGE NOISE TEMPERATURE:	163.9		AVERAGE GAIN ± RIPPLE:	21.9±1.2		
MIN. INPUT RETURN LOSS:	6.1		MIN. OUTPUT RETURN LOSS:	9.4		

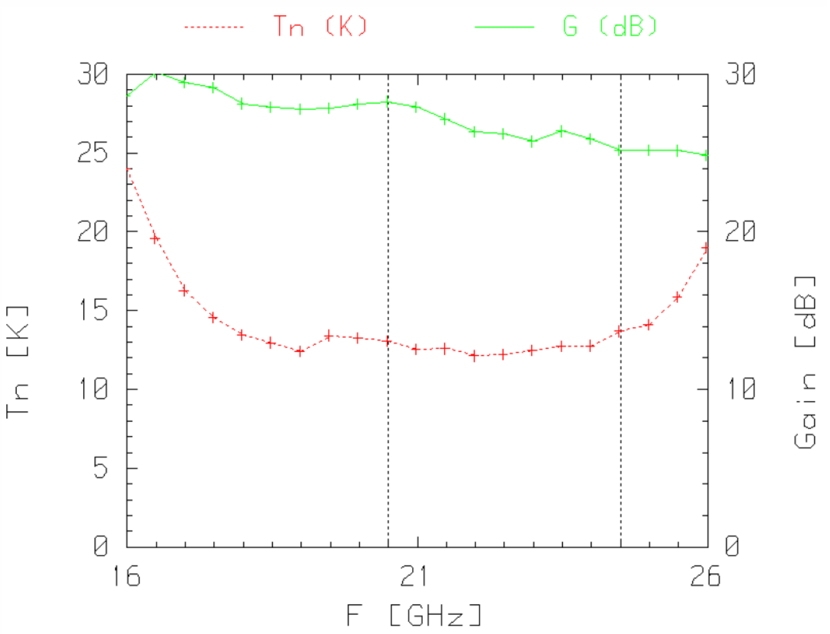
CRYOGENIC TEMPERATURE DATA (T=14 K)

OPTIMUM BIAS (9 mW)	V_{d1} =	1.5	I_{d1} =	5.44	V_{g1} =	0.16
	V_{d2} =	1.4	I_{d2} =	6.45	V_{g2} =	0.02
	V_{d3} =	1.4	I_{d3} =	7	V_{g3} =	0.15
AVERAGE NOISE TEMPERATURE:	12.69		AVERAGE GAIN ± RIPPLE:	27.7±1.5		
MIN. INPUT RETURN LOSS:			MIN. OUTPUT RETURN LOSS:			

REMARKS:	Noise and Gain values taken with transistors no illuminated The value of the Gain is from the Noise Figure Meter measurements

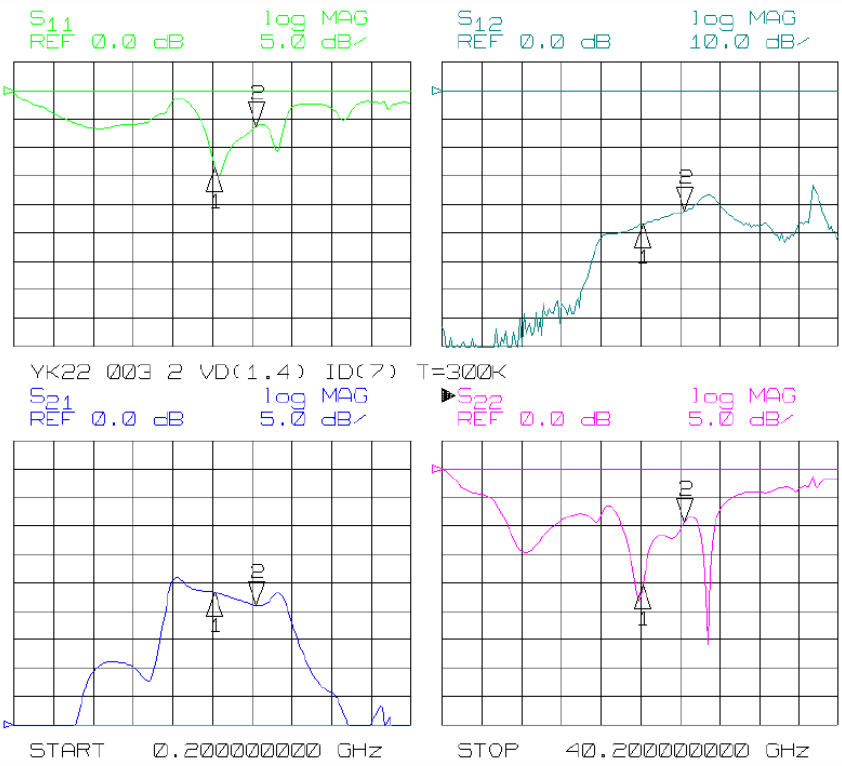
V_d in Volts, I_d in mA, Noise temperature in K, Gain and Return loss in dB, Frequency band in GHz, Gain fluctuations in $1/\sqrt{Hz}$

T=15K



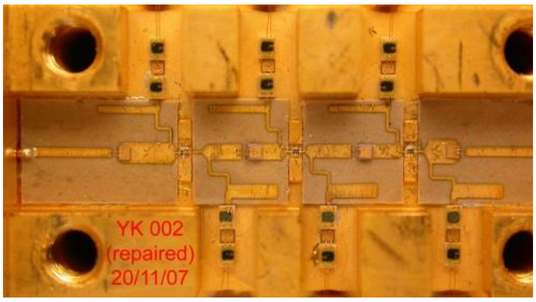
Noise temperature and gain.

T=300K

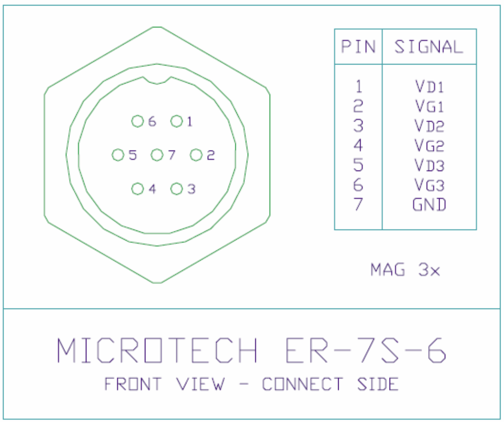


S parameters.

11.2. YK22 002 amplifier specifications



Amplifier internal view.



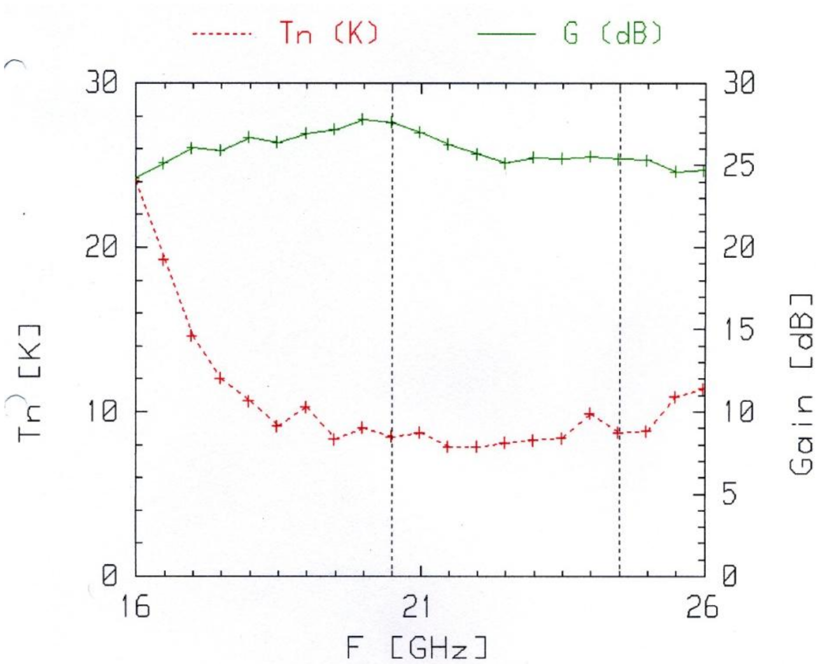
DC connector pin-out.

OPTIMUM BIAS:

YK 002			T=15 K LED OFF		
Vd1 (V)	Vd2 (V)	Vd3 (V)	Id1 (mA)	Id2 (mA)	Id3 (mA)
1.40	1.40	1.40	5.00	7.00	7.00

Average Noise Temperature (20.5-24.5 GHz): **8.48 K**
Average Gain (20.5-24.5 GHz): **25.95 dB**

This amplifier **should be operated** with **LED OFF**.
(The noise degrades by 0.1 K with LED ON).

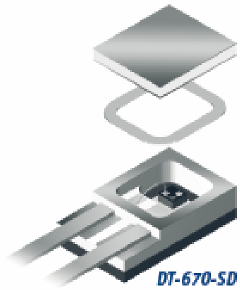


Noise temperature and gain.

11.3. Temperature sensors specifications

Silicon Diodes

DT-670 Silicon Diodes



DT-670-SD

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 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.

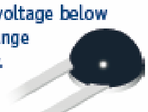
PACKAGING OPTIONS BO, BR, CO, CU, CY, ET, LR, MT

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.

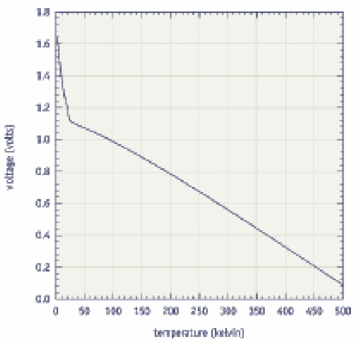
DT-621-HR Miniature Silicon Diode

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.

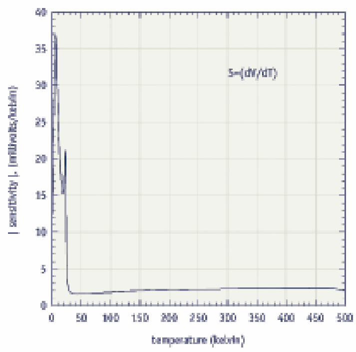


DT-621-HR

Typical DT-670 Diode Voltage Values



Typical DT-670 Diode Sensitivity Values



www.lakeshore.com Lake Shore Cryotronics, Inc. (614) 891-2244 fax: (614) 818-1600 e-mail: info@lakeshore.com

11.4. Vacuum Window Specifications

Technical Information - Polyethylene terephthalate

Close

Polyethylene terephthalate

Polyester, PET, PETP

We stock and supply the following standard forms:

Common Brand Names:	Arnite, Dacron, Hostaphan, Impet, Melinar, Melinex, Mylar, Rynite, Terylene, Trevira
General Description:	General Description: The most common thermoplastic polyester, this polymer is often called just "polyester". This often causes confusion - not only is the chemically similar PBT also a (thermoplastic) polyester, the most common resin system used in GRP is also a polyester system - and also often called just "polyester". (In this latter case, however, the polyesters are chemically unsaturated and are "free-radical polymerised" into a thermoset).

PET is a hard, stiff, strong, dimensionally stable material that absorbs very little water. It has good gas barrier properties and good chemical resistance except to alkalis (which hydrolyse it). Its crystallinity varies from amorphous to fairly high crystalline; it can be highly transparent and colourless but thicker sections are usually opaque and off-white.

It is widely known in the form of biaxially oriented and thermally stabilised films usually referred to by their main brand names Mylar, Melinex or Hostaphan. Strictly speaking, these names should be used only for this type of film whose properties are different from, and in several respects superior to, those of "ordinary" PET film.

These "Mylar®-type" films are used for capacitors, graphics, film base and recording tapes etc. PET is also used for fibres for a very wide range of textile and industrial uses (Dacron®, Trevira®, Terylene®). Other applications include bottles and electrical components.

Chemical Resistance

Acids - concentrated	Good-Poor
Acids - dilute	Good
Alcohols	Good
Alkalis	Poor
Aromatic hydrocarbons	Good-Fair
Greases and Oils	Good
Halogenated Hydrocarbons	Good-Poor
Halogens	Fair-Poor
Ketones	Good-Fair

Electrical Properties

Dielectric constant @1MHz	3.0
Dielectric strength (kV mm^{-1})	17
Dissipation factor @ 1kHz	0.002
Surface resistivity (Ohm/sq)	10^{13}
Volume resistivity (Ohmcm)	$>10^{14}$

Mechanical Properties

Coefficient of friction	0.2-0.4
Hardness - Rockwell	M94-101
Izod impact strength ($J\ m^{-1}$)	13-35
Poisson's ratio	0.37-0.44(oriented)
Tensile modulus (GPa)	2-4
Tensile strength (MPa)	80, for biax film 190-260

Physical Properties

Density ($g\ cm^{-3}$)	1.3-1.4
Flammability	HB
Limiting oxygen index (%)	21
Radiation resistance	Good
Refractive index	1.58-1.64
Resistance to Ultra-violet	Fair?
Water absorption - equilibrium (%)	<0.7
Water absorption - over 24 hours (%)	0.1

Thermal Properties

Coefficient of thermal expansion ($x10^{-6}\ K^{-1}$)	20-80
Heat-deflection temperature - 0.45MPa (C)	115
Heat-deflection temperature - 1.8MPa (C)	80
Lower working temperature (C)	-40 to -60
Specific heat ($J\ K^{-1}\ kg^{-1}$)	1200 - 1350
Thermal conductivity @23C ($W\ m^{-1}\ K^{-1}$)	0.15-0.4
Upper working temperature (C)	115-170

Properties for Polyethylene terephthalate Film

Property		Value
Dielectric Strength @25µm thick	$kV\ mm^{-1}$	300
Dissipation Factor @1MHz		0.016
Elongation at Break	%	60-165
Initial Tear Strength	$g\ \mu m^{-1}$	18-54
Permeability to Carbon Dioxide @25C	$x10^{-13}\ cm^3.\ cm\ cm^{-2}\ s^{-1}\ Pa^{-1}$	0.2
Permeability to Hydrogen @25C	$x10^{-13}\ cm^3.\ cm\ cm^{-2}\ s^{-1}\ Pa^{-1}$	0.4
Permeability to Nitrogen @25C	$x10^{-13}\ cm^3.\ cm\ cm^{-2}\ s^{-1}\ Pa^{-1}$	0.004
Permeability to Oxygen @25C	$x10^{-13}\ cm^3.\ cm\ cm^{-2}\ s^{-1}\ Pa^{-1}$	0.03
Permeability to Water @25C	$x10^{-13}\ cm^3.\ cm\ cm^{-2}\ s^{-1}\ Pa^{-1}$	100
Permeability to Water @38C	$x10^{-13}\ cm^3.\ cm\ cm^{-2}\ s^{-1}\ Pa^{-1}$	150
Specific Heat	$kJ\ kg^{-1}\ K^{-1}$	1.3
Thermal Conductivity @23C	$W\ m^{-1}\ K^{-1}$	0.13-0.15

11.5. DC wiring

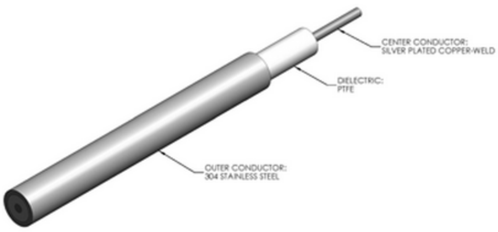
Small section wire Kynar 30 awg. specifications:

✔	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

11.6. 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

	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

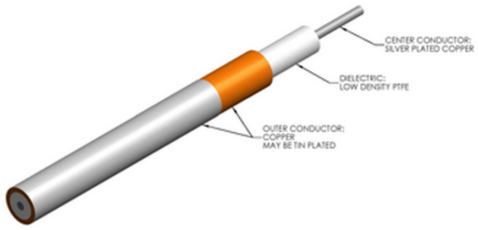
ELECTRICAL CHARACTERISTICS

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

	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

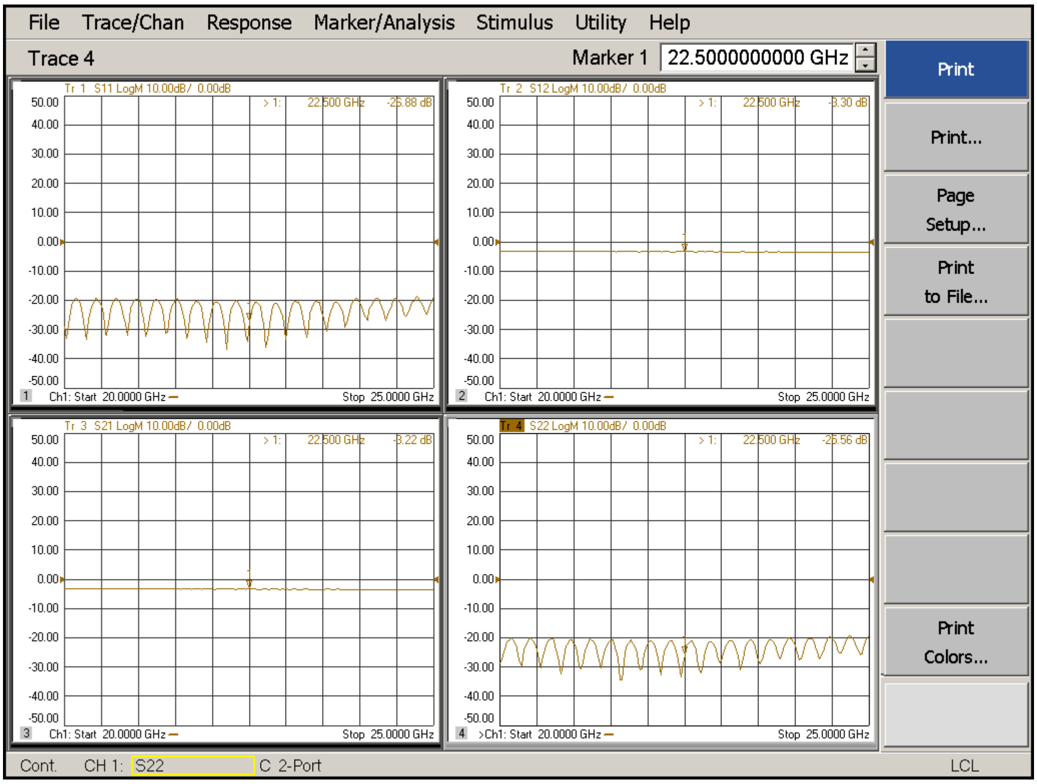
Outer Conductor Integrity Temp.	°C	250
Operating Temperature (Max)	°C	250
Inside Bend Radius (Minimum)	In	0.500
	mm	12.700
Weight	lbs / 100ft	3.18
	kg / 100m	4.77

ELECTRICAL CHARACTERISTICS

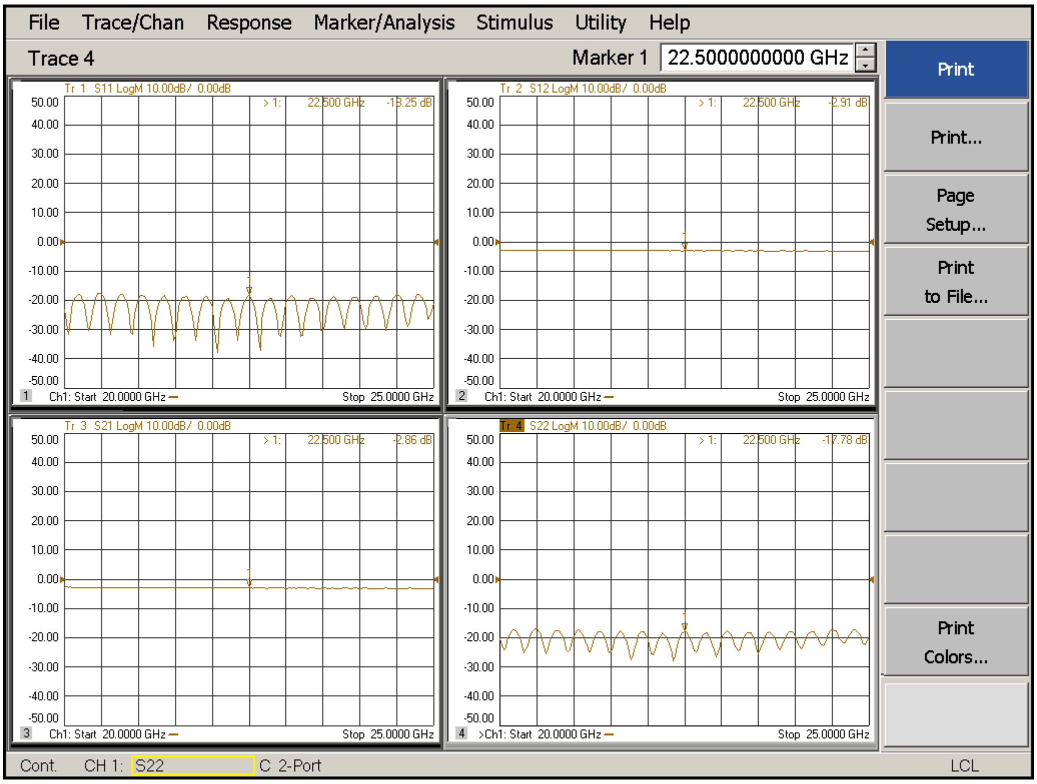
Characteristic Impedance	ohm	50
Capacitance	pF / ft	26.5
	pF / m	86.8
Corona Extinction Voltage	VRMS @ 60 Hz	2800
Voltage Withstanding	VRMS @ 60 Hz	8400
Higher Order Mode Frequency	GHz	37.0
Attenuation (Db / 100 Ft Typical)	0.5 GHz	7
	1.0 GHz	10
	5.0 GHz	23
	10.0 GHz	33.2
	18.0 GHz	45.6
	26.5 GHz	56.5
	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.

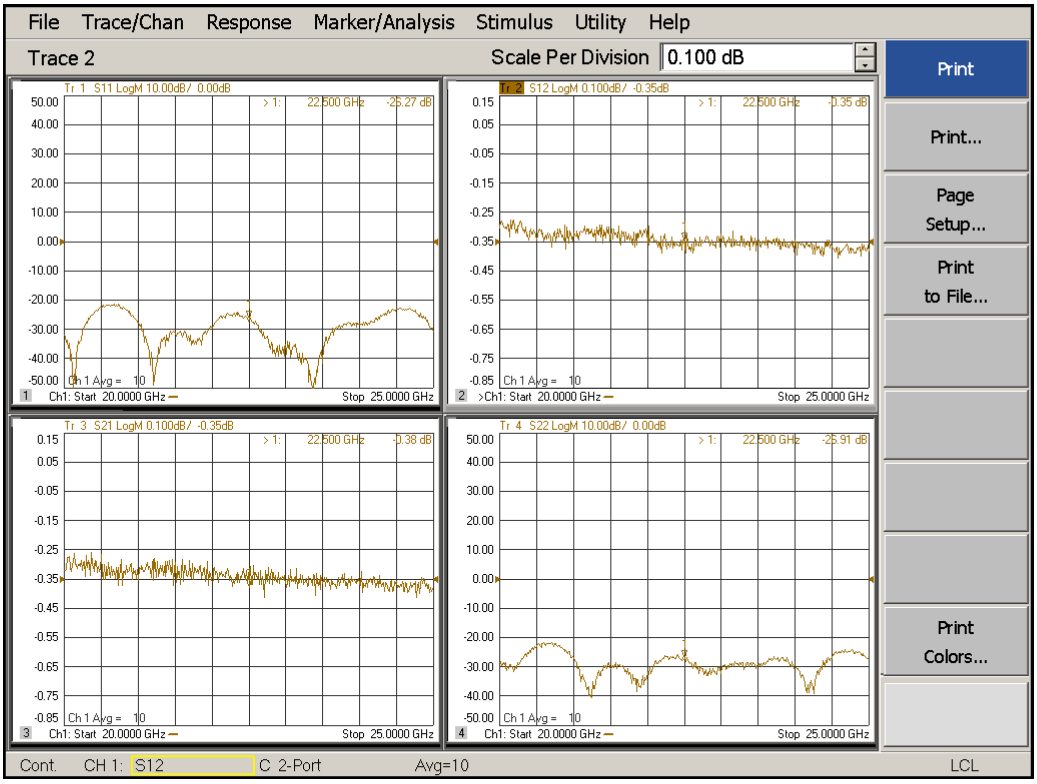
11.7. RF Measurements



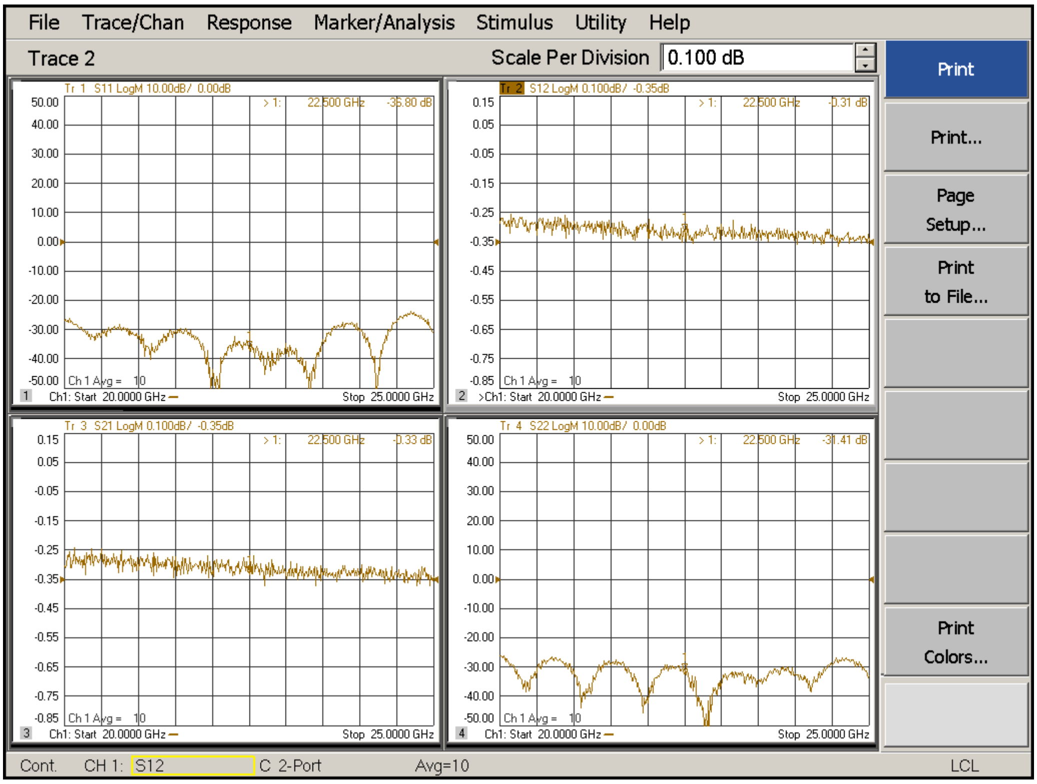
RCP output cable, UT-85B-SS, 39 cm length.



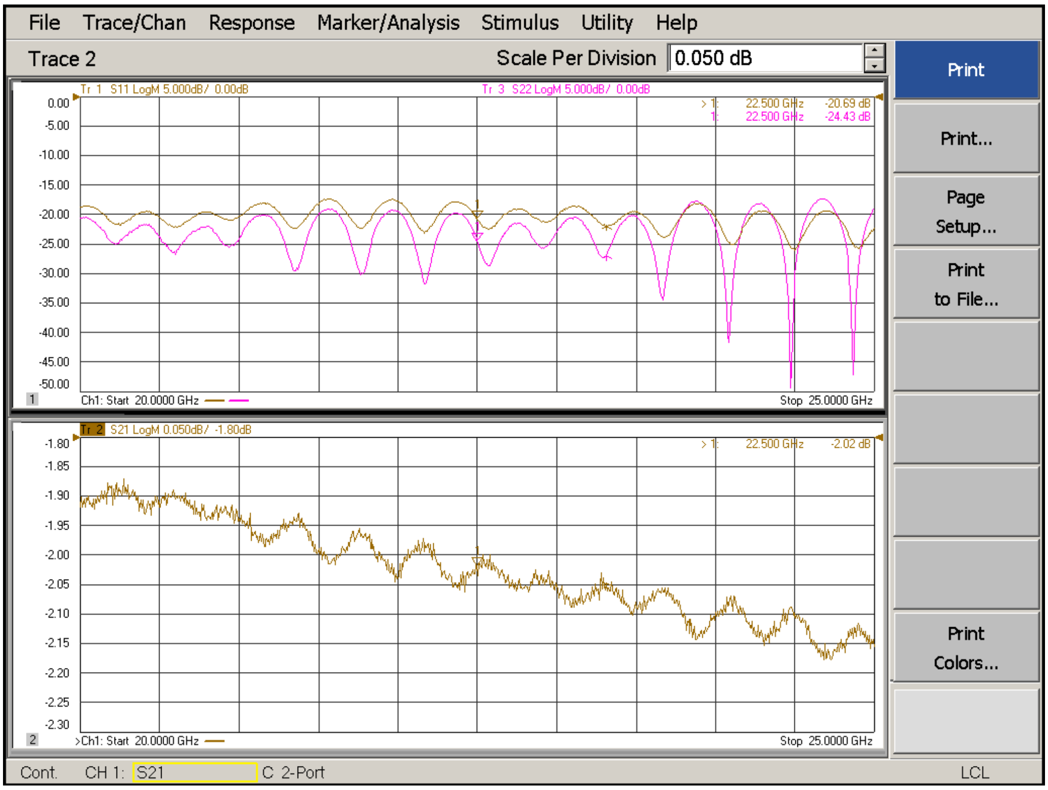
LCP output cable, UT-85B-SS, 37 cm length.

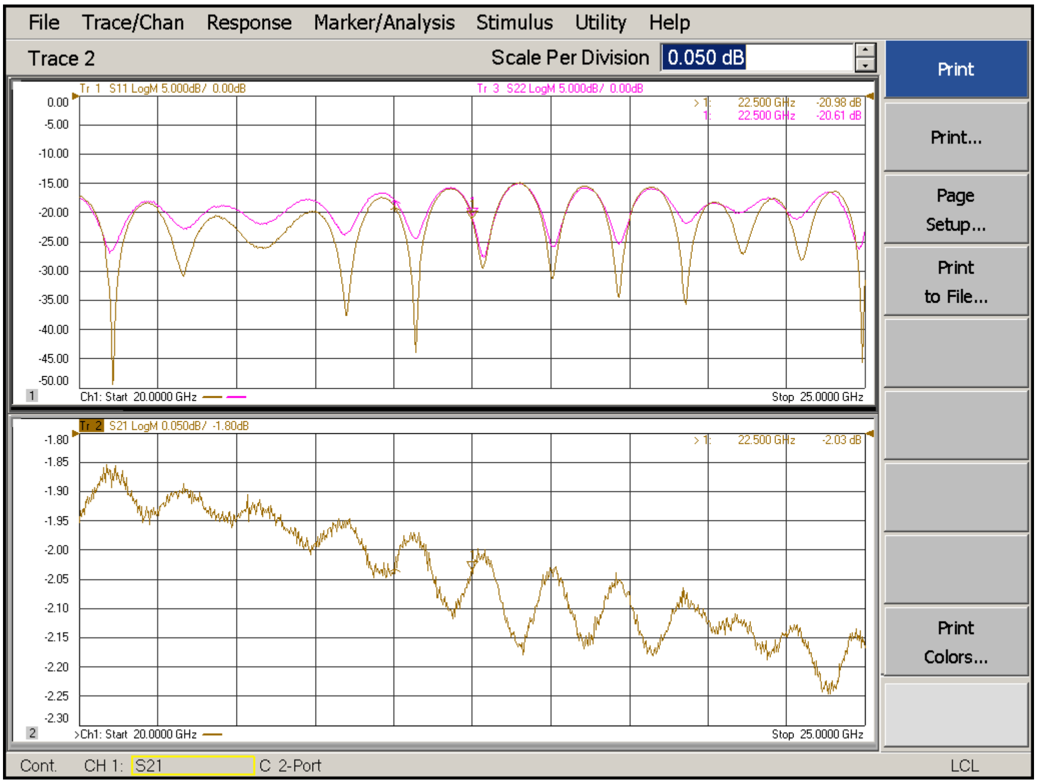


Polarizer – LNA YK003 RCP, UT-141C-LL.



Polarizer – LNA YK002 LCP, UT-141C-LL.





Calibration cables, UT-85B-SS.