



**CRYOGENIC
AMPLIFIER REPORT**

**Cryogenic LNA for the
O'Higgins Spare X-Band
Receiver: YXA 1178**

IT-CDT 2016-13

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INDEX OF DOCUMENTS

- 1. YXA 1 4-12 GHz amplifier report**
- 2. YXA 1178 Measurement data**
- 3. ESD and power supply leakage protection of InP cryogenic HEMT amplifiers**

YXA 1 4-12 GHz AMPLIFIER REPORT

1. Introduction

YXA series 1 are C+X band low noise cryogenic amplifiers designed and built at the *Centro Astronómico de Yebes* and originally developed for ALMA project. This document includes a description of the amplifiers and how to operate them, details about the tests performed, the measurements techniques utilized and plots with the relevant data collected (an index is provided thereafter). Attached to the document in its digital version will be a collection of files with the numerical data corresponding to the measurements.

The amplifier is intended to be used together with a **cryogenic isolator** connected to its input. PAMTECH has designed several 4-12 GHz models for this purpose like the CWJ1015K9.

The unit should be biased by a **servo controlled power supply**, which sets the gate voltage for any given drain current. Details about a NRAO style power supply produced in Yebes for our HEMT amplifiers are available.

2. Description and operating conditions of the amplifier

- Figure 1 shows an outside view of the amplifier. RF input and output connectors are SMA. DC connector is a 9 pin microminiature D-type ITT-Cannon. The pinout is provided in figure 2. As seen in the figure, the RF input connector is the one located closer to the DC connector; the serial number of the unit is stamped on the long side of the amplifier, besides de DC connector. All the holes used to fix the lid are M2 thru-holes and can be used from the other side to attach the amplifier to a cold plate. Be aware of the limited length of thread available, due to the small height of the amplifier.

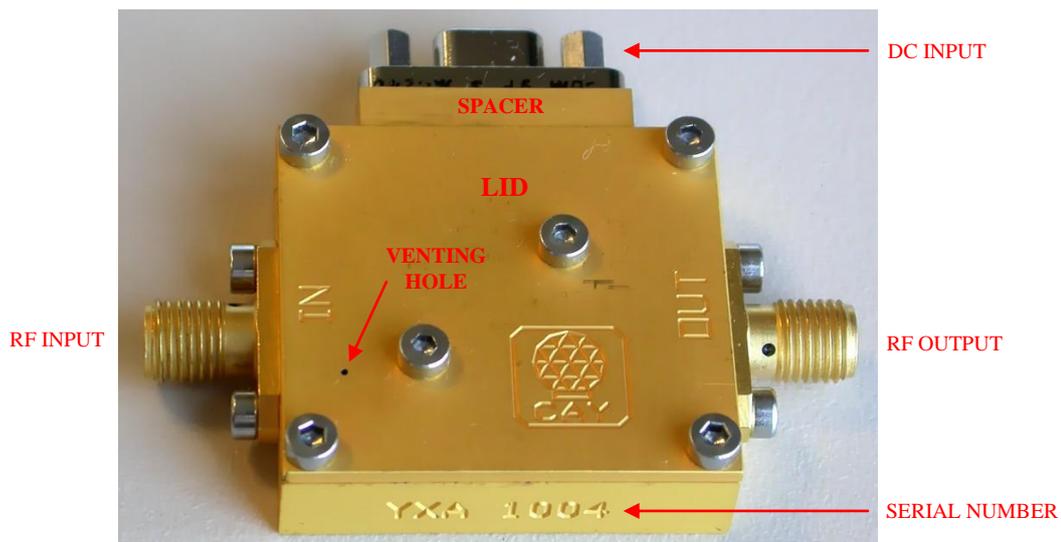


Figure 1: Amplifier external view. Box dimensions are 32×29×9 mm (excluding connectors and screws).

- The external dimensions and mechanical interfaces of the amplifier are shown in figure 4.
- These YXA 1 delivered are three stage amplifiers implementing HRL¹ InP transistors. The InP devices are very **ESD sensitive**; cautions must be taken in its manipulation. The bias circuits built in the amplifier include a 10 nF capacitor which acts as a charge divider to prevent damage to the transistors, but no diodes. A ~1:10 voltage divider is also implemented at the gates input lines to improve EMC and protect against ESD: high operating values of the gate voltages are normal. A schematic of these circuits is shown in figure 3. Information on ESD prevention procedures, and safe unit handling and storage is provided in the “ESD and power supply leakage protection of InP HEMT cryogenic amplifiers” section.
- One bias condition has been selected for the amplifier, which optimizes the device for noise, gain ripple, output reflection and gain fluctuations, *keeping the power dissipation below 9 mW*. Some improvement in noise and gain may be expected using a higher bias. Never exceed a drain voltage/current of 1.5 V / 10 mA for InP transistors.

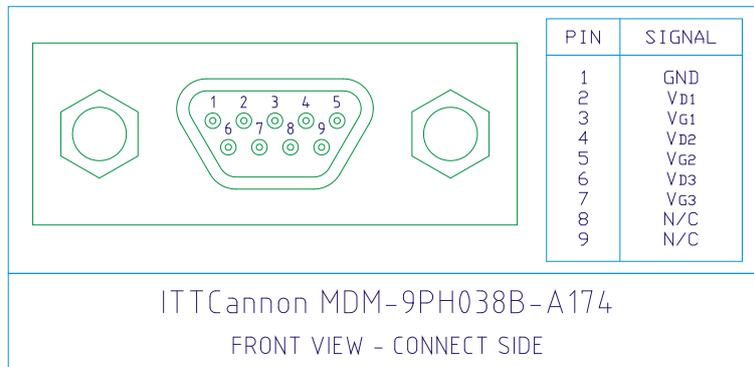


Figure 2: DC Connector pinout

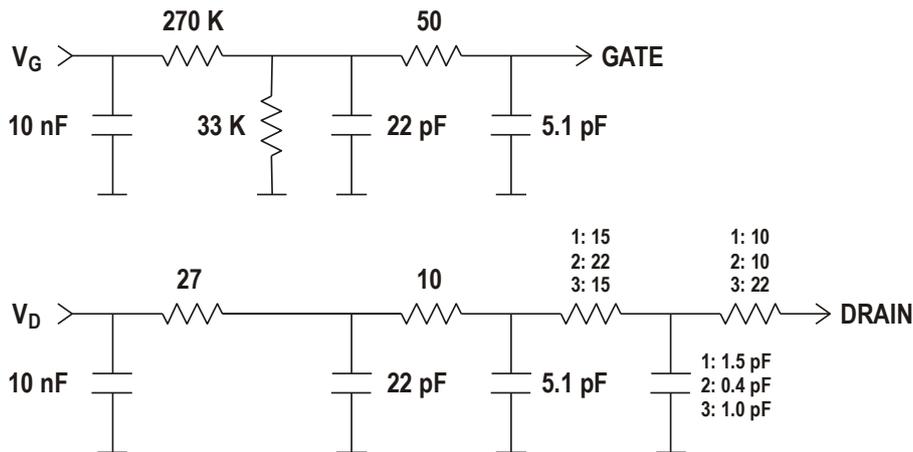


Figure 3: Schematic of the bias circuits. Gate lines are identical for all stages, while drain lines differ in the component values of the higher frequency filtering and resistive loading sections (they are marked 1:, 2: and 3: after each stage number))

¹ Transistors provided by Hughes Research Laboratories.

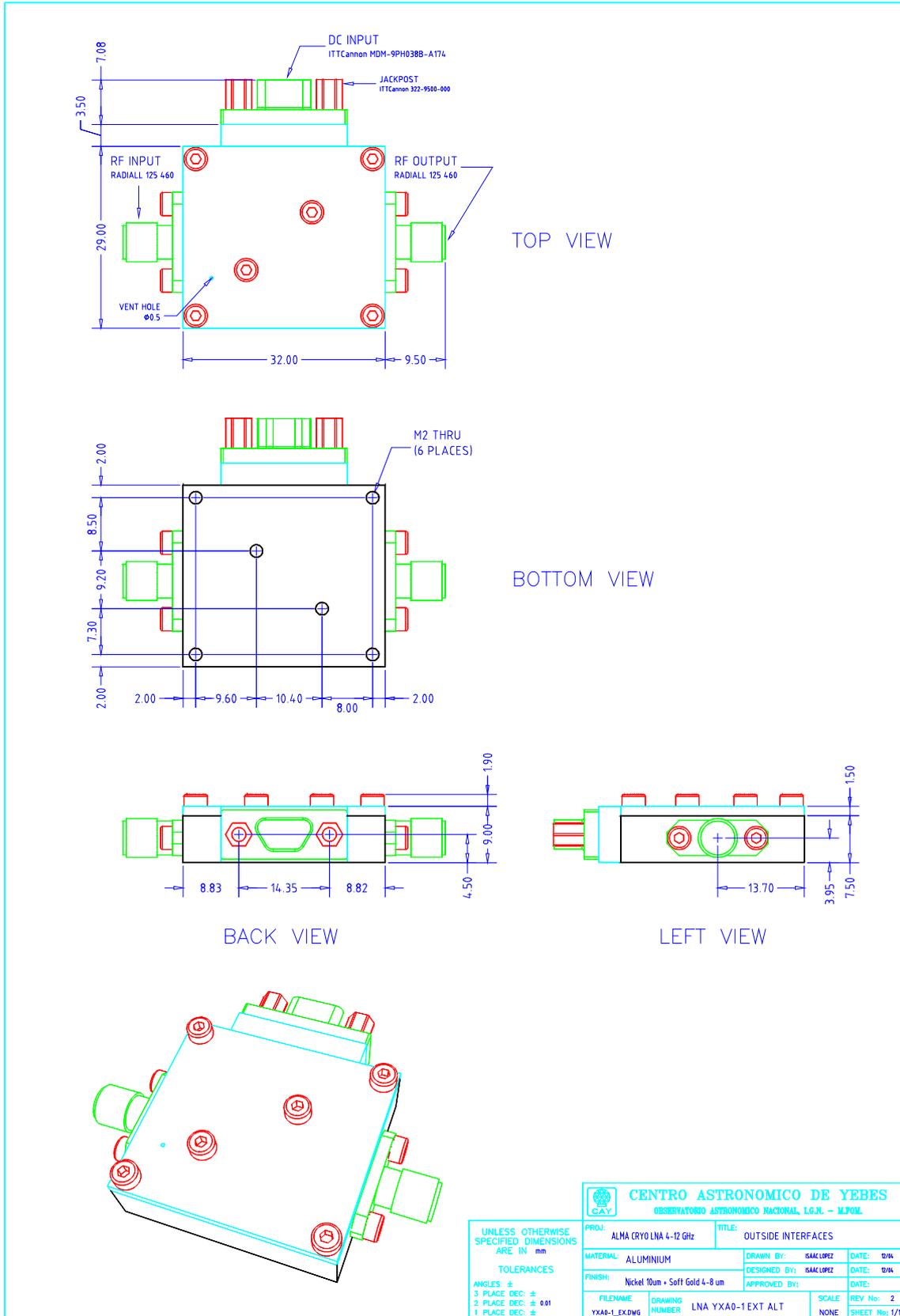


Figure 4: YXA 1 external dimensions

3. Measurements

3.1 Description

Noise temperature (and gain) was measured with a system based in a computer controlled Agilent N8975A Noise Figure Meter described in detail in [1], [2]. Room temperature data was obtained with an Agilent N4000A noise diode. The DUT is cooled in a dewar with a CTI 1020 refrigerator. Cryogenic measurements were taken with the "cold attenuator" method, using an Agilent N4002A noise diode (at room temperature) plus a 15 dB attenuator and a Heat-Block device cooled at cryogenic temperature. Temperature is carefully monitored in the attenuator body using a Lake Shore sensor diode. The accuracy of the system for the amplifiers measured can be estimated with methods presented in [3]. For present case, absolute accuracy (@ 2σ) of measured noise temperature is estimated in 14 K at $T_{amb}=297$ K and 1.7 K at $T_{amb}=14$ K. Repeatability is better than this values by an order of magnitude.

S parameters were measured in the same dewar with an Agilent E8364B Vector Network Analyzer from 0.1 to 20 GHz. A detailed description of the measurement procedure used at cryogenic temperature can be found in [1], [2]. The amplifier output is connected to one of the stainless steel dewar transitions and its input to the other through a semi-flexible Cu cable. A full two port calibration is done at room temperature with the electronic calibration kit Agilent N4693-60001 inside the dewar in place of the amplifier, with the same semi-flexible cable. The stainless steel lines are supposed to be invariant with temperature. The Cu cable is measured at cryogenic temperature independently and its loss is taken into account to correct S11 and S21. Time domain gating is used to correct for the residual phase changes in the lines Note that the amplifier design is not optimized for input reflection, as it is intended to be used with an isolator at the input.

Simultaneously, the amplifier was checked for signs of possible out of band instability. Rollet constant was greater than 1 at all frequencies. Selected amplifiers were also tested with a spectrum analyzer Agilent 9565 EC (0-50 GHz) and wide band detector from a HP 8757 A Scalar Network Analyzer in AC (modulated) mode, sensitive to higher frequency oscillations. Stability tests were carried out with a wide range of bias settings.

3.2 Index of plots

We provide plots of the vector network analyzer measurements and noise figure meter measurements at ambient and cryogenic temperatures, for the optimum bias points.

1. Summary of performance, characteristics and bias in the:
 - a. 4-12 GHz band
 - b. 7.5-9 GHz band
2. Noise and gain measurements
 - a. Noise temperature & gain at room temperature
 - b. Noise temperature & gain at cryogenic temperature
3. Return loss measurements
 - a. Input & output reflection loss at room temperature
 - b. Input & output reflection loss at cryogenic temperature

References

- [1] J. D. Gallego, I. López-Fernández, C. Diez, “A Measurement Test Set for ALMA Band 9 Amplifiers”, 1st Radionet Engineering Forum Workshop, 23-24/06/2009, Gothenburg (available at http://www.radionet-eu.org/fp7wiki/lib/exe/fetch.php?media=na:engineering:ew:lopez-fernandez_final.pdf)
- [2] I. López-Fernández, J. D. Gallego, C. Diez, A. Barcia, “Development of Cryogenic IF Low Noise 4-12 GHz Amplifiers for ALMA Radio Astronomy Receivers”, 2006 IEEE MTT-S Int. Microwave Symp. Dig. pp. 1907-1910, 2006.
- [3] J. D. Gallego, J. L. Cano, “Estimation of Uncertainty in Noise Measurements Using Monte Carlo Analysis”, 1st Radionet Engineering Forum Workshop, 23-24/06/2009, Gothenburg (available at http://www.radionet-eu.org/fp7wiki/lib/exe/fetch.php?media=na:engineering:ew:gallego_final.pdf)



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NOEMA CRYO-LNA REPORT

DATE: 18/01/16

BAND:	4 - 12 GHz	S/N:	YXA 1178
TRANSISTOR 1 st STAGE:	HRL 150x0.1 um T-85 #25		
TRANSISTOR 2 nd STAGE:	HRL 150x0.1 um T-85 #13		
TRANSISTOR 3 rd STAGE:	HRL 150x0.1 um T-85 #13		

ROOM TEMPERATURE DATA		T = 295.5	
OPTIMUM BIAS	$V_{d1} = 1.5$	$I_{d1} = 10$	$V_{g1} = -3.86$
	$V_{d2} = 1.5$	$I_{d2} = 10$	$V_{g2} = -3.96$
	$V_{d3} = 1.5$	$I_{d3} = 10$	$V_{g3} = -2.95$
AVERAGE NOISE TEMP:	60.2	MIN. INPUT RETURN LOSS:	-3.1
AVERAGE GAIN:	33.9	MIN. OUTPUT RETURN LOSS:	-12.1

CRYOGENIC TEMPERATURE DATA		T = 12.8	
OPTIMUM BIAS	$V_{d1} = 0.90$	$I_{d1} = 4.0$	$V_{g1} = -1.46$
	$V_{d2} = 0.60$	$I_{d2} = 4.0$	$V_{g2} = -1.05$
	$V_{d3} = 0.50$	$I_{d3} = 4.0$	$V_{g3} = -0.57$
(P _{diss} = 8.00 mW)			
AVERAGE NOISE TEMP:	5.02	MAX. / MIN. NOISE TEMP:	5.88 3.88
AVERAGE GAIN:	33.3	GAIN SPAN FULL BAND:	1.8
MIN. INPUT RETURN LOSS:	-3.1	MIN. OUTPUT RETURN LOSS:	-14.0

REMARKS: Gain data from VNA measurements

V_d in Volts, I_d in mA, Noise temperature in K, Gain and Return loss in dB, Frequency band in GHz



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NOEMA CRYO-LNA REPORT

DATE: 18/01/16

BAND:	7.5 -9 GHz	S/N:	YXA 1178
TRANSISTOR 1 st STAGE:	HRL 150x0.1 um T-85 #25		
TRANSISTOR 2 nd STAGE:	HRL 150x0.1 um T-85 #13		
TRANSISTOR 3 rd STAGE:	HRL 150x0.1 um T-85 #13		

ROOM TEMPERATURE DATA		T = 295.5	
OPTIMUM BIAS	$V_{d1} = 1.5$	$I_{d1} = 10$	$V_{g1} = -3.51$
	$V_{d2} = 1.5$	$I_{d2} = 10$	$V_{g2} = -3.57$
	$V_{d3} = 1.5$	$I_{d3} = 10$	$V_{g3} = -2.65$
AVERAGE NOISE TEMP: 33.2	MIN. INPUT RETURN LOSS: -3.5		
AVERAGE GAIN: 33.3	MIN. OUTPUT RETURN LOSS: -19.8		

CRYOGENIC TEMPERATURE DATA		T = 12.8	
OPTIMUM BIAS	$V_{d1} = 0.90$	$I_{d1} = 4.0$	$V_{g1} = -1.46$
	$V_{d2} = 0.60$	$I_{d2} = 4.0$	$V_{g2} = -1.05$
	$V_{d3} = 0.50$	$I_{d3} = 4.0$	$V_{g3} = -0.57$
(P _{diss} = 8.00 mW)			
AVERAGE NOISE TEMP: 5.33	MAX. / MIN. NOISE TEMP: 5.85 4.96		
AVERAGE GAIN: 33.0	GAIN SPAN FULL BAND: 0.8		
MIN. INPUT RETURN LOSS: -3.1	MIN. OUTPUT RETURN LOSS: -14.0		

REMARKS: Gain data from VNA measurements

V_d in Volts, I_d in mA, Noise temperature in K, Gain and Return loss in dB, Frequency band in GHz

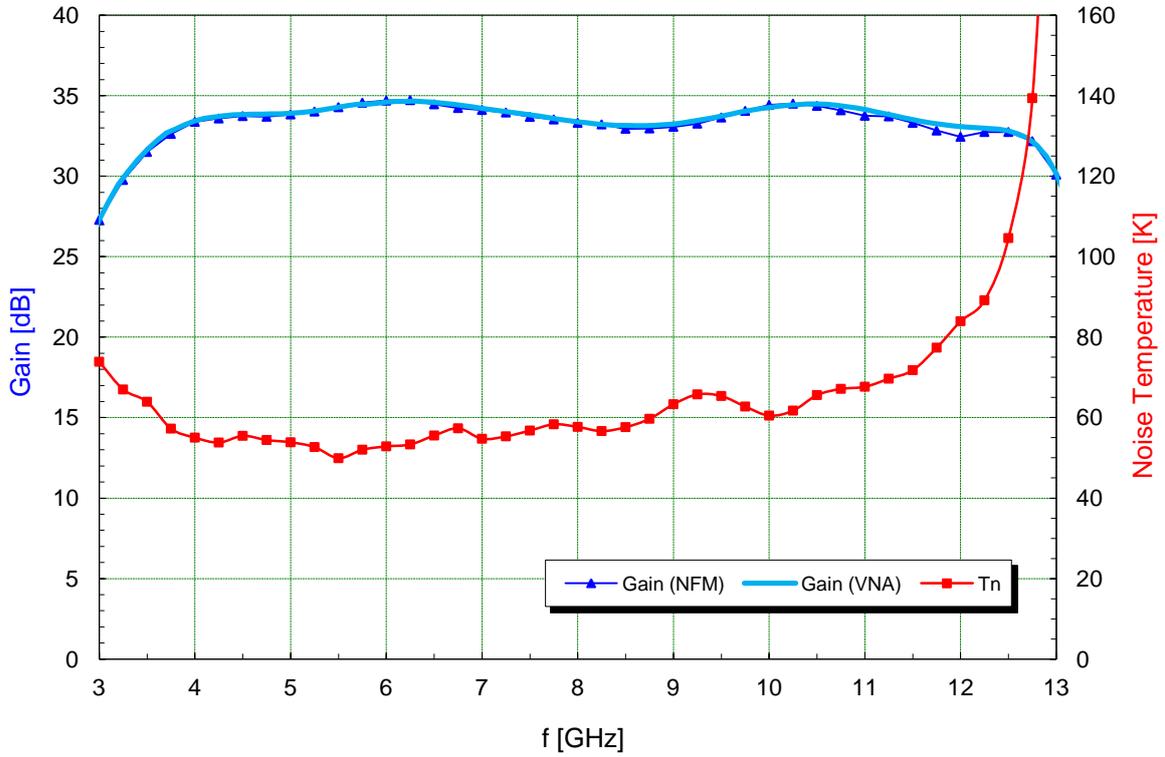


YXA 1178 (14)

$V_{D(1,2,3)} = (1.5, 1.5, 1.5)$

$I_{D(1,2,3)} = (10, 10, 10)$

T=295.5

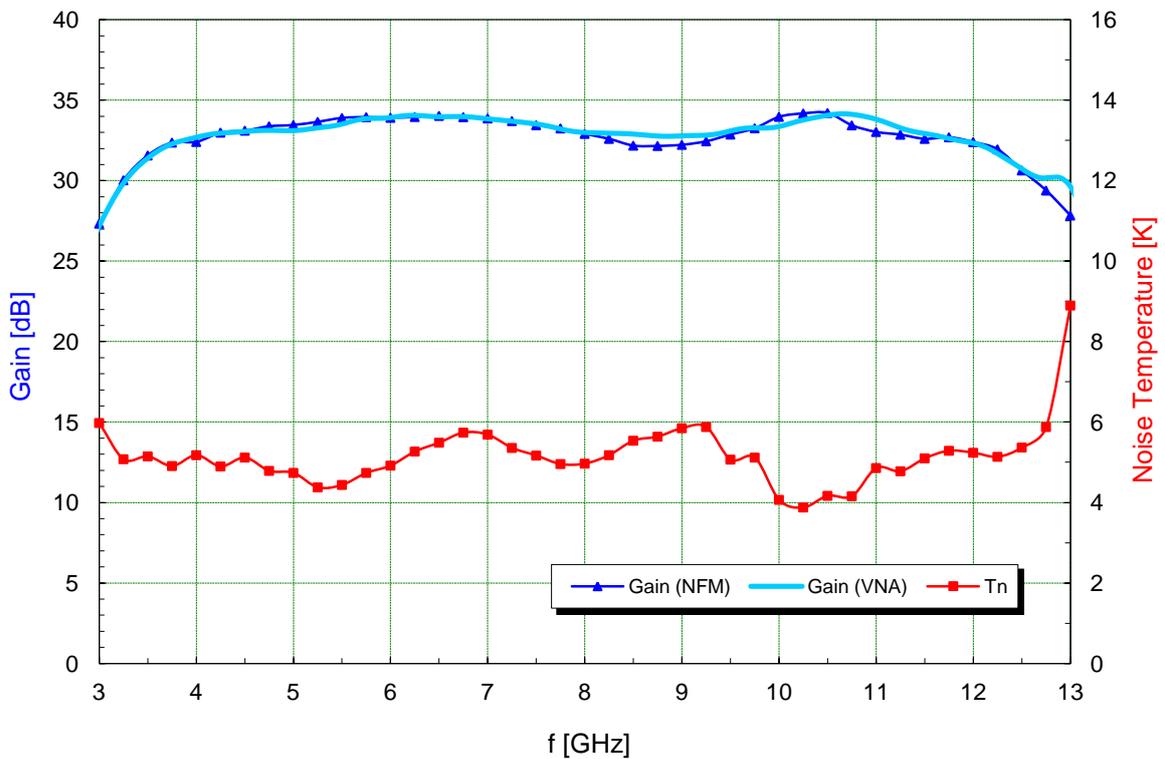


YXA 1178 (14)

$V_{D(1,2,3)} = (0.9, 0.6, 0.5)$

$I_{D(1,2,3)} = (4, 4, 4)$

T=12.8



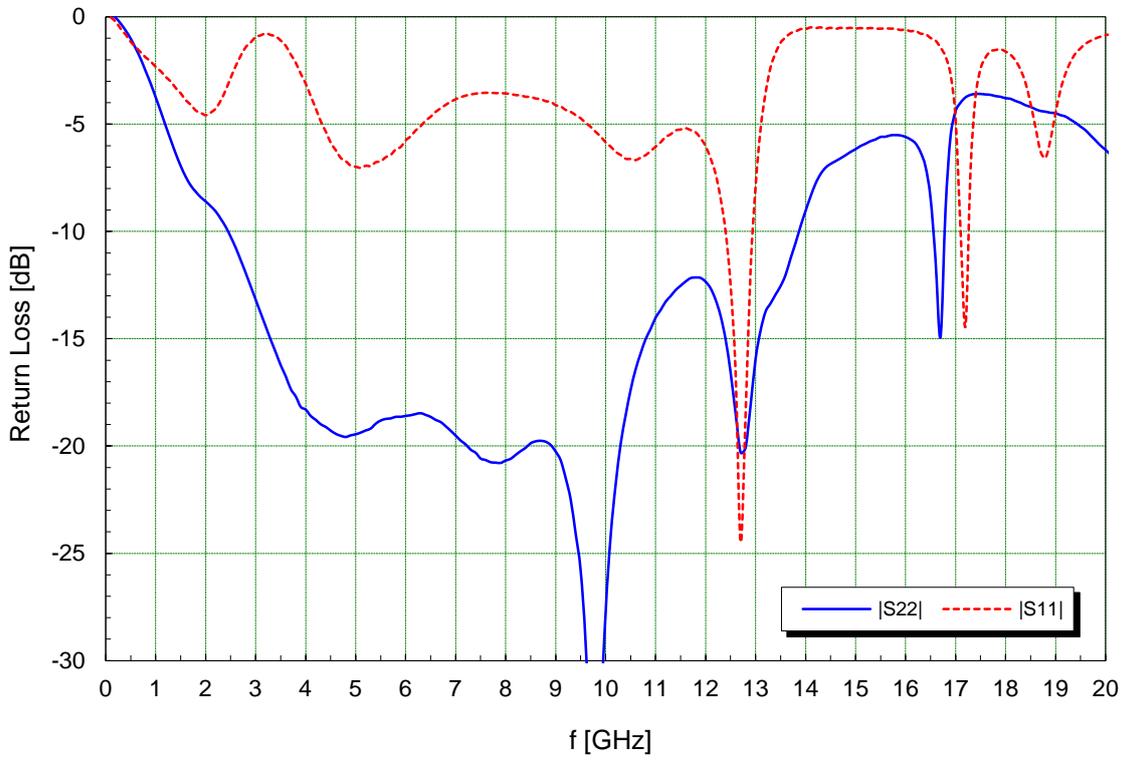


YXA 1178 (14)

VD=(1.5,1.5,1.5)

ID=(10,10,10)

T=295.5

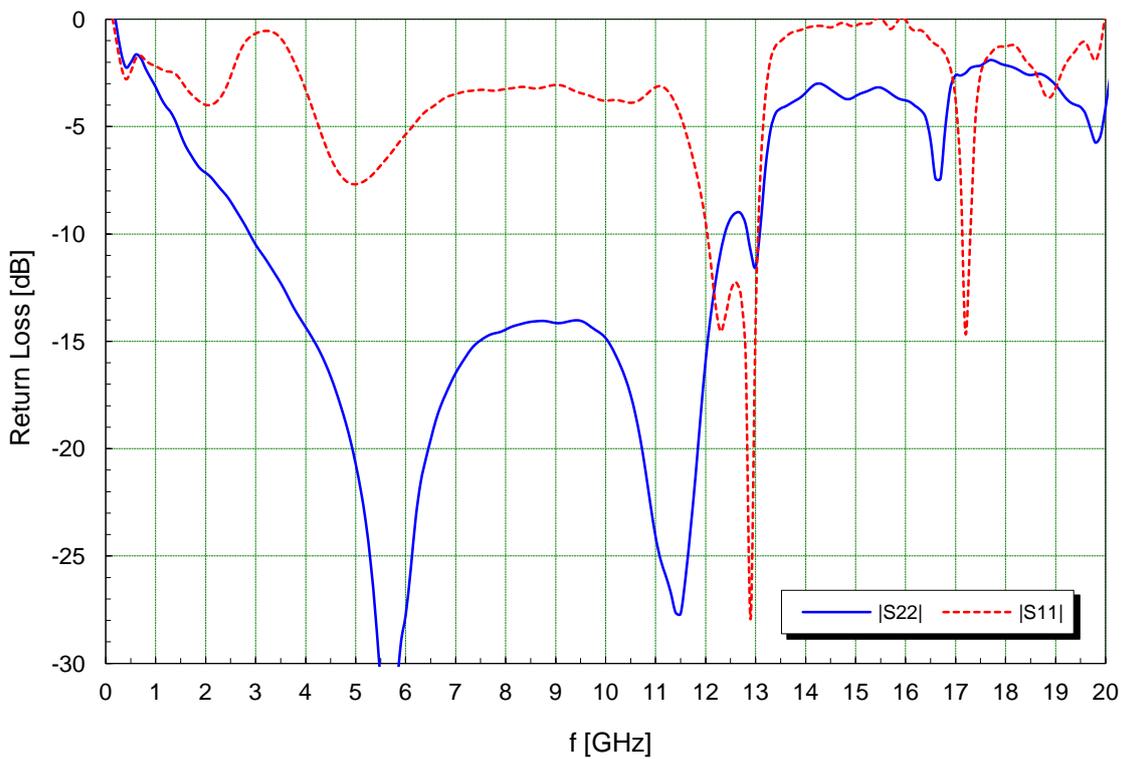


YXA 1178 (14)

VD=(0.9,0.6,0.5)

ID=(4,4,4)

T=17



ESD AND POWER SUPPLY LEAKAGE PROTECTION OF InP CRYOGENIC HEMT AMPLIFIERS

Introduction

Cryogenic amplifiers made with InP HEMTs have been found very sensitive to ESD (electrostatic discharges) and leakage from the power supplies. The handling of these devices requires especial precautions beyond the normal care taken with cryogenic amplifiers made with commercial GaAs HEMTs. Especial procedures should be followed during assembly of the amplifiers as well as during tests and operation to avoid permanent damage to the devices. The most common mode of failure is the total or partial destruction of the gate of the transistors. Partially damaged devices may lose one or more gate fingers and show poor or no pinch off, even if the gate junction still shows diode characteristics. Totally damaged devices may appear as a short circuit (or low resistance) from drain to source. Sometimes, but not often, the device may appear as an open circuit.

ESD is not the only problem. Leakage of soldering irons, bonding machines and even power supplies of the amplifiers has produced many failures. All the equipment used in the assembly test and operation of the amplifiers should be checked for leakage. Most of the field problems detected have been caused by 50 Hz current leakage of input transformers of floating DC power supplies. This leakage is due to the capacitive coupling between primary and secondary of the transformers and it is always present unless there is a grounded Faraday shield between the two windings or other especial precautions are taken.

Procedure for assembly of the amplifiers

1. Technicians manipulating amplifiers should wear grounded wrist straps.
2. The bench for the assembly of the amplifiers should have a dissipative mat connected to ground.
3. A short circuit should be put in the power connector of the amplifier at all times during assembly (the short circuit should short all pins together to the case). The short circuit will only be removed for testing the amplifier or when connected for operation.
4. Coaxial SMA short circuits should be connected to input and output RF connectors at all times during assembly. The short circuits will only be removed for testing the amplifier or when connected for operation.
5. The soldering irons used for assembly should be adequately grounded. It should be checked that no voltage respect to ground is measured on the tip with the soldering iron on and off. The maximum voltage allowed will be 0.020 V_{rms} respect to ground measured with a high input impedance (> 10 M Ω) voltmeter in AC mode.
6. The tip of the bonding and welding machines used for assembly of the amplifier should be adequately grounded. It should be checked that no voltage respect to ground is measured with machines on or off. The maximum voltage allowed will be 0.020 V_{rms} respect to ground measured with a high input impedance (> 10 M Ω) voltmeter in AC mode.
7. Be very careful with any measurement instrument used during assembly. If ohmmeters are used for verification of internal cabling, battery operated units are preferred. Make all necessary verifications before the assembly of the transistors when possible. The assembly of the transistors should be the last operation to avoid unnecessary risks.

Procedure for test and operation of the amplifiers

1. The amplifier should be kept with a short circuit in the power connector when not in use. The short circuit should short all pins together and to the case. The short circuit should only be removed if adequate ESD and leakage protection precautions have been taken.
2. Most failures in cryogenic amplifiers are produced when connecting or disconnecting the amplifier to/from the power supply. **A very careful procedure should be followed.**
3. Make sure that the power supply is **off** before connecting or disconnecting the power supply cable to/from the amplifier.
4. Make sure that the power supply and the amplifier are connected to the same protective ground before connecting or disconnecting the power supply cable to/from the amplifier.
5. Very especial care should be taken in case of a DC power supply floating respect to the protective ground. This produces most failures. It is safer to connect the **return** terminal at the output of the DC power supply to the protective **ground** permanently on the power supply side. If this is not possible (for example to avoid ground loops with long cables), a provisional connection from the return of the power supply to the amplifier case should be **made prior to any connection or disconnection** of the power supply cable. Always make sure that there is no voltage between the return of the power supply and the protective ground (case of the amplifier) before connecting the power supply cable. The maximum allowed voltage will be 0.020 Vrms measured with a high input impedance ($> 10 \text{ M}\Omega$) voltmeter in AC mode.
6. The power supply should have adequate built in protection to avoid excessive voltage and currents in the transistors in case of power supply failure and during the transients produced when the power supply is switched on or off. Adequate Zenner diodes can be used in parallel with the outputs, and adequate series resistors in series. If the protections are designed adequately, the amplifier will survive even in case of errors in the connections of the cables.

Storage of the amplifiers

1. The amplifiers should be stored in a clean dry anti-static environment.
2. The amplifier should be stored with short circuits in the power and RF connectors.
3. For permanent storage desiccators with less than 20% relative humidity should be used. The preferred method of storage is in dry nitrogen containers.
4. For transportation, and for short-term storage, anti-static plastic bags with silica gel bags to keep low relative humidity should be used.