Cryogenic Q Band LNA
YQN 1007
(Test Report)

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YQN 1 31-50 GHz AMPLIFIER REPORT

1. Introduction

YQN series 1 is a millimeter wave cryogenic low noise amplifier operating in an expanded Q band from 31 to 50 GHz. It is a four-stage hybrid amplifier using InP discrete transistors fabricated by Diramics.

The input and output ports were designed to accommodate either a coaxial 2.4 mm connector or a transition to WR-22 waveguide. All amplifiers were tested first in coaxial configuration, which eases tuning and bias optimization and allows the identification of out-of-band oscillations.

These amplifiers were built for the frontends of the Nanocosmos project. For this application the amplifiers are delivered with two WR-22 ports.

This document includes a description of the amplifiers and how to operate them, details about the tests performed, the measurements techniques utilized and datasheets and plots with the relevant data collected (an index is provided in section 3.2).

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 on request.

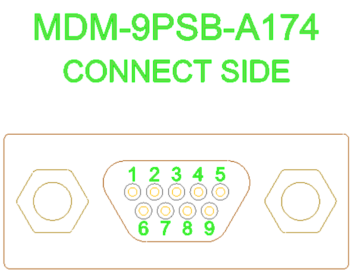
2. Description and operating conditions of the amplifier

- **Figure 1** shows an outside view of the amplifier, while the external dimensions and mechanical interfaces are shown in **figure 3**. This unit could present 2.4 mm coaxial input and output connectors or WR-22 waveguide ports. Input and output ports are marked “IN” and “OUT” on the lid side. The amplifier serial number is engraved on the lid and chassis.
- Four **UNC 4-40** threaded holes (normally used to fix waveguide flanges) on the bottom side of the chassis may be used to attach the amplifier to a cold plate. *Take into account the limited thread length available and **do not use bolts exceeding 5 mm inside the chassis***. Two additional **M2** threaded holes, which can be seen on the front side of the chassis in figure 1, can also be used for the same purpose.
- The **DC bias connector** is a 9 pin, plug Micro-D with metal shell. This connector complies with standard MIL-DTL-32139. The corresponding aerial plugs with cables could be obtained from GLENAIR (MWDM2L-9S-6K7-18B). The pinout is provided in figure 2.
- This unit has four stages of Diramics InP 0.1×50 µm transistors. These devices are ESD sensitive; cautions must be taken during its manipulation and operation. The bias circuits built in the amplifier include GaAs Schottky diodes (VF ≈ 0.8 V @ 15 K) which limit the drain (with two diodes in series) and gate voltages (two diodes in antiparallel)

to prevent damage to the transistors. A 10 nF capacitor acts as a charge divider reducing the ESD impact. Information on ESD prevention procedures and safe unit handling and storage is provided in the "ESD and power supply leakage protection of HEMT cryogenic amplifiers" section.

- Never exceed a drain voltage/current of 1.5 V / 15 mA per stage.
- One bias condition has been selected for each amplifier, which optimizes the device for noise, gain, ripple and reflection. There is data available on other bias settings in case a reduced power dissipation or a higher gain were required.

Figure 1: YQN1 amplifier view showing waveguide configuration at the input. Box dimensions are 29.5×20×10 mm (43×20×10 mm with input and output waveguide configuration).



PIN	SIGNAL
1	GND
2	VD1
3	VG1
4	VD2
5	VG2
6	VD3
7	VG3
8	VD4
9	VG4

Figure 2: DC Connector pinout

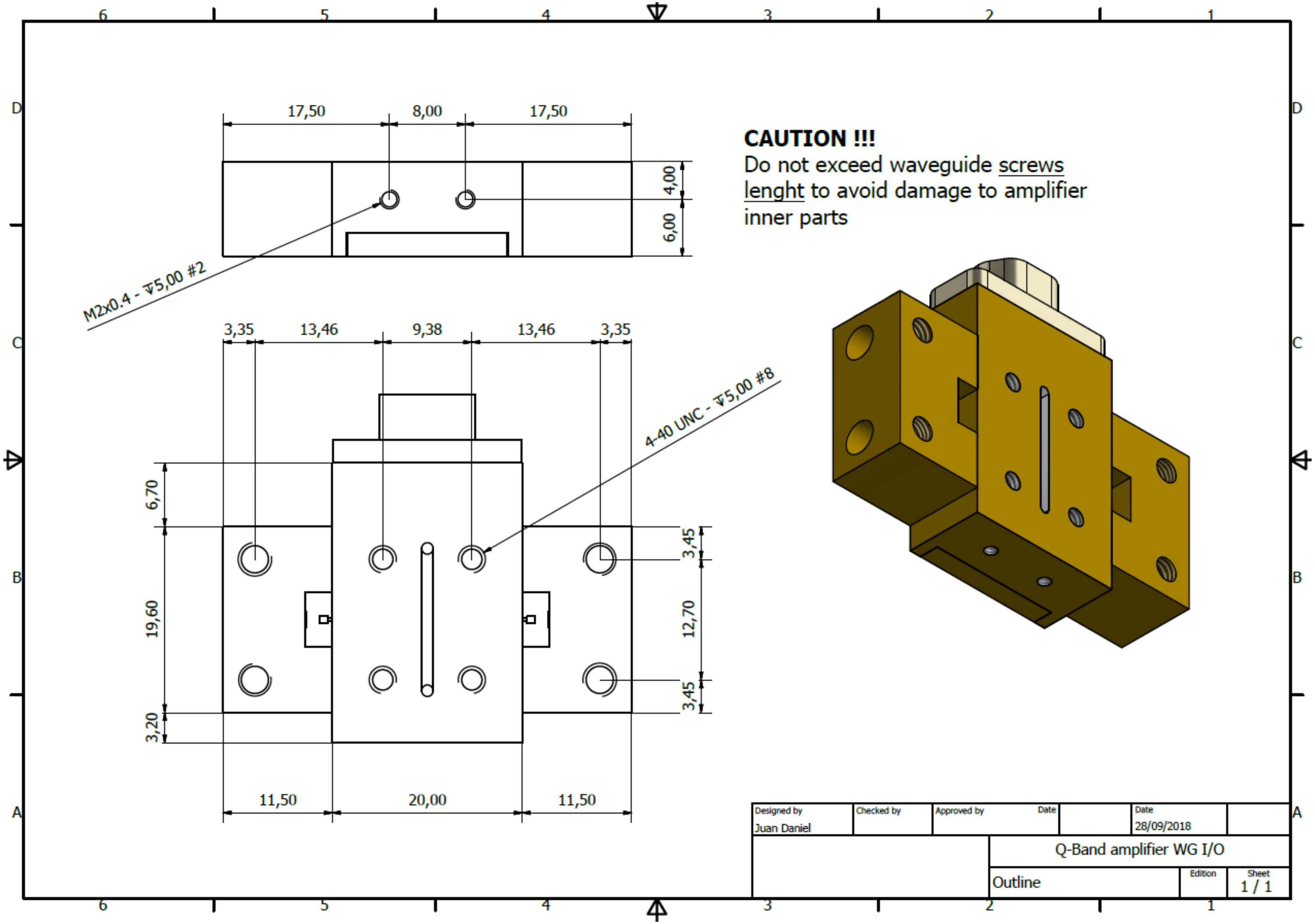


Figure 3: *YQN 1* external dimensions

3. Measurements

3.1 Description

Noise temperature (and gain) was measured with a system based on a computer controlled HP 8970 B Noise Figure Meter, using an external mixer. Coaxial and waveguide measurements were taken.
Coaxial measurements were obtained with an Agilent 346CK01 noise source followed by a commercial 10 dB attenuator (at room temperature) or a special 15 dB quartz attenuator[1] cooled (at cryogenic temperature, according to the "cold attenuator" method). The DUT is cooled in a Dewar with a CTI 1020 refrigerator. These measurements were used to optimize the bias of the amplifier.
Waveguide measurements were performed with the hot/cold load method using a high precision variable temperature waveguide load. This method measures the noise in a configuration very similar to which it would be used in a real receiver, but does not allow real time tuning of the amplifier.

S parameters at room temperature were measured with DUT in coaxial and waveguide configuration. Waveguide measurements were performed with a Keysight PNA-X (N5247 A) Vector Network Analyzer (VNA), using HP R281A/B precision WR-22 to 2.4 mm coaxial transitions. A full TRL calibration was done at the WR-22 ports from 30 to 50 GHz.
Cryogenic S parameters were measured in the same Dewar as the noise temperature measurements only in coaxial configuration, using a HP 8510 C VNA in the 0-50 GHz frequency range. The effect of the hermetic transitions and stainless steel access lines is de-embedded in real time using custom software. The change with temperature of the cryogenic flexible cable at the DUT output is also taken into account in the de-embedding. The stainless steel lines are considered invariant with temperature, and the small variations of the transitions upon cooling are corrected by using time domain gating.

The amplifiers were first checked in coaxial configuration at room and cryogenic temperature seeking oscillations out of the waveguide band. The Rollet constant (K factor) was measured at cryogenic temperature in the same setup used for S parameter characterization, at several bias points in the 0-50 GHz band of the VNA. Drain current versus voltage (I-V) curves for all stages were taken to spot any possible anomaly for the widest possible range of bias settings. These irregularities in the I-V plots usually indicate the presence of oscillations. Using a spectrum analyzer Agilent 8565 EC the oscillations can be identified when they lie below the 50 GHz limit of the instrument. For higher frequencies a power sensor: HP 8487A (-70, +20 dBm) in combination with a power meter Agilent N1913A is used.

[1] The attenuator design allows an efficient cooling of the resistive elements and an accurate reading of its temperature by a Lakeshore sensor diode, minimizing the effect of the stray heating produced by the inner conductor of the input coaxial cable. An absolute accuracy (@ 3σ) of ≈3 K and 0.9 dB at Tamb=14 K for an amplifier of 25 dB of gain and 20 K of noise can be estimated with methods presented in [1]. Repeatability is better than these values by an order of magnitude.

3.2 Index of plots

The **report for each amplifier** which follows this page includes:

1) Data-sheet:
   Amplifier identification, nominal bias and a summary of the measurements performed at room and cryogenic temperature.
2) Noise and gain plots:
   a) Room temperature noise and gain measured in waveguide configuration.
   b) Cryogenic temperature noise and gain measured in waveguide configuration. The gain is measured with the NFM and is not corrected for the output cable losses.
3) Return loss plots:
   a) Room temperature input and output return loss in waveguide configuration.
   b) Cryogenic temperature input and output return loss in coaxial configuration. Only the band of interest is presented in the |S11| and |S22| plots.

References

[1] 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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CRYOGENIC LNA DATA SHEET

DATE: 04/06/18

BAND:	Q (31-50)	S/N:	**YQN 1007**
Devices:	Diramics 50×0.1µm	Run:	09/17

ROOM TEMPERATURE DATA T = 296

NOMINAL BIAS			
	V_{d1} = 1.2	I_{d1} = 6.0	V_{g1} = 0.04
	V_{d2} = 1.2	I_{d2} = 6.0	V_{g2} = 0.03
	V_{d3} = 1.2	I_{d3} = 6.0	V_{g3} = 0.03
	V_{d4} = 1.2	I_{d4} = 6.0	V_{g4} = 0.03

	FREQUENCY BAND:	31-50
COAXIAL MEASUREMENTS	AVERAGE NOISE TEMP:	140.4
	AVERAGE GAIN:	30.7
	MIN. INPUT RETURN LOSS:	-4.6
	MIN. OUTPUT RETURN LOSS:	-5.7
WAVEGUIDE MEASUREMENTS	AVERAGE NOISE TEMP:	144.5
	AVERAGE GAIN:	31.5
	MIN. INPUT RETURN LOSS:	-5.1
	MIN. OUTPUT RETURN LOSS:	-6.6
	COMPRESSION (P_{1dB}):	-2.9

CRYOGENIC TEMPERATURE DATA T = 15

NOMINAL BIAS			
	V_{d1} = 1.0	I_{d1} = 3.0	V_{g1} = 0.00
	V_{d2} = 1.0	I_{d2} = 3.0	V_{g2} = 0.00
	V_{d3} = 1.0	I_{d3} = 3.0	V_{g3} = -0.01
(P_{diss}= 16.0 mW)	V_{d4} = 1.4	I_{d4} = 5.0	V_{g4} = 0.00

	FREQUENCY BAND:	31-50
COAXIAL MEASUREMENTS	AVERAGE NOISE TEMP:	18.47
	AVERAGE GAIN:	34.32
	GAIN FLATNESS:	4.2
	MIN. INPUT RETURN LOSS:	-5.2
	MIN. OUTPUT RETURN LOSS:	-6.5
WAVEGUIDE INPUT MEASUREMENTS	AVERAGE NOISE TEMP:	**14.7**
	AVERAGE GAIN:	**35.30**
	GAIN FLATNESS:	**3.6**
	OSCILLATIONS (INP. SHORT):	-

REMARKS:

Coaxial noise measurements according to cold att. method

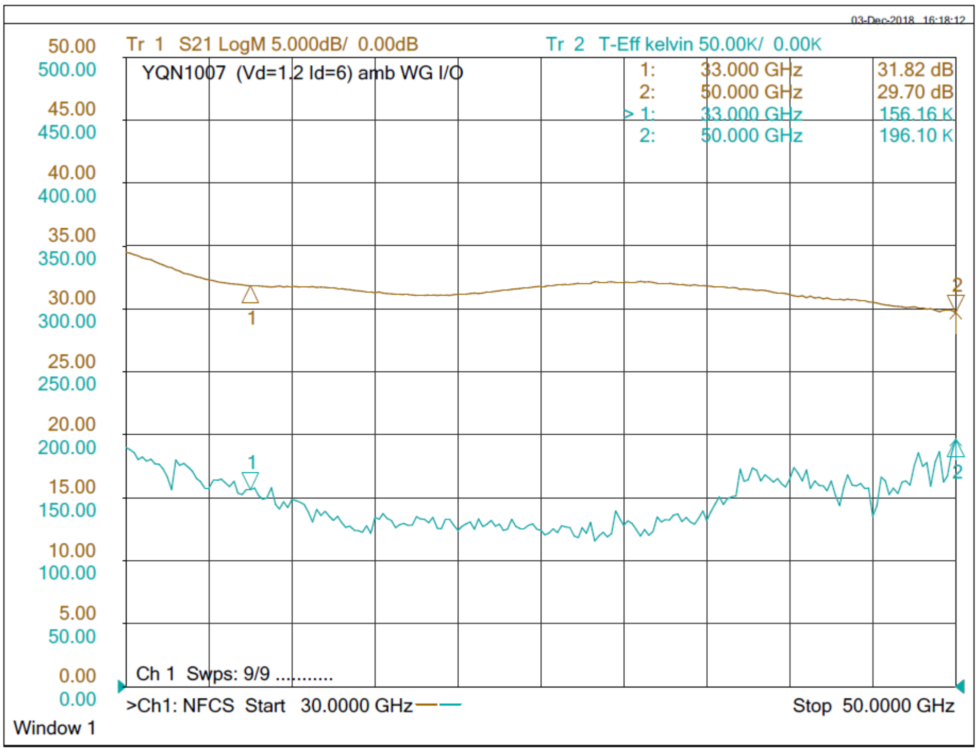
Gain data from PNA at room temperature and from NFM at cryogenic measurements

Bias in the receiver set to $Vd_{(1,2,3,4)}$=(0.8,1,1,1.4) V and $Id_{(1,2,3,4)}$=(3,3,3,5) mA due to instability problems in the final configuration.

V_d in Volts, I_d in mA, Noise temperature in K, Gain and Return loss in dB, Frequency band in GHz, P1dB in dBm

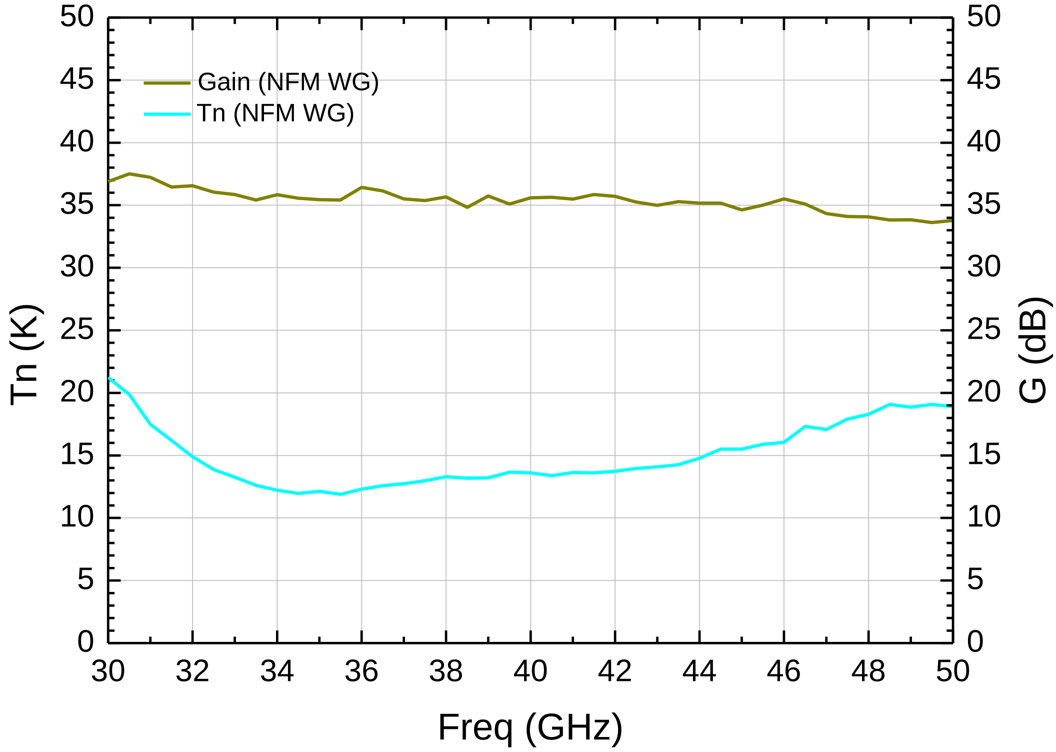
YQN 1007

$V_{D(1,2,3,4)}$= (1.2,1.2,1.2, 1.2) $I_{D(1,2,3,4)}$= (6,6,6,6) **T=290**



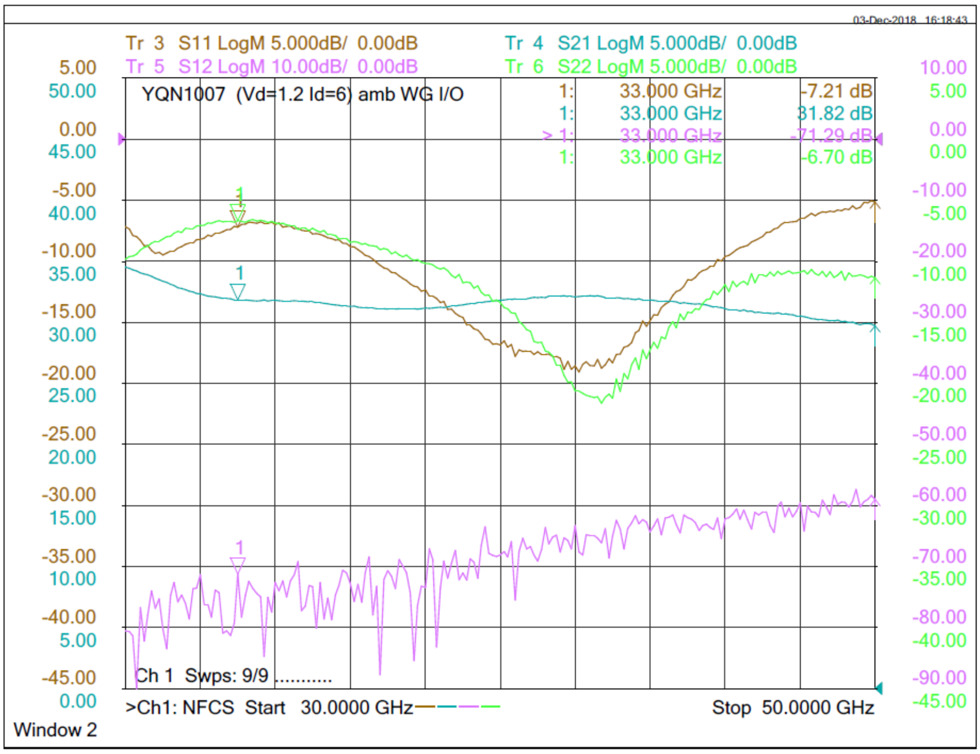
YQN 1007

$V_{D(1,2,3,4)}$= (1,1,1,1.4) $I_{D(1,2,3,4)}$= (3,3,3,5) **T=15**



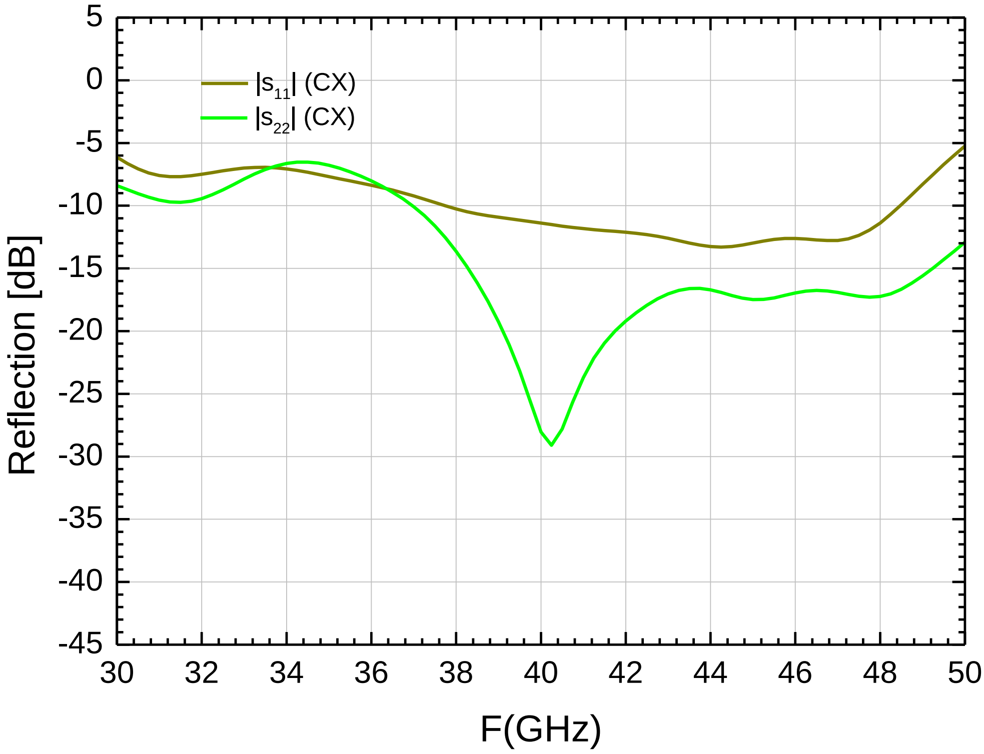
YQN 1007

$V_{D(1,2,3,4)}$= (1.2,1.2,1.2, 1.2) $I_{D(1,2,3,4)}$= (6,6,6,6) **T=290**



YQN 1007

$V_{D(1,2,3,4)}$= (1,1,1,1.4) $I_{D(1,2,3,4)}$= (3,3,3,5) **T=15**



ESD AND POWER SUPPLY LEAKAGE PROTECTION OF CRYOGENIC HEMT AMPLIFIERS

Introduction

Cryogenic amplifiers made with InP HEMTs or GaAs metamorphic 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 loose one or more gate fingers and show poor or no pinch off, even if the gate junction still show 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 map 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 Vrms respect to ground measured with a high input impedance (> 10 MΩ) 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 Vrms respect to ground measured with a high input impedance (> 10 MΩ) 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. Keep the amplifier in an anti-static bag at all times. When it is outside the protective bag, do not touch the contacts of the power connector with bare fingers or with any tool. If possible, 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 MΩ) 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.