Y214G 1012 2-14 GHz cryogenic low noise amplifier report

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INDEX OF DOCUMENTS

Y214G 1 AMPLIFIER REPORT

1. Introduction

Y214G series 1 are ultra-wide band, 2-14 GHz low noise cryogenic amplifiers designed and built at the *Observatorio de Yebes* for the development of a receiver for the VGOS next generation geodetic VLBI band.

Amplifier Y214G 1012 has been modified to improve the output 1 dB compression point by using a GaAs commercial transistor in the third stage.

This document includes a description of the amplifier and how to operate it, details about the tests performed, the measurements techniques utilized and datasheets and plots with the relevant data collected.

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 for TTI[1] for our HEMT amplifiers are available upon request.

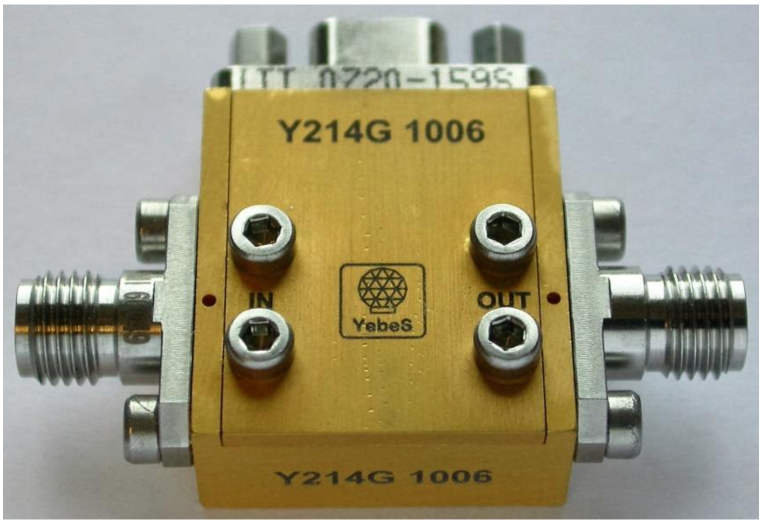

Figure 1: External view of the Y214G LNA. Dimensions excluding connectors are 20×22×9 mm (X×Y×Z in the picture)

[1] TTI Norte, Santander (Spain) www.ttinorte.es

2. Description and operating procedures of the amplifier

2.1 Dimensions and mechanical interfaces

Figure 1 shows an outside view of an amplifier. The external dimensions and mechanical interfaces of the amplifier are shown in figure 2. The amplifier chassis is made of aluminum and plated with soft gold.

Several M2 threaded holes, which can be seen on the bottom side of the LNA chassis in figure 2, could be used for thermal anchoring.

2.2 Electrical interfaces

Input and output ports are female field replaceable 2.92 mm coaxial connectors (for glass beads with 0.012" pin diameter).

The **DC bias connector** is a 9 pin microminiature D-type ITT-Cannon. The pin out is provided in figure 2.

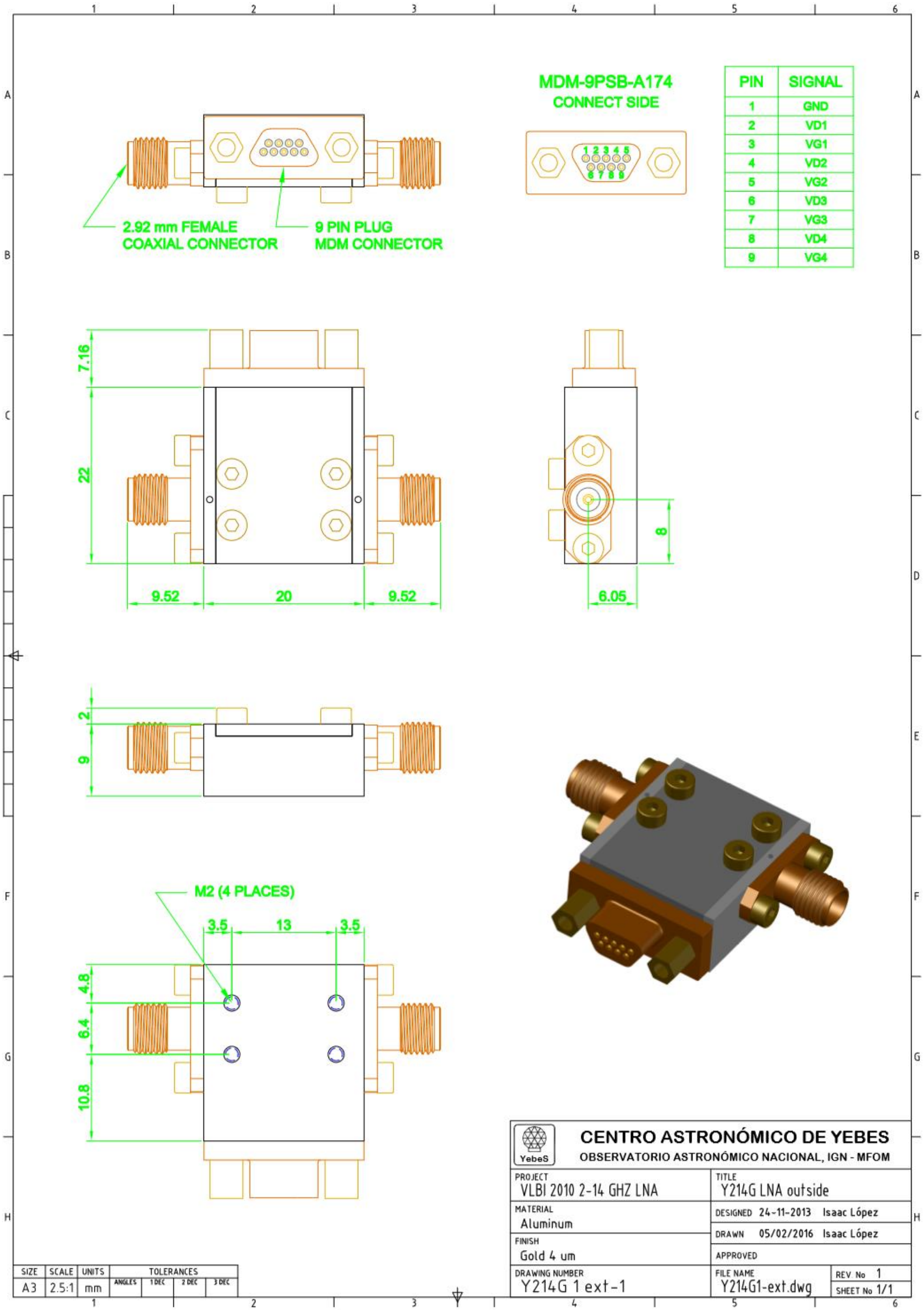

Figure 2: *YXW 1 mechanical and electrical interface, external dimensions and DC connector pinout.*

2.3 Bias and ESD

This unit has three stages of HEMT transistors. The third stage device is a GaAs commercial transistor. The first and second stages devices are InP transistors, very **ESD** sensitive; cautions must be taken during the manipulation and operation of the unit. Each gate bias circuit built in the amplifier include two GaAs Schottky diodes in antiparallel ($V_F \approx 0.8$ V @ 15 K) which limit the gate voltages to prevent damage to the transistors. A 1 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 InP HEMT cryogenic amplifiers” section.

The nominal **bias** condition selected for the amplifier optimizes the device for noise, gain, ripple, reflection and gain compression. An additional bias point is given for improved gain compression but yields higher power dissipation.

Never exceed a drain voltage/current of 1.5 V / 10 mA for InP/InAs transistors. Note that the first stage has two transistors in parallel and therefore admits more current. A schematic of the bias circuits is shown in figure 3. There is a significant voltage drop in the drain lines due to the 120-170 ohm total series resistance which should be taken into account when biasing the amplifiers.

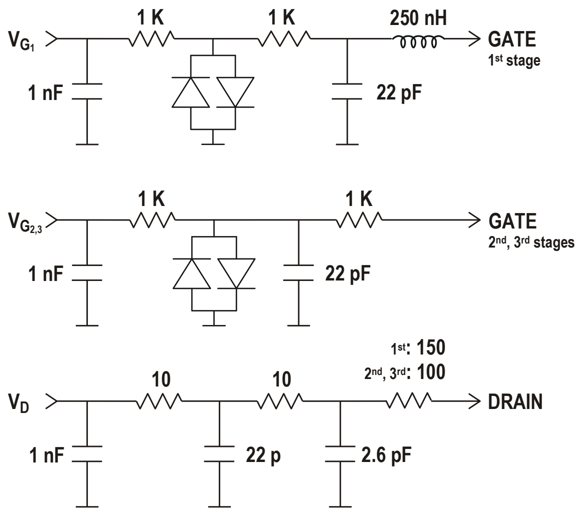

Figure 3: Bias circuit (inside the amplifier)

3. Measurements

Noise temperature (and gain) was measured with a system based on a computer controlled Agilent N8975A Noise Figure Meter described in detail in [1], [2]. Room temperature data were 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. An absolute accuracy (@ 2 σ) of 14 K at T_{amb}=297 K and 1.7 K at T_{amb}=14 K can be estimated with methods presented in [3]. Repeatability is better than these 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 20.1 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 reflection changes in the lines.

1 dB compression at the input is measured with the same VNA in power sweep mode and using a HP 8487A Power Sensor and a HP 437B Power Meter for absolute power calibration and cable losses measurements. Linearity was checked at 3, 6 and 12 GHz. Data is presented only for 3 GHz, frequency for which the worst values were obtained.

Additional measurements to ensure the absence of oscillations of the amplifiers were performed at room and cryogenic temperatures.

Two reports for this amplifier follow this page. The first one includes measurements at the optimum bias, and the next one with a higher bias for the 3rd stage in order to improve the 1 dB compression point, at the expense of an increase in the dissipated power. Each one contains:

1) Data-sheet:
   Amplifier identification, nominal bias and a summary of the measurements performed at room and cryogenic temperature.
2) Noise and gain plots: Noise temperature and available gain at room and cryogenic temperature. Gain curves are taken with the Vector Network Analyzer and with the Noise Figure Meter during noise measurements.
3) Return loss plots: |S11| and |S22| at room and cryogenic temperature
4) 1 dB compression plot: Output power and gain curves at cryogenic temperature for 3 GHz.

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)

OBSERVATORIO DE YEBES

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CRYOGENIC LNA DATA SHEET

DATE: 06/10/16

BAND:	2- 14 GHz	S/N:	Y214G 1012
TRANSISTORS:	ST1: 2×T-273	ST2: T-78	ST3: T-57

ROOM TEMPERATURE DATA   T = 296.2

NOMINAL BIAS			
	V_{d1} = 4.0	I_{d1} = 20.0	V_{g1} = 0.00
	V_{d2} = 2.0	I_{d2} = 10.0	V_{g2} = -0.23
	V_{d3} = 3.0	I_{d3} = 15.0	V_{g3} = -0.17

MEASUREMENTS			
FREQUENCY BAND:	2-14	2-4	4-8
AVERAGE NOISE TEMP:	62.3	50.5	57.5
AVERAGE GAIN:	30.9	31.7	30.8
MIN. INPUT RETURN LOSS:	-1.7	-1.7	-5.1
MIN. OUTPUT RETURN LOSS:	-19.1	-19.1	-19.8

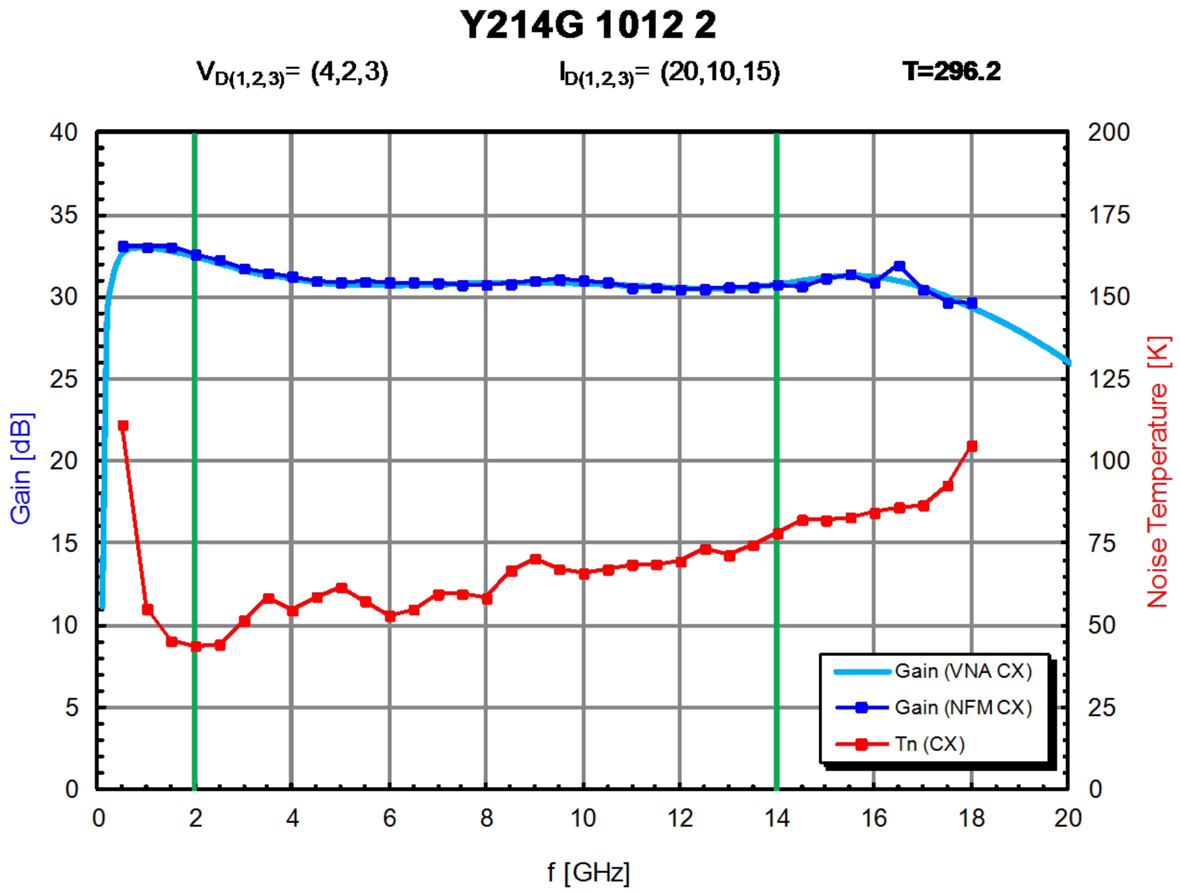
CRYOGENIC TEMPERATURE DATA   T = 13.8

NOMINAL BIAS			
	V_{d1} = 2.50	I_{d1} = 10.0	V_{g1} = 0.02
	V_{d2} = 1.20	I_{d2} = 5.0	V_{g2} = -0.14
(P_{diss} = 76.00 mW)	V_{d3} = 3.00	I_{d3} = 15.0	V_{g3} = -0.11

MEASUREMENTS			
FREQUENCY BAND:	2-14	2-4	4-8
AVERAGE NOISE TEMP:	6.1	5.2	5.7
MIN. - MAX. NOISE TEMP:	5.1-7.1	5.1-5.6	5.2-6.4
AVERAGE GAIN:	34.3	35.1	34.3
GAIN SPAN FULL BAND / 2 GHz:	2.2 / 1.2	1.1 / 1.1	0.4 / 1.2
MIN. INPUT RETURN LOSS:	-1.5	-1.5	-4.5
MIN. OUTPUT RETURN LOSS:	-16.1	-16.1	-18.6
MIN. INPUT 1dB COMPRESSION:	-30.9		

REMARKS: Gain data from VNA measurements
Coaxial noise measurements according to cold att. method

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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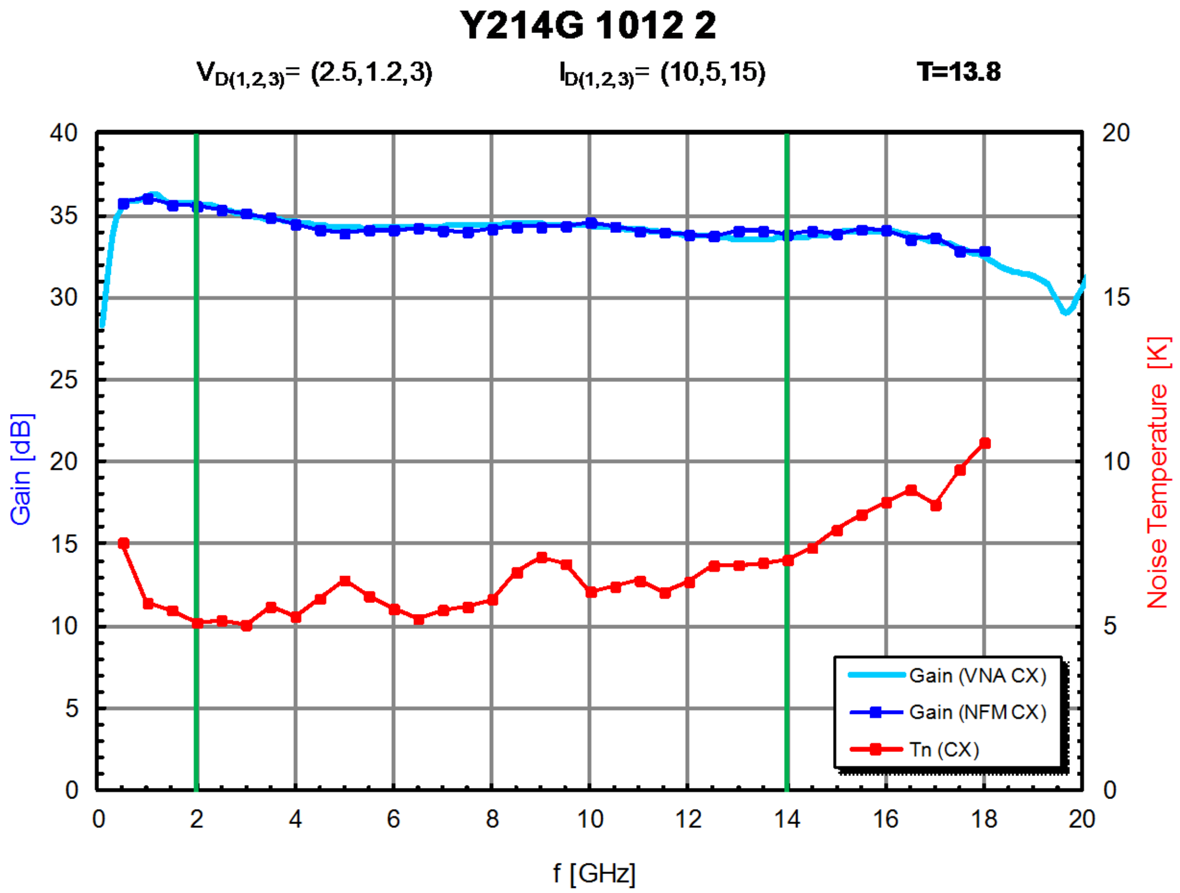
ID(1,2,3)= (20,10,15)
T=296.2
Gain [dB]
Noise Temperature [K]
f [GHz]
Gain (VNA CX)
Gain (NFM CX)
Tn (CX)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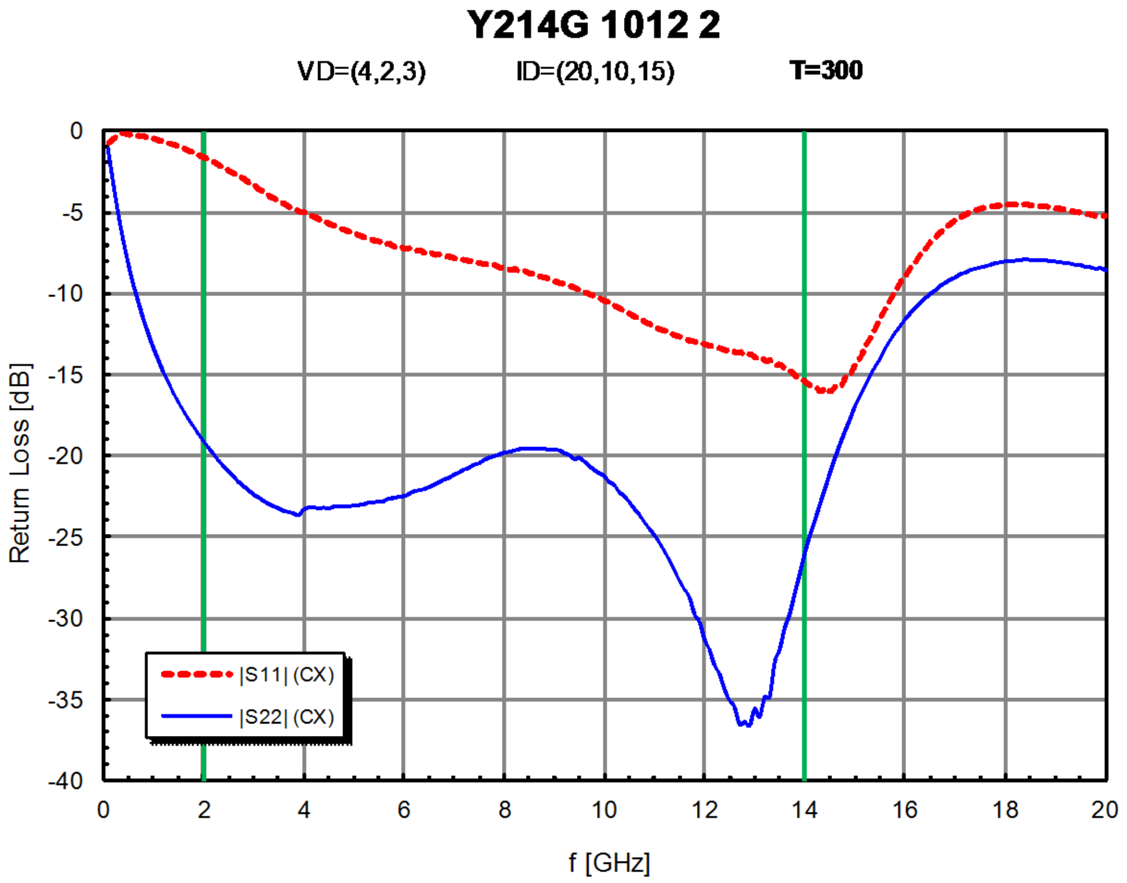
Gain [dB]
Noise Temperature [K]
f [GHz]
Gain (VNA CX)
Gain (NFM CX)
Tn (CX)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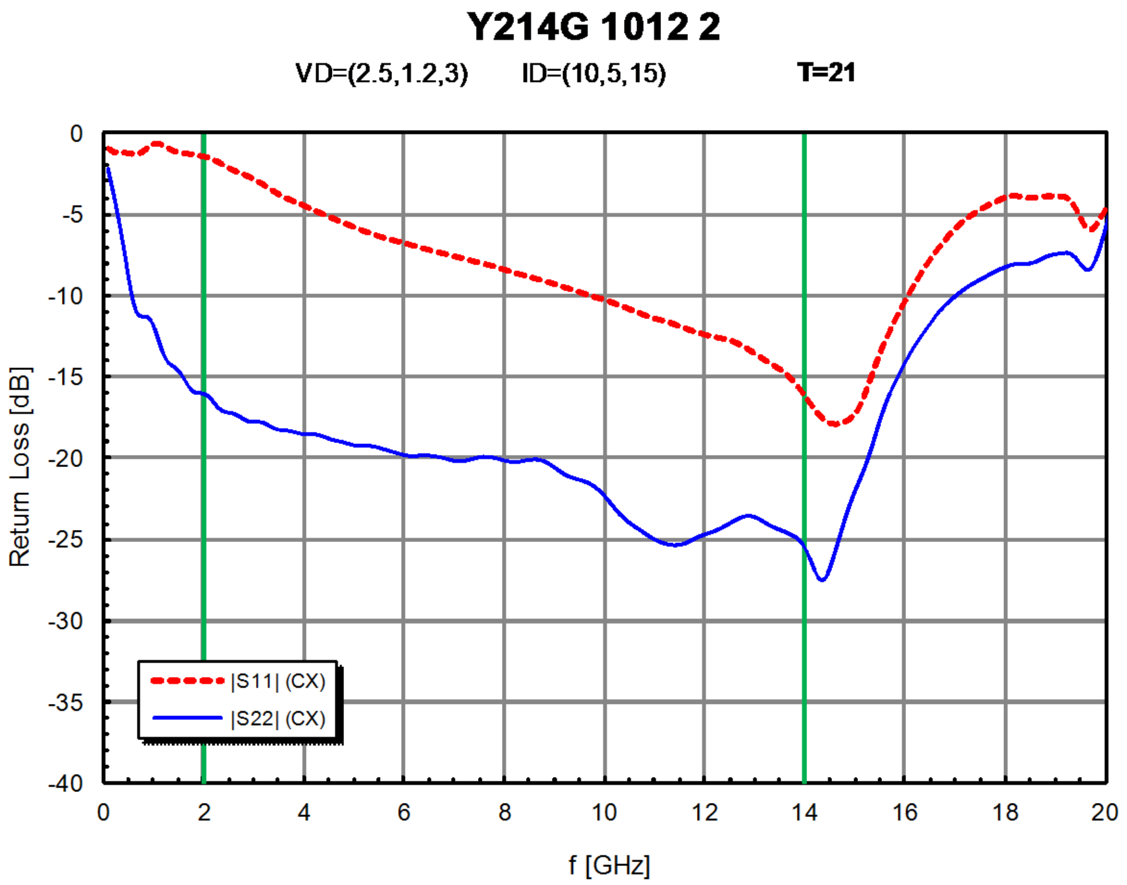
VD=(4,2,3)
ID=(20,10,15)
T=300
Return Loss [dB]
f [GHz]
|S11| (CX)
|S22| (CX)
0
-5
-10
-15
-20
-25
-30
-35
-40
0
2
4
6
8
10
12
14
16
18
20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T=21
Return Loss [dB]
f [GHz]
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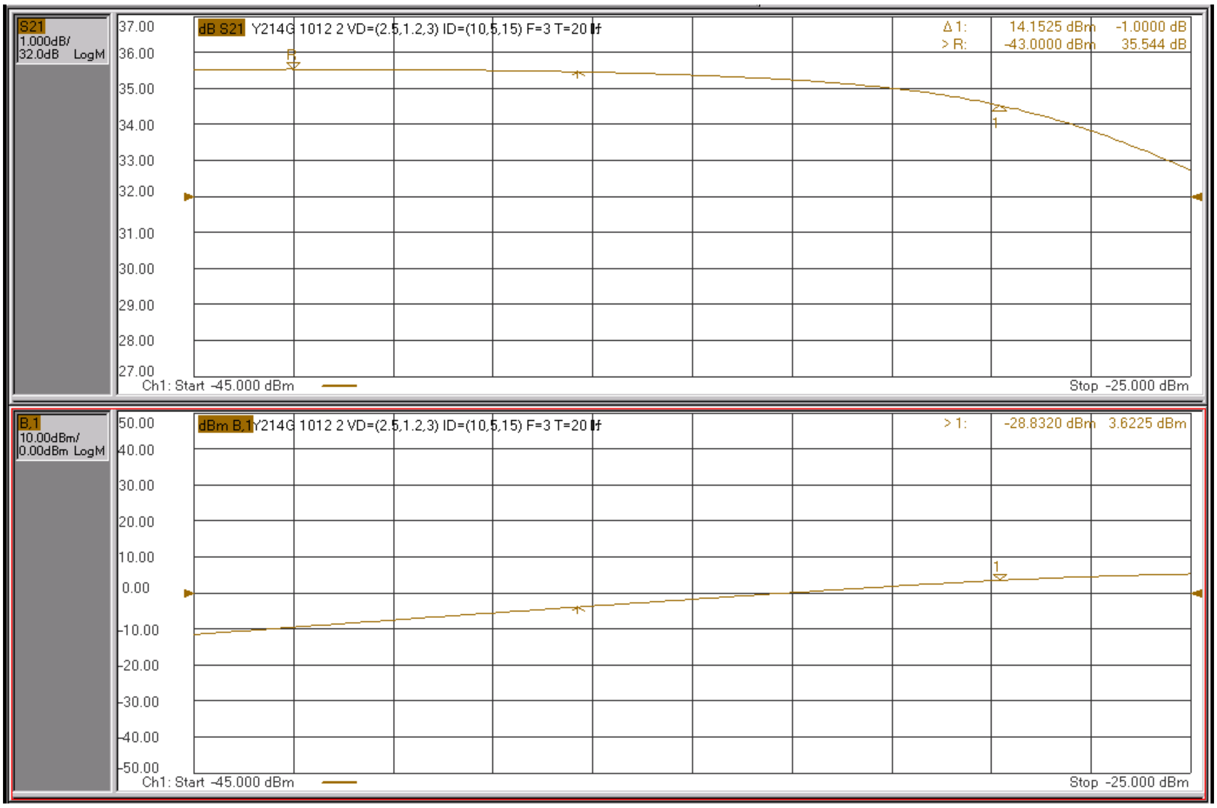
|S22| (CX)
0
-5
-10
-15
-20
-25
-30
-35
-40
0
2
4
6
8
10
12
14
16
18
20


S21
1.000dB/
32.0dB LogM
dB S21 Y214G 1012 2 VD=(2.5,1.2,3) ID=(10,5,15) F=3 T=20 If
Δ 1: 14.1525 dBm -1.0000 dB
> R: -43.0000 dBm 35.544 dB
37.00
36.00
35.00
34.00
33.00
32.00
31.00
30.00
29.00
28.00
27.00
Ch1: Start -45.000 dBm
Stop -25.000 dBm
B,1
10.00dBm/
0.00dBm LogM
dBm B,1 Y214G 1012 2 VD=(2.5,1.2,3) ID=(10,5,15) F=3 T=20 If
> 1: -28.8320 dBm 3.6225 dBm
50.00
40.00
30.00
20.00
10.00
0.00
-10.00
-20.00
-30.00
-40.00
-50.00
Ch1: Start -45.000 dBm
Stop -25.000 dBm

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	V_{d3} = 3.0	I_{d3} = 15.0	V_{g3} = -0.17

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MEASUREMENTS	AVERAGE NOISE TEMP:	62.3	50.5	57.5
	AVERAGE GAIN:	30.9	31.7	30.8
	MIN. INPUT RETURN LOSS:	-1.7	-1.7	-5.1
	MIN. OUTPUT RETURN LOSS:	-19.1	-19.1	-19.8

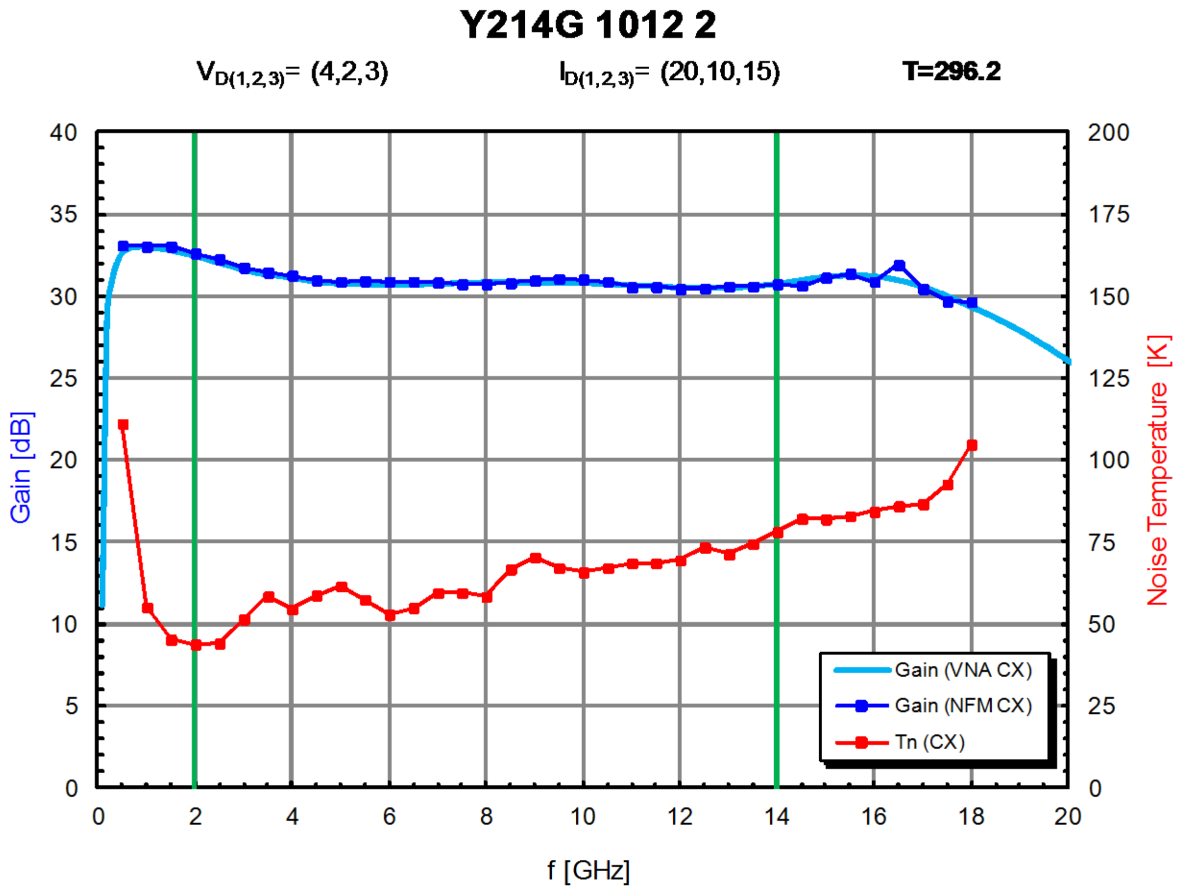
CRYOGENIC TEMPERATURE DATA T = 13.9

OPTIMUM P1dB BIAS	V_{d1} = 2.50	I_{d1} = 10.0	V_{g1} = 0.03
	V_{d2} = 1.20	I_{d2} = 5.0	V_{g2} = -0.14
(P_{diss} = 111.00 mW)	V_{d3} = 4.00	I_{d3} = 20.0	V_{g3} = -0.1

	FREQUENCY BAND:	2-14	2-4	4-8
MEASUREMENTS	AVERAGE NOISE TEMP:	6.3	5.5	5.9
	MIN. - MAX. NOISE TEMP:	5.3-7.3	5.3-5.8	5.5-6.5
	AVERAGE GAIN:	34.7	35.5	34.7
	GAIN SPAN FULL BAND / 2 GHz:	2.2 / 1.1	1.1 / 1.1	0.4 / 1.1
	MIN. INPUT RETURN LOSS:	-1.5	-1.5	-4.5
	MIN. OUTPUT RETURN LOSS:	-16.6	-16.6	-19.6
	MIN. IN. POWER 1dB COMPR::	-29.6		

REMARKS: Gain data from VNA measurements
Coaxial noise measurements according to cold att. method

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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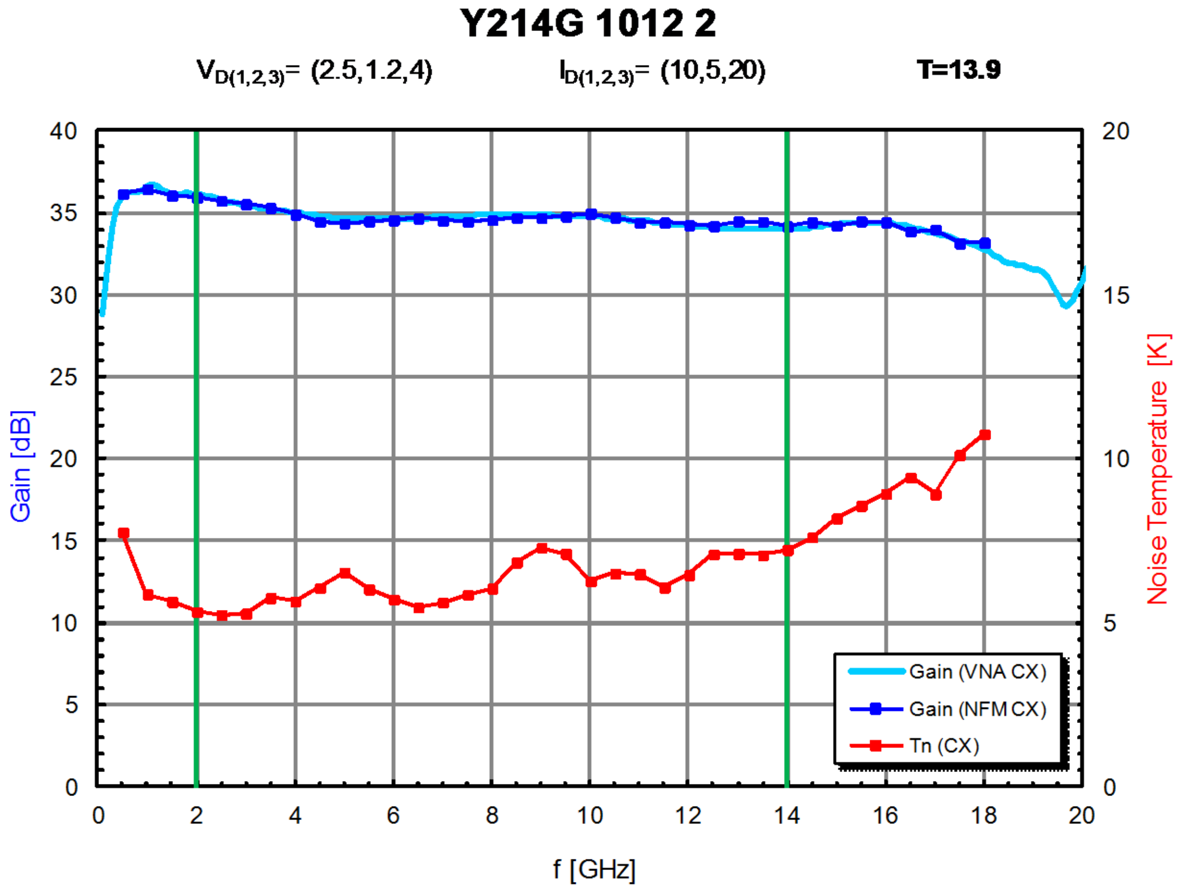
VD(1,2,3)= (4,2,3)
ID(1,2,3)= (20,10,15)
T=296.2
Gain [dB]
Noise Temperature [K]
f [GHz]
Gain (VNA CX)
Gain (NFM CX)
Tn (CX)



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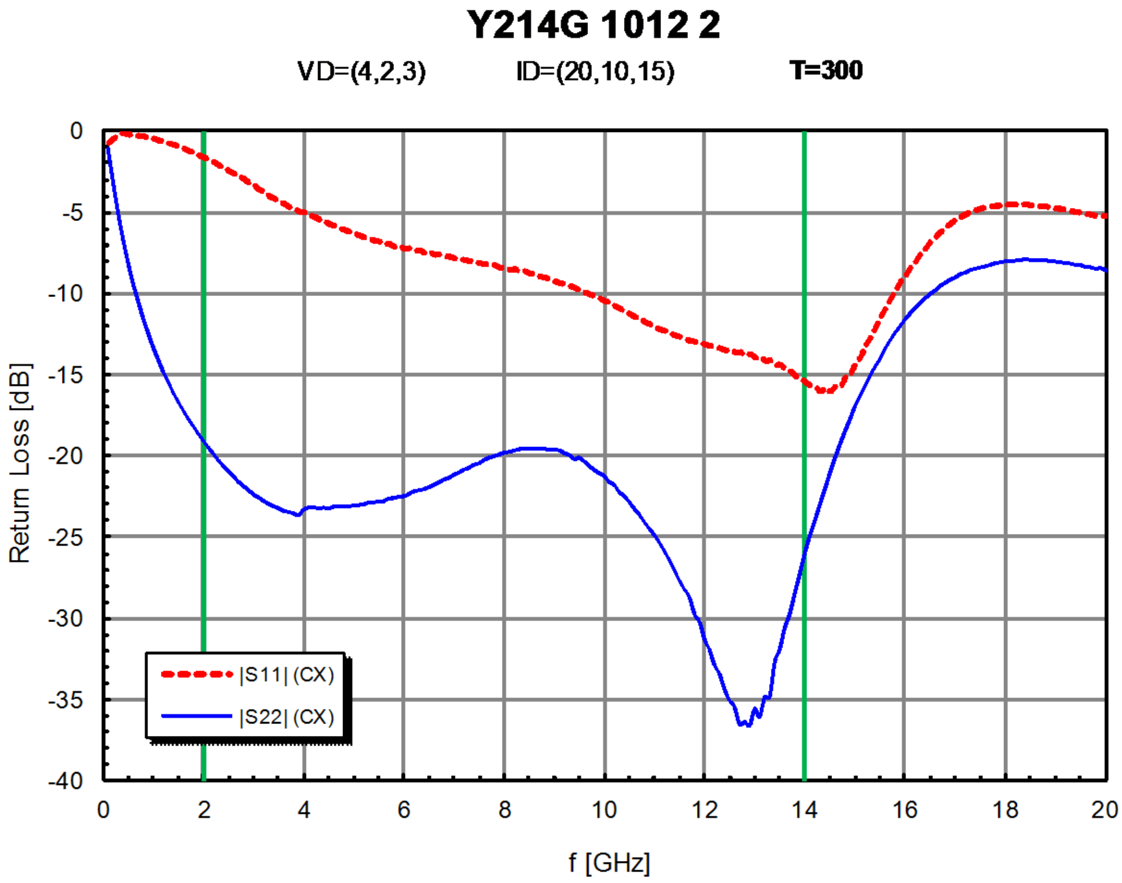
VD(1,2,3)= (2.5,1.2,4)
ID(1,2,3)= (10,5,20)
T=13.9
Gain [dB]
Noise Temperature [K]
f [GHz]
Gain (VNA CX)
Gain (NFM CX)
Tn (CX)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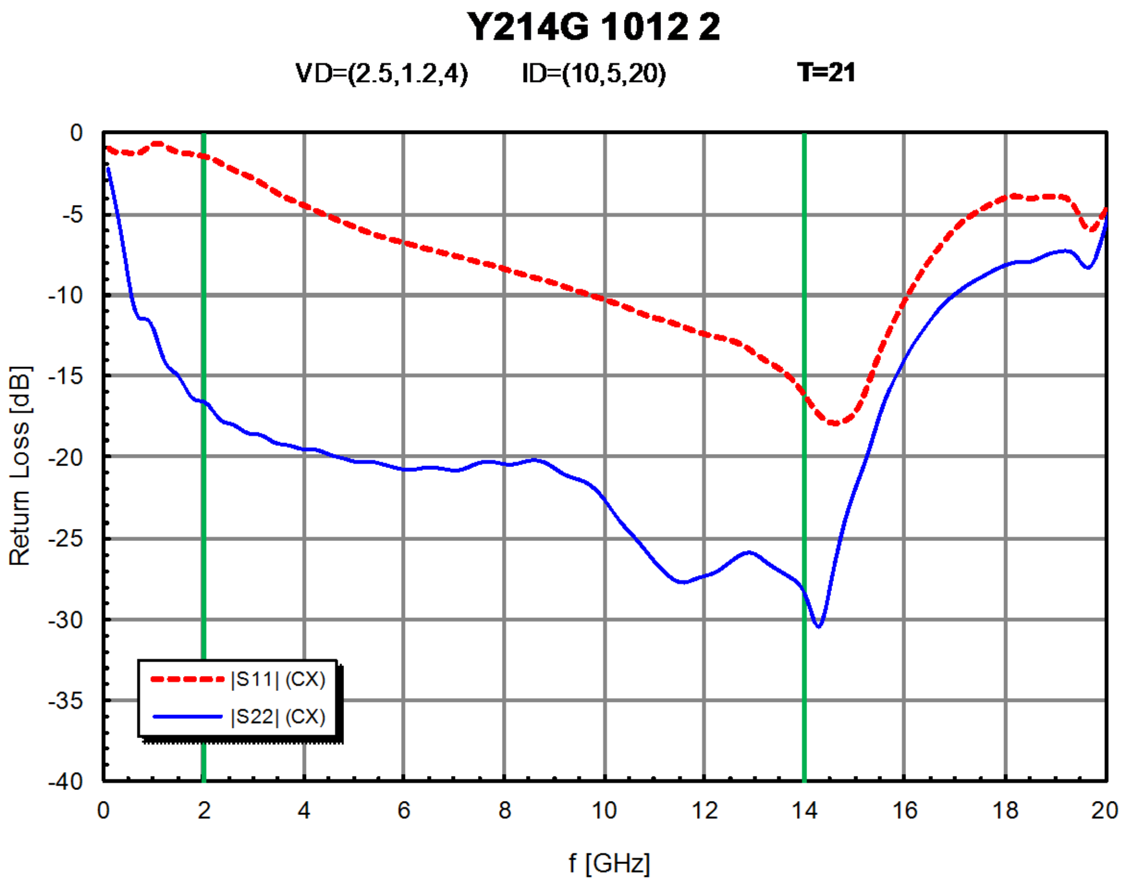
ID=(20,10,15)
T=300
Return Loss [dB]
f [GHz]
|S11| (CX)
|S22| (CX)
0
-5
-10
-15
-20
-25
-30
-35
-40
0
2
4
6
8
10
12
14
16
18
20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ID=(10,5,20)
T=21
Return Loss [dB]
f [GHz]
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|S22| (CX)
0
-5
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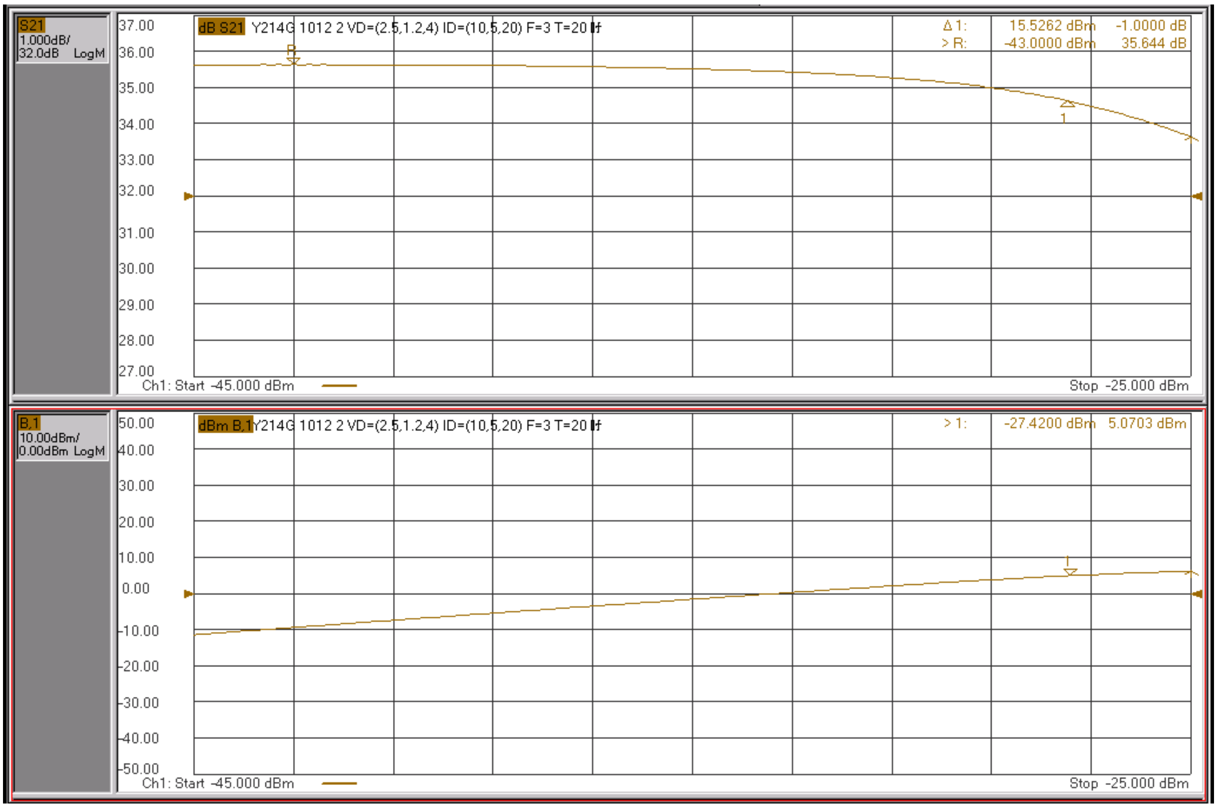
S21
1.000dB/
32.0dB LogM
dB S21 Y214G 1012 2 VD=(2.5,1.2,4) ID=(10,5,20) F=3 T=20 K
Δ 1: 15.5262 dBm -1.0000 dB
> R: -43.0000 dBm 35.644 dB
Ch1: Start -45.000 dBm
Stop -25.000 dBm
B,1
10.00dBm/
0.00dBm LogM
dBm B,1 Y214G 1012 2 VD=(2.5,1.2,4) ID=(10,5,20) F=3 T=20 K
> 1: -27.4200 dBm 5.0703 dBm
Ch1: Start -45.000 dBm
Stop -25.000 dBm

ESD AND POWER SUPPLY LEAKAGE PROTECTION OF CRYOGENIC HEMT AMPLIFIERS

Introduction

Cryogenic amplifiers made with InP, InAs and metamorphic GaAs 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 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. 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 ($> 10\ M\Omega$) 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.