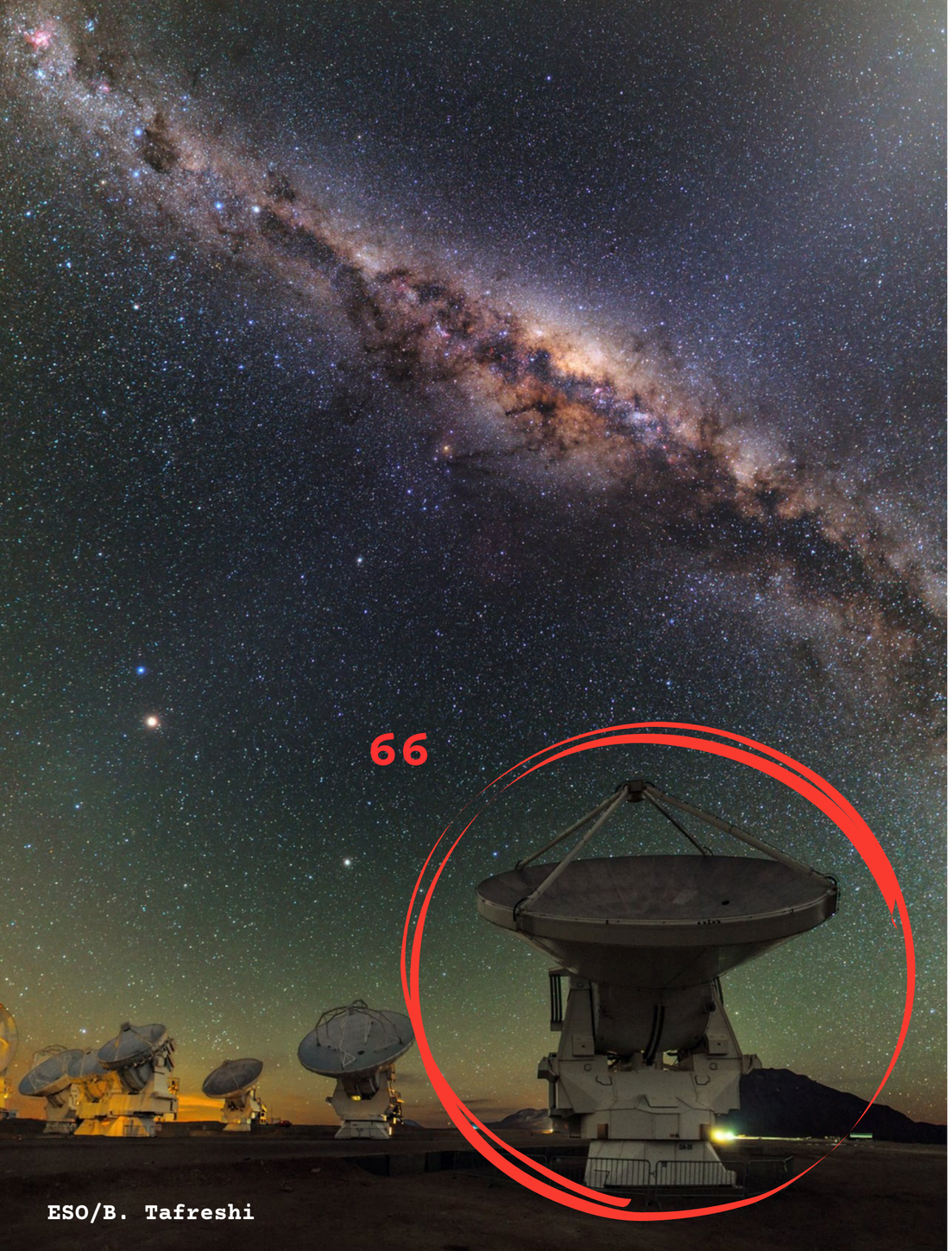
ALMA Band 2 - Testing and characterization of Low Noise Amplifiers

A.E. Camisasca, P. Yagoubov,
+ ECOGAL group

ESO/B. Tafreshi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ESO/B. Tafreshi


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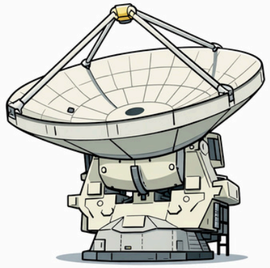
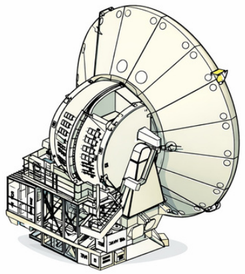
ESO/B. Tafreshi



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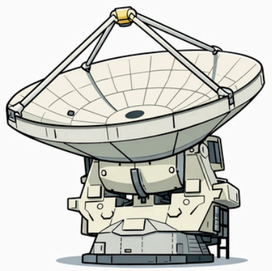

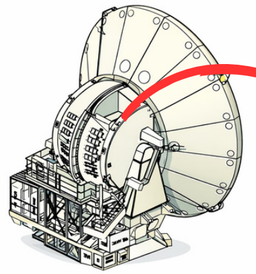


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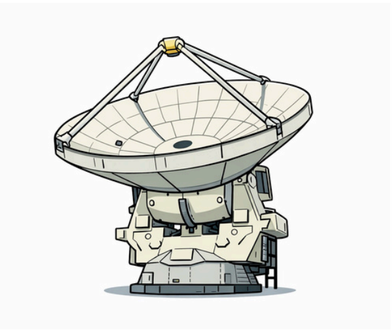
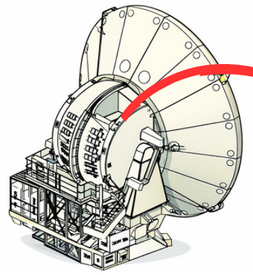
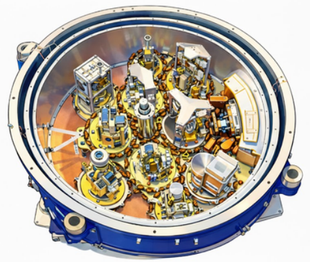
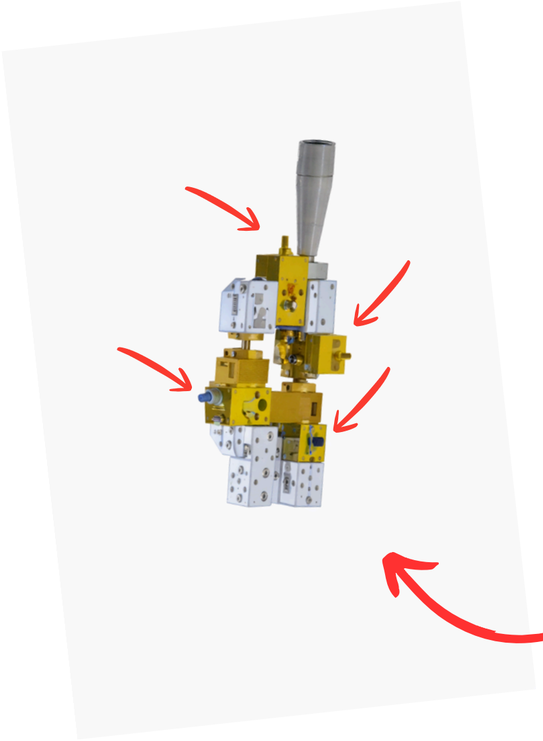
ESO/B. Tafreshi







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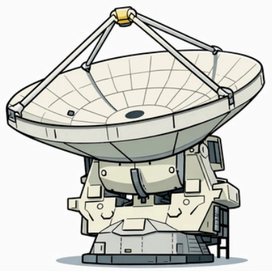
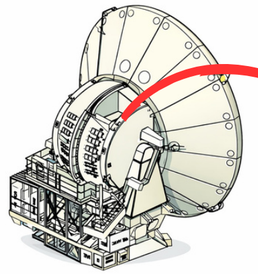
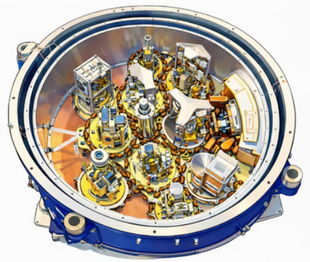
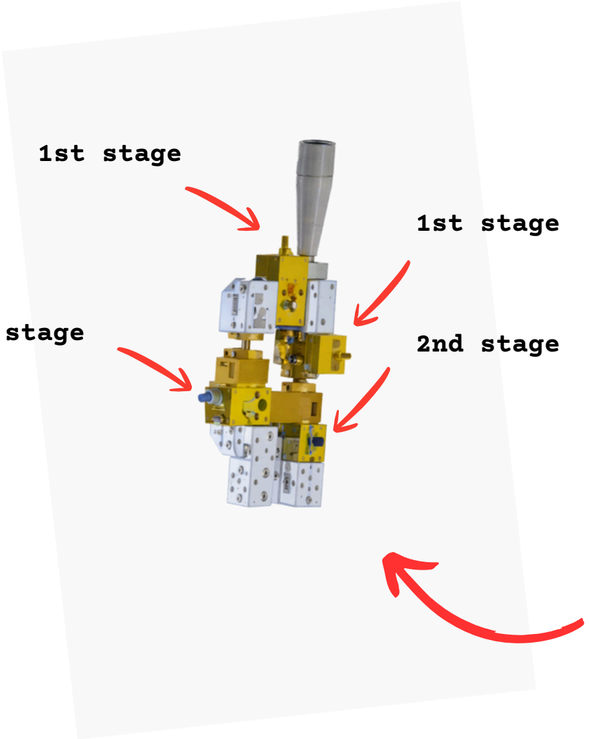
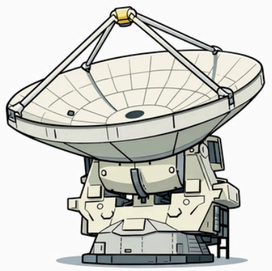


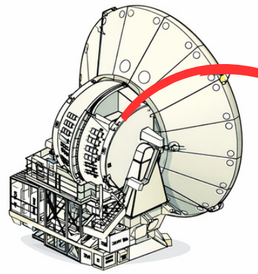




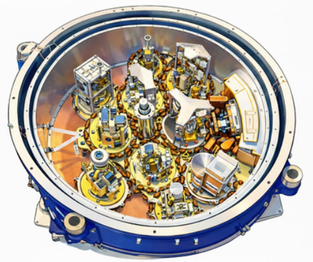

1st stage
1st stage
2nd stage
2nd stage

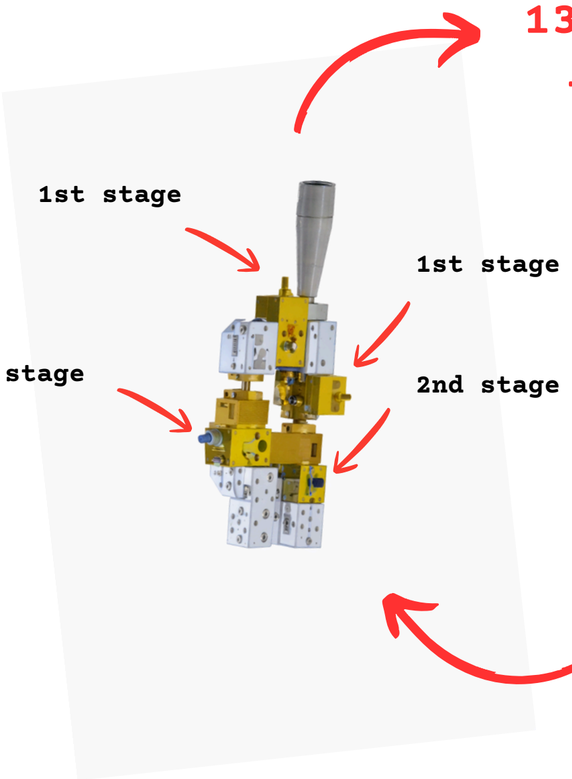
ESO/B. Tafreshi



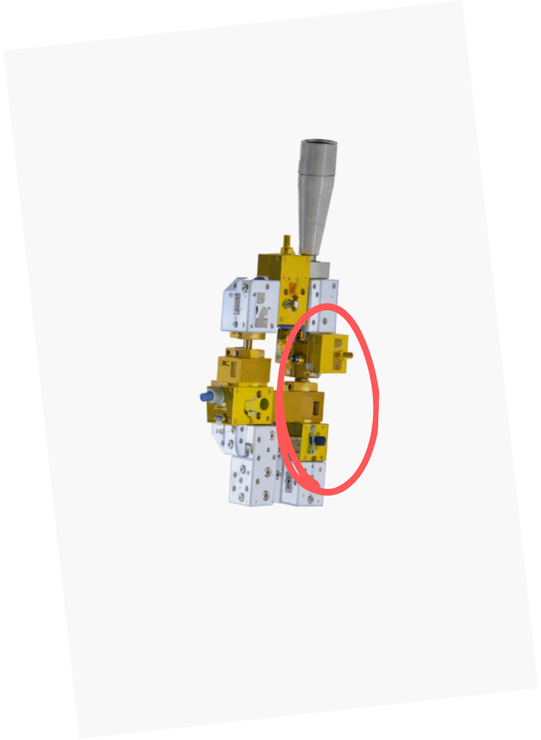


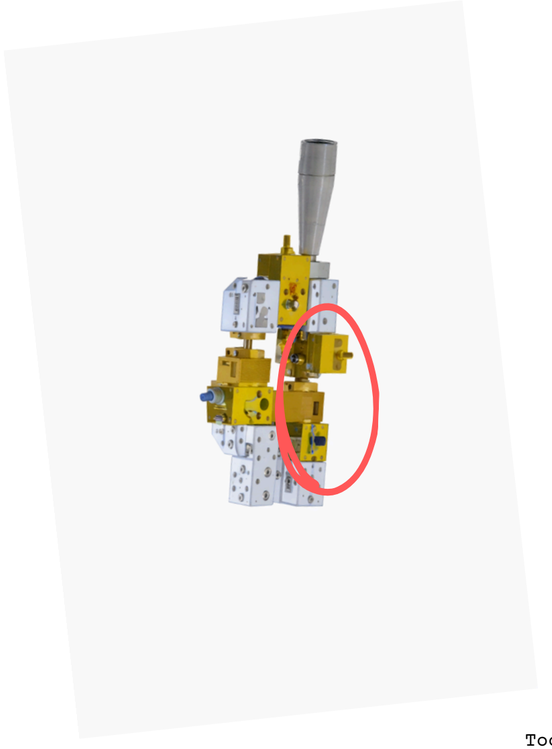
132 chains,
+ spares





Illustrations: ESO/AEM Consortium;
Pictures: X. M. Jubier, S. Otarola, ALMA(ESO/NAOJ/NRAO)



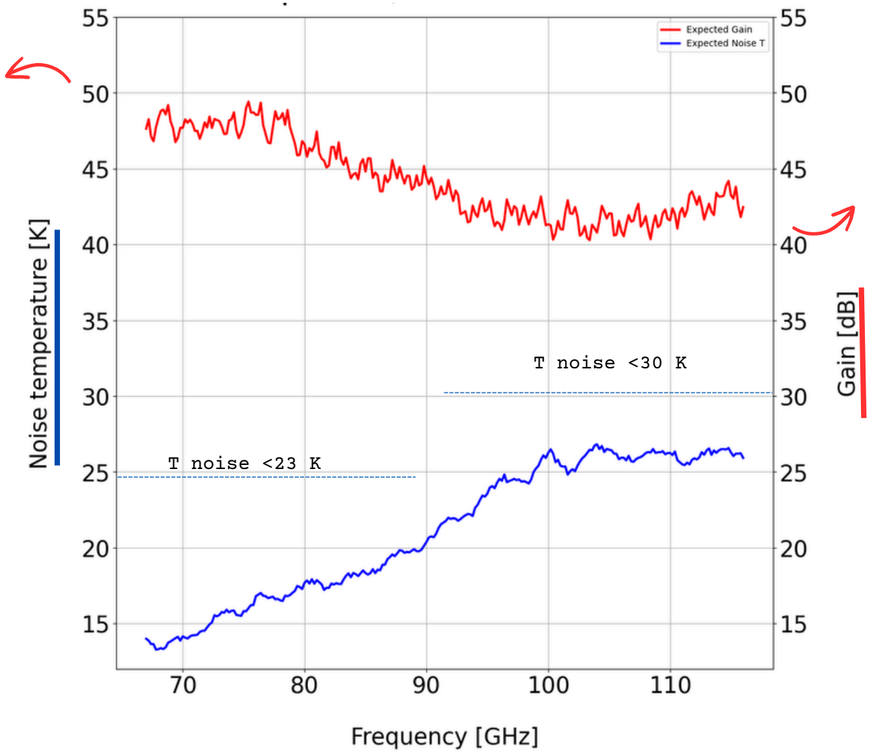


Specification	Value
Bandwidth	67–116 GHz
Noise temperature (67–90 GHz)	< 23 K
Noise temperature (90–116 GHz)	< 30 K
Input reflection	< -6 dB
Output reflection	< -10 dB
Gain	> 40 dB
Nominal operating temperature	15 K

P. Yagoubov et al., 2019

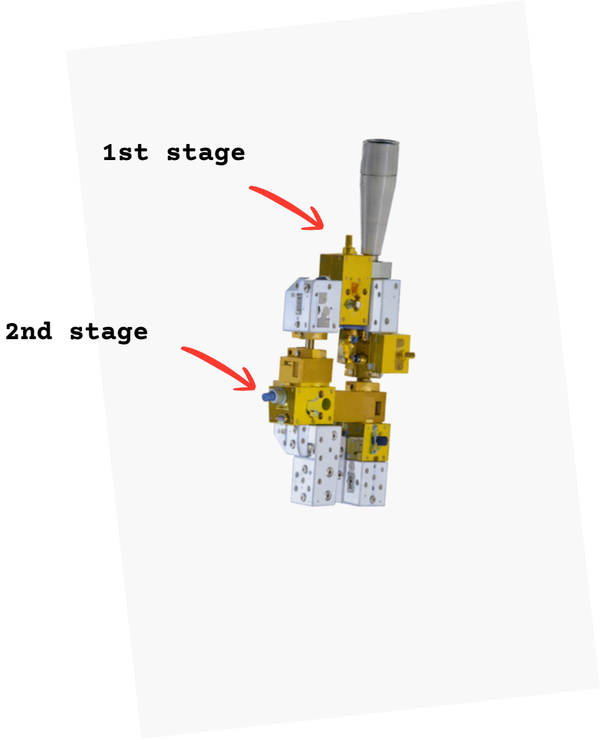
Too high G can give WCA saturation.

Specification:
G < 50 dB



lower gain is not sufficient for good detections.

Specification:
G > 40 dB



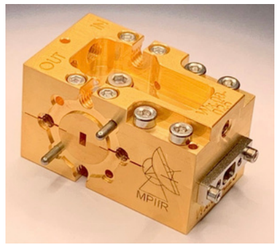
Band 2 Cryogenic 1st-2nd Stage RF Low Noise Amplifier Technical Specifications - ESO

	1st stage	**2nd stage**
$T_{\text{operating}}$	10–18 K	10–18 K
Frequency	67–116 GHz	67–116 GHz
Gain	24–27 dB	21–24 dB
Noise Temperature:		
- 67 GHz $\leq f <$ 90 GHz		
80% frequency range	$T_{\text{noise}} < 22$ K	$T_{\text{noise}} < 35$ K
100% frequency range	$T_{\text{noise}} < 25$ K	$T_{\text{noise}} < 40$ K
- 90 GHz $\leq f <$ 116 GHz		
80% frequency range	$T_{\text{noise}} < 28$ K	$T_{\text{noise}} < 45$ K
100% frequency range	$T_{\text{noise}} < 32$ K	$T_{\text{noise}} < 50$ K
# Bias stages	3	3
m	< 78 g	< 35 g

Band 2 Cryogenic 1st-2nd Stage RF Low Noise Amplifier Technical Specifications - ESO

Developed by the Max-Planck-Institute for Radio Astronomy (MPIfR) and the Fraunhofer Institute for Applied Solid-State Physics (IAF), Germany

1st stage



Bias stages = 4

m < 71 g

	1st stage	**2nd stage**
$T_{\text{operating}}$	10–18 K	10–18 K
Frequency	67–116 GHz	67–116 GHz
Gain	24–27 dB	21–24 dB
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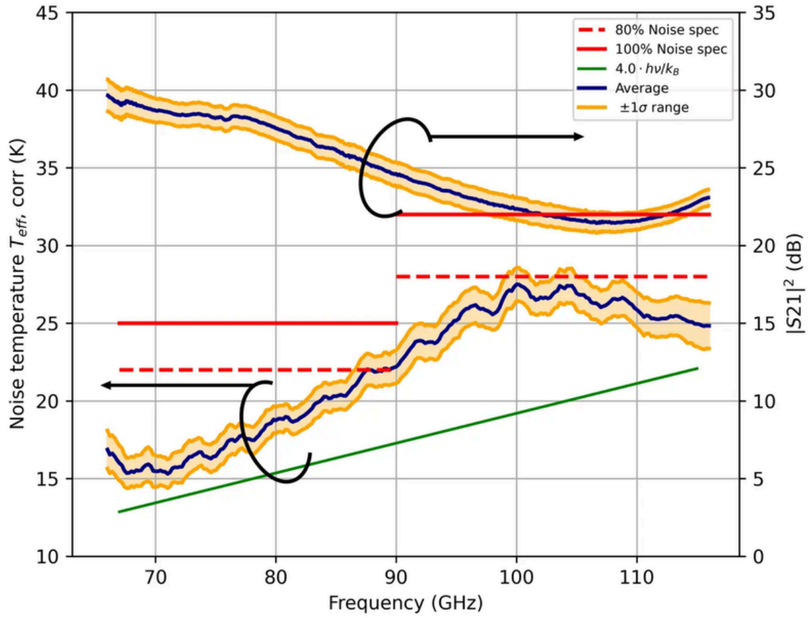
# Bias stages	3	3
m	< 78 g	< 35 g



LNA measured at T = 15 K. The data is averaged for 90 LNA qualified and delivered to ESO. © MPIfR

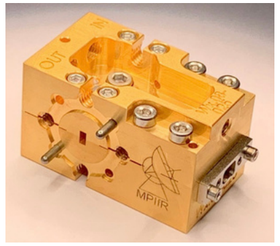
https://www.mpifr-bonn.mpg.de/technology/electronics/projects/almaband2lna

Band 2 Cryogenic 1st-2nd Stage RF Low Noise Amplifier Technical Specifications - ESO

	1st stage	2nd stage
$T_{operating}$	10–18 K	10–18 K
Frequency	67–116 GHz	67–116 GHz
Gain	24–27 dB	21–24 dB
Noise Temperature:		
- 67 GHz $\leq f <$ 90 GHz		
80% frequency range	$T_{noise} < 22$ K	$T_{noise} < 35$ K
100% frequency range	$T_{noise} < 25$ K	$T_{noise} < 40$ K
- 90 GHz $\leq f <$ 116 GHz		
80% frequency range	$T_{noise} < 28$ K	$T_{noise} < 45$ K
100% frequency range	$T_{noise} < 32$ K	$T_{noise} < 50$ K
# Bias stages	3	3
m	< 78 g	< 35 g

1st stage

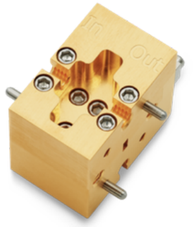
Developed by the Max-Planck-Institute for Radio Astronomy (MPIfR) and the Fraunhofer Institute for Applied Solid-State Physics (IAF), Germany



Bias stages = 4

m < 71 g

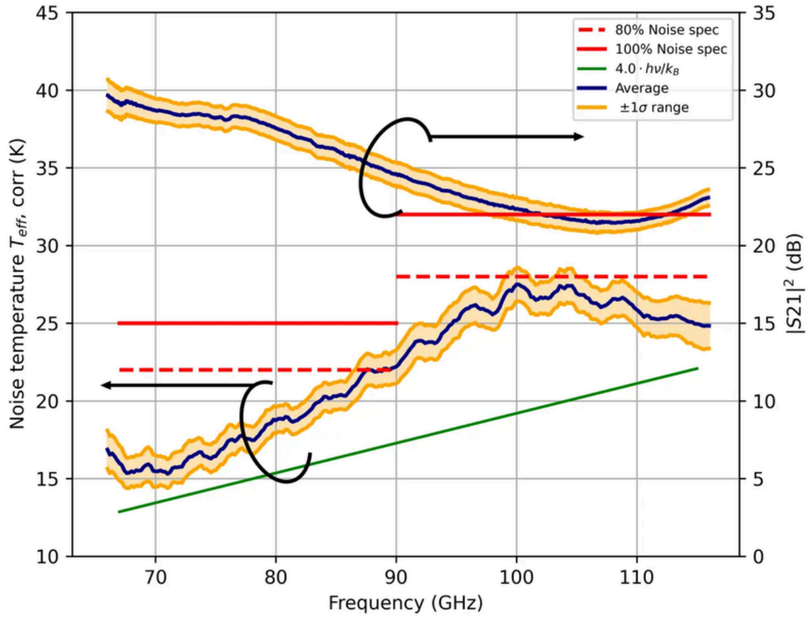
2nd stage



Developed by the Low Noise Factory AB, Göteborg, Sweden

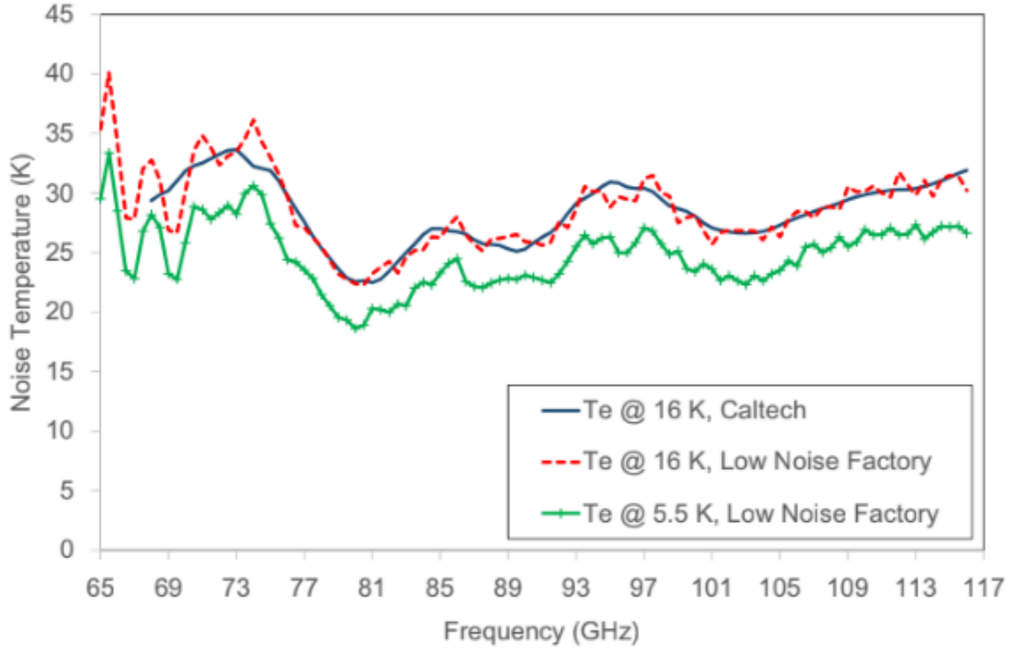
Bias stages = 4

m < 17 g



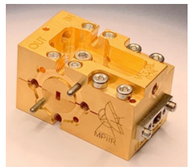
LNA measured at T = 15 K. The data is averaged for 90 LNA qualified and delivered to ESO. © MPIfR

https://www.mpifr-bonn.mpg.de/technology/electronics/projects/almaband2lna



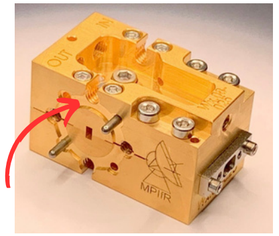
Y. Tang et al., 2017

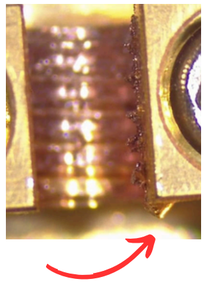
Goals:

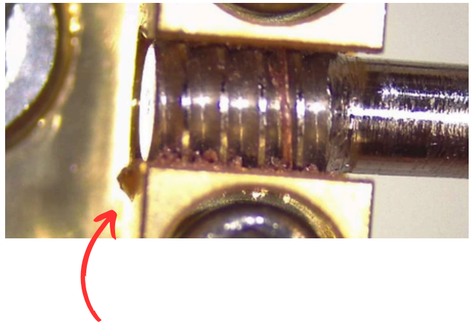
1. Coupling amplifiers  + 
2. Measuring amplifier-chains performances
3. Tuning amplifiers

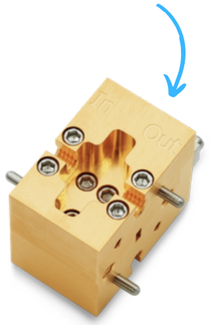
0 Visual inspection

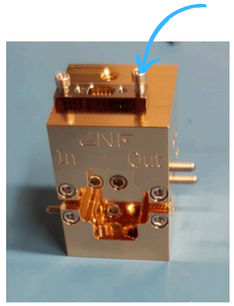
0 Visual inspection

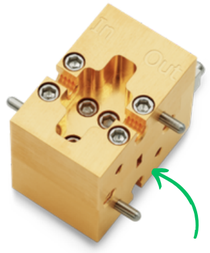


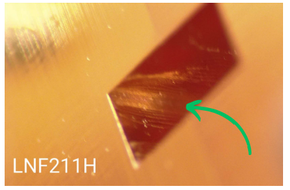


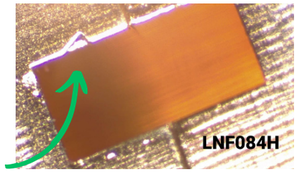






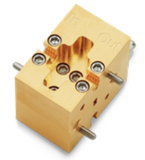




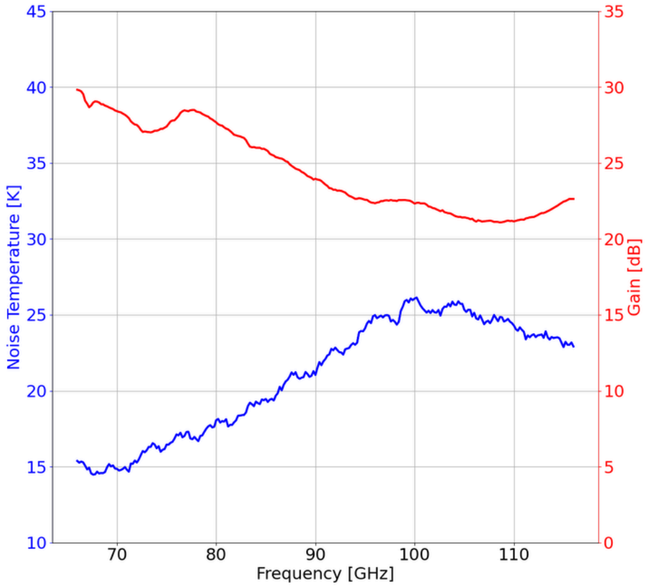


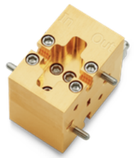
1 Coupling amplifiers

+

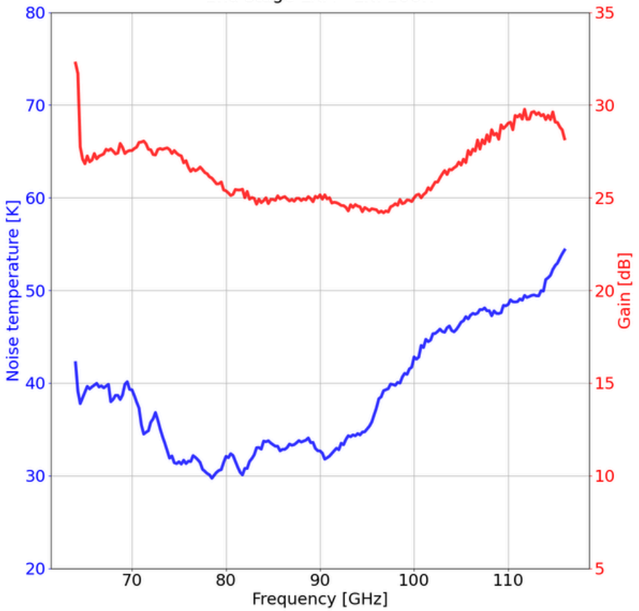


1st stage LNA - Wx.225

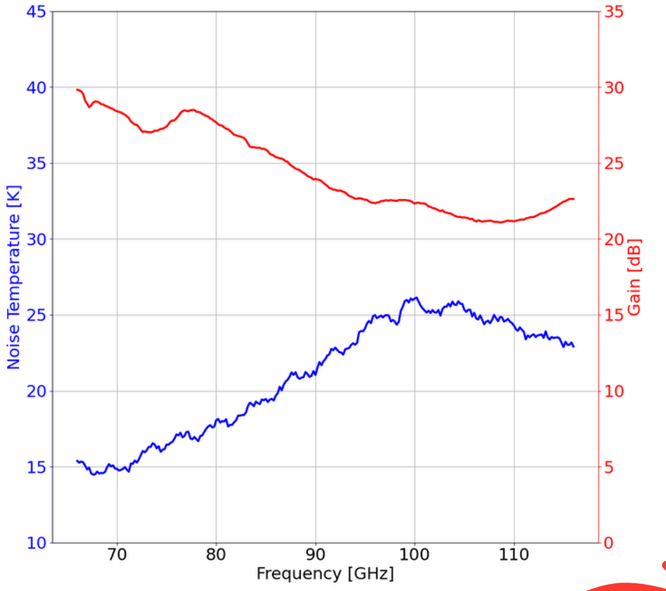




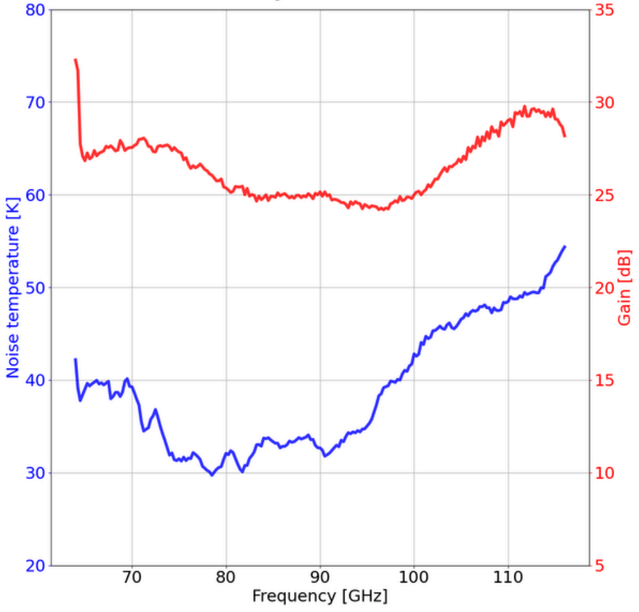
2nd stage LNA - LNF206H



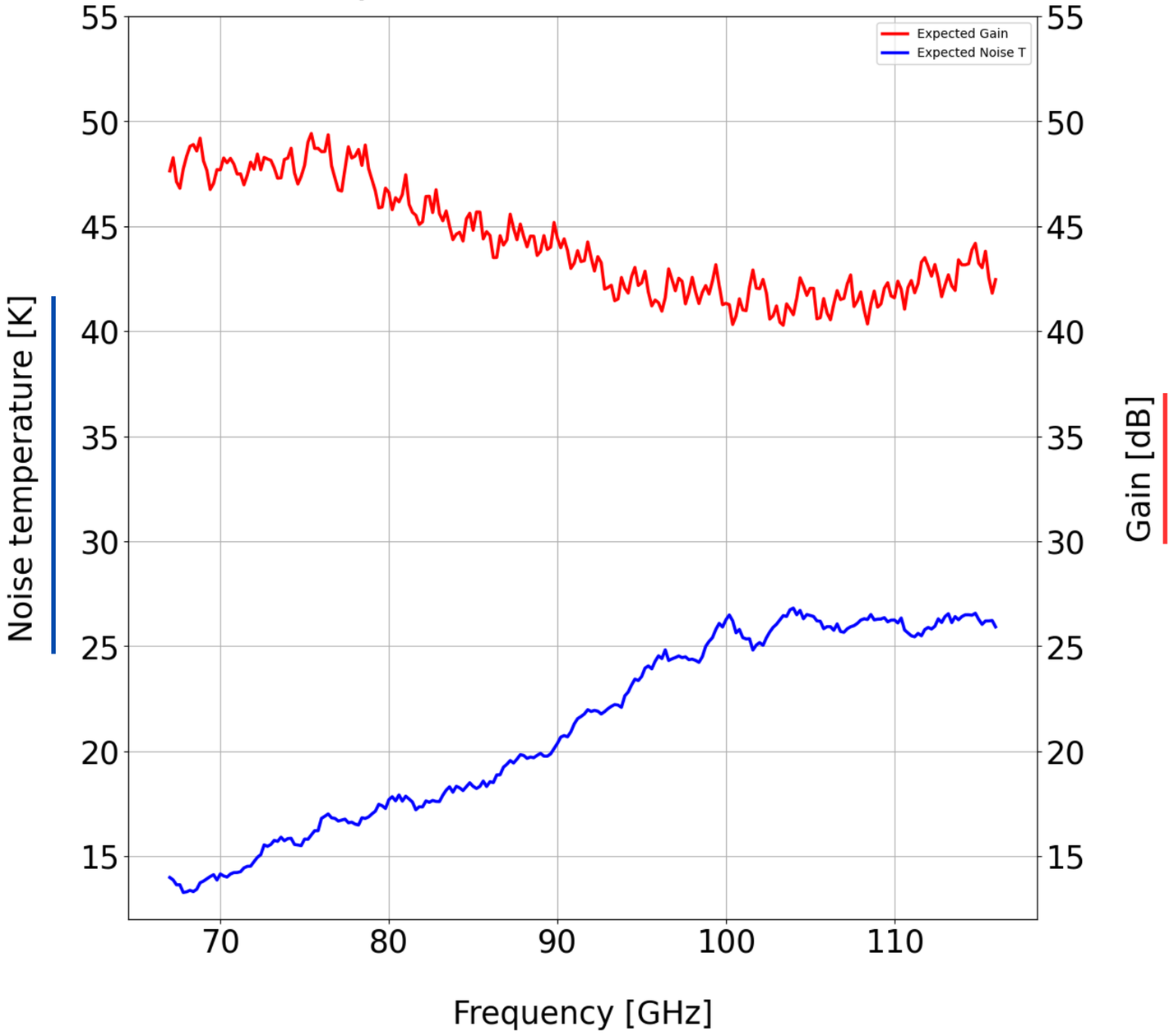
1st stage LNA - Wx.225

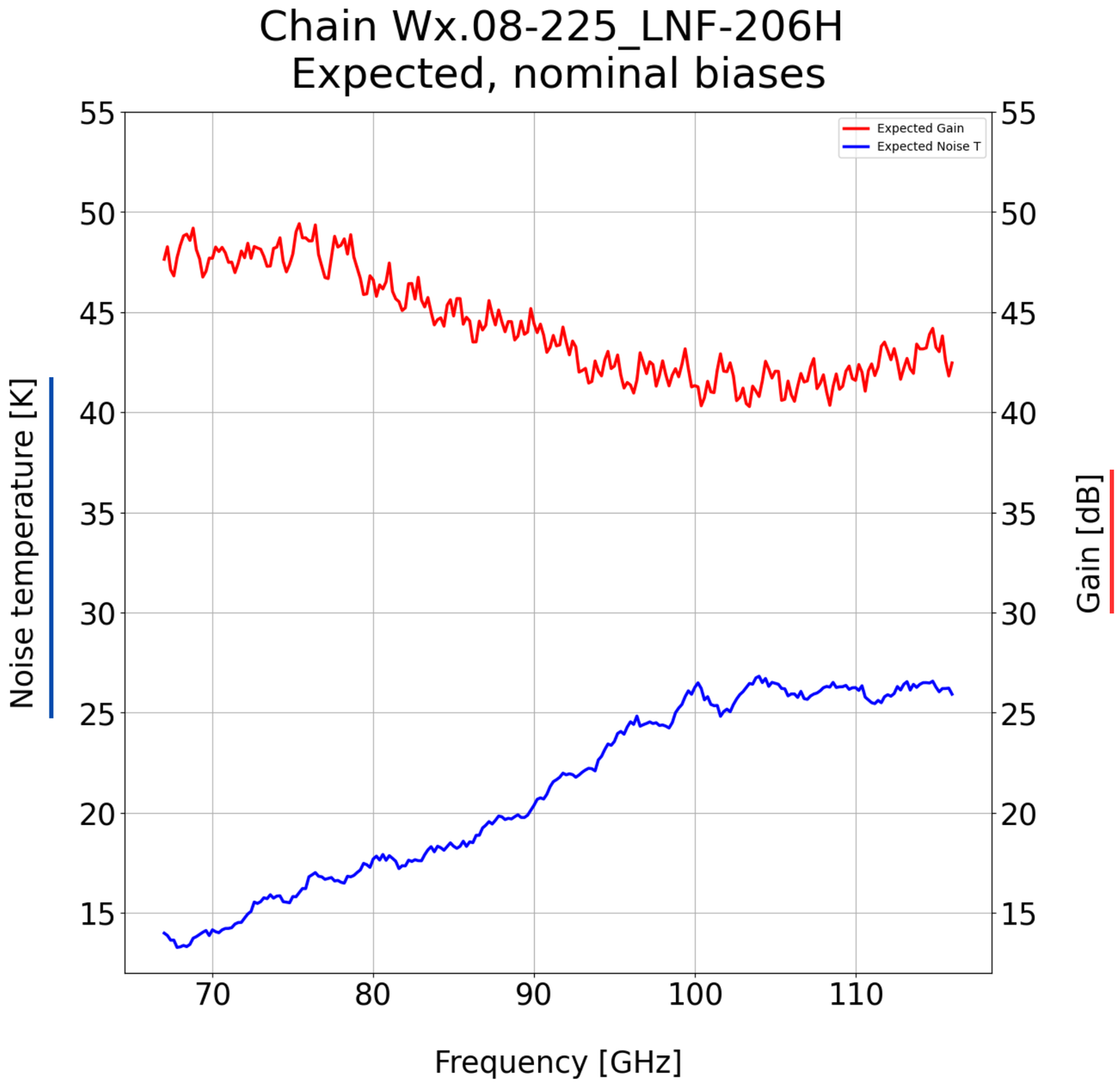


2nd stage LNA - LNF206H



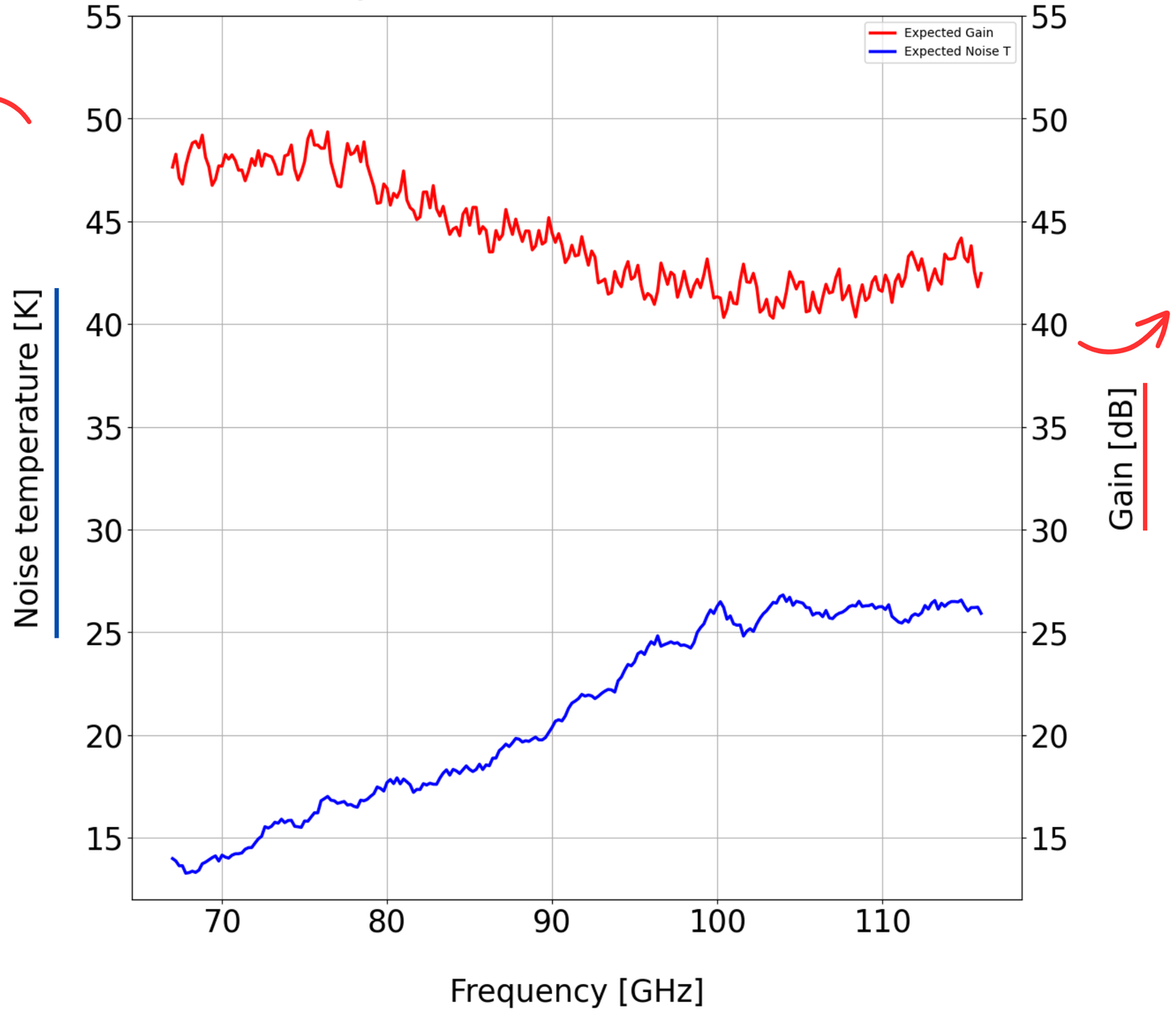
Chain Wx.08-225_LNF-206H
Expected, nominal biases




Chain Wx.08-225_LNF-206H
Expected, nominal biases
Expected Gain
Expected Noise T
Noise temperature [K]
Gain [dB]
Frequency [GHz]
55
50
45
40
35
30
25
20
15
70
80
90
100
110

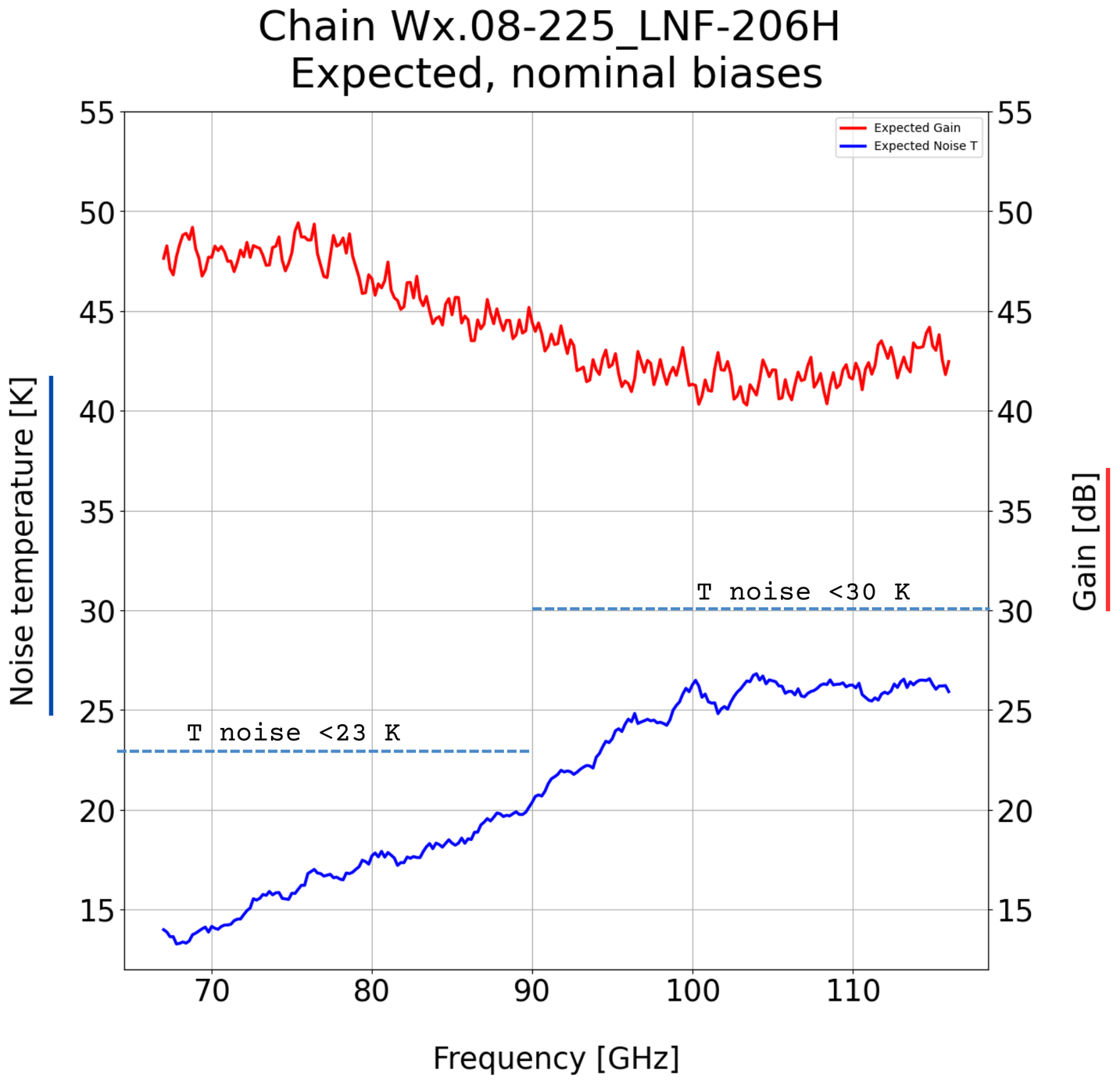
Too high G can give WCA saturation.

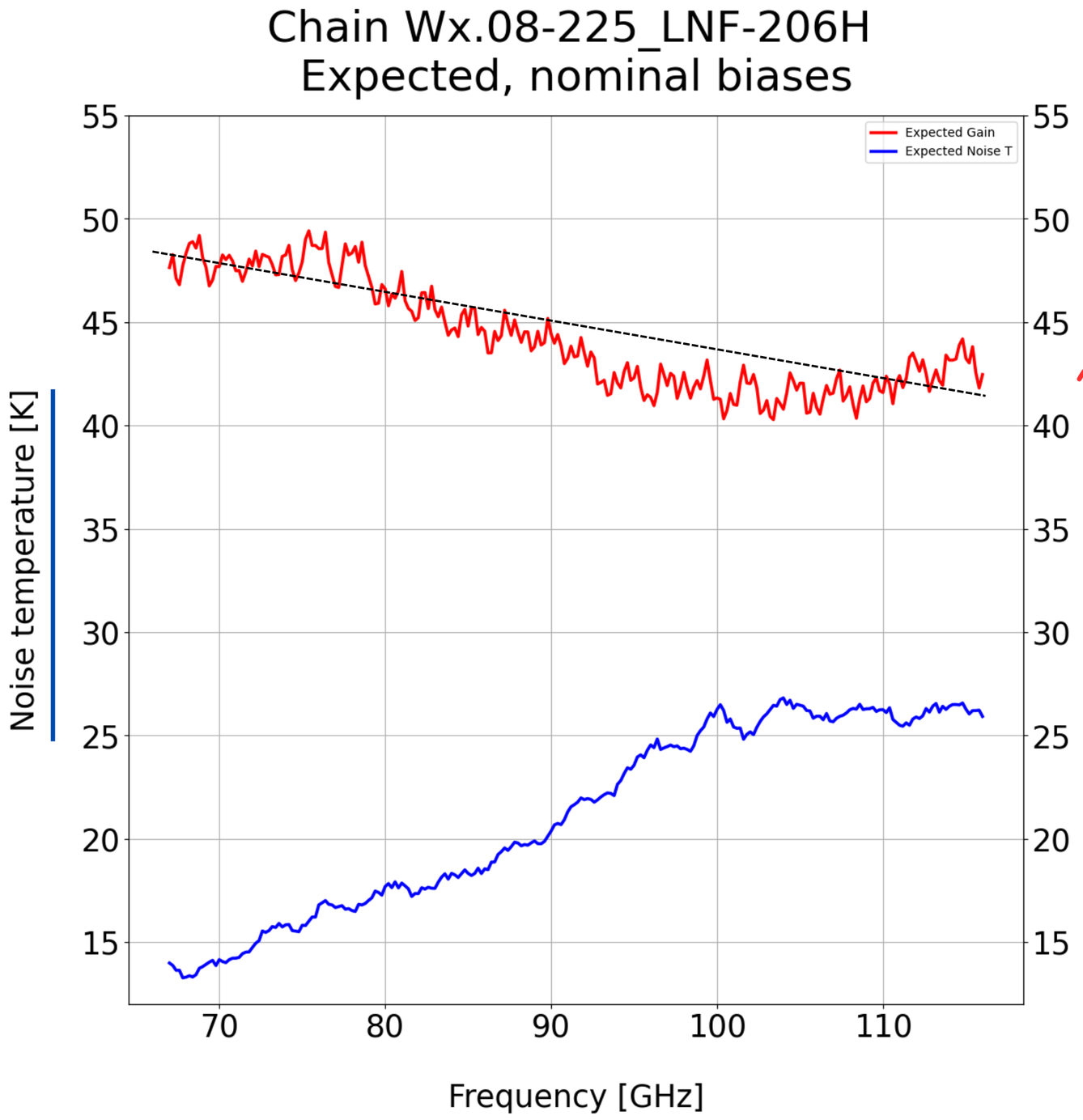
Specification:
G < 50 dB



lower gain is not sufficient for good detections.

Specification:
G > 40 dB

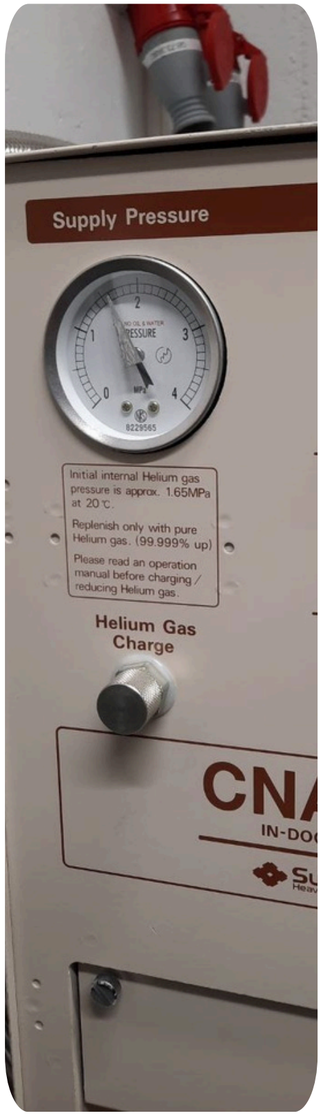

Chain Wx.08-225_LNF-206H
Expected, nominal biases
Expected Gain
Expected Noise T
T noise <30 K
T noise <23 K
Noise temperature [K]
Gain [dB]
Frequency [GHz]
55
50
45
40
35
30
25
20
15
70
80
90
100
110

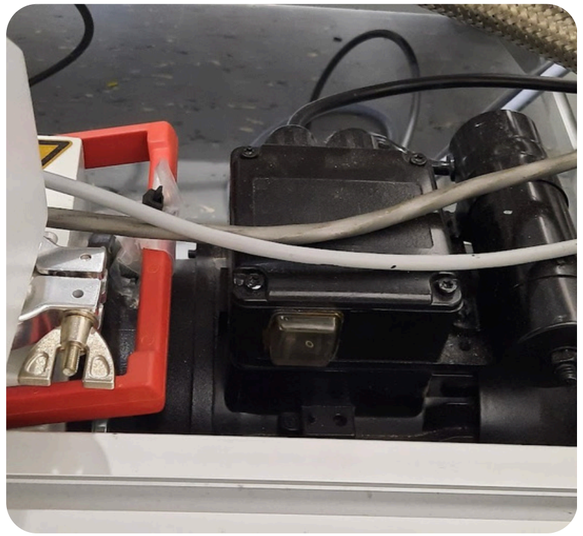


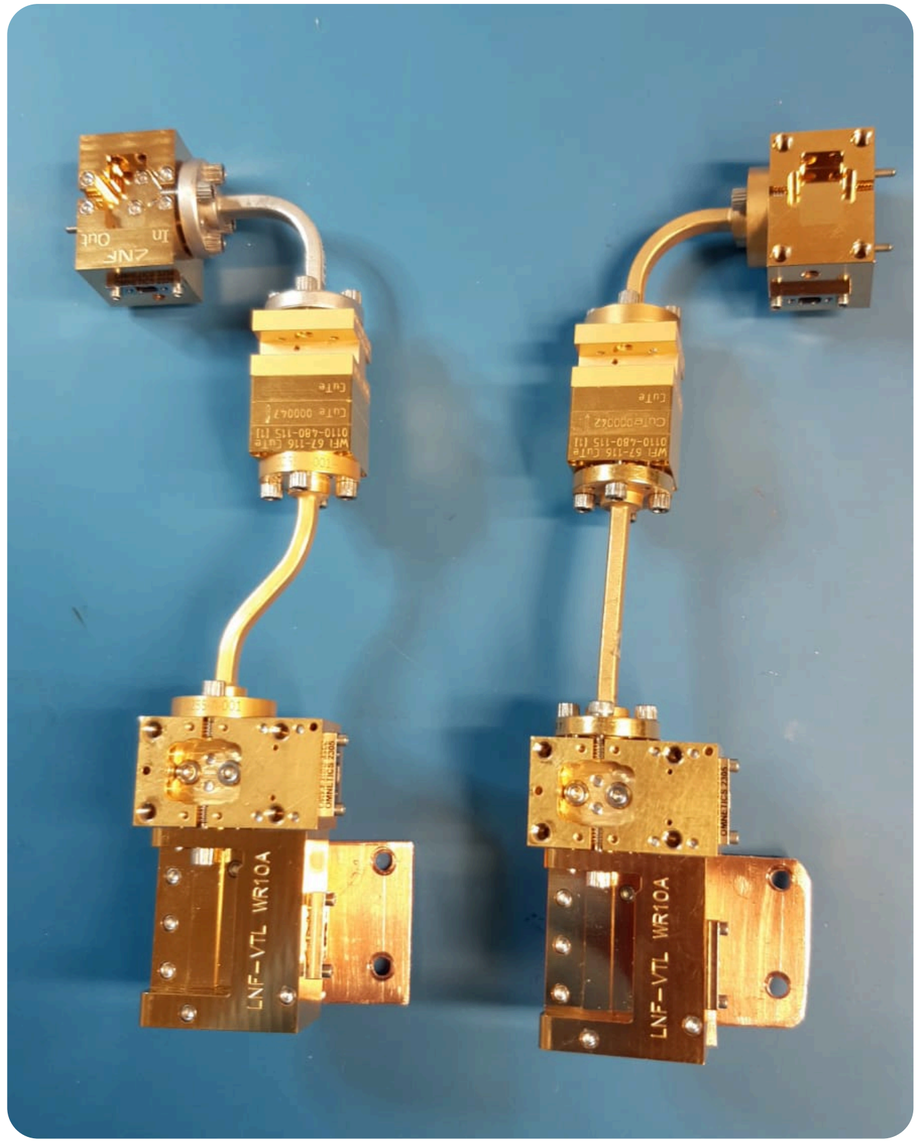
The goal is to achieve a gain that is as **linear** and **flat** as possible.

2 Measuring amplifier-chains performances

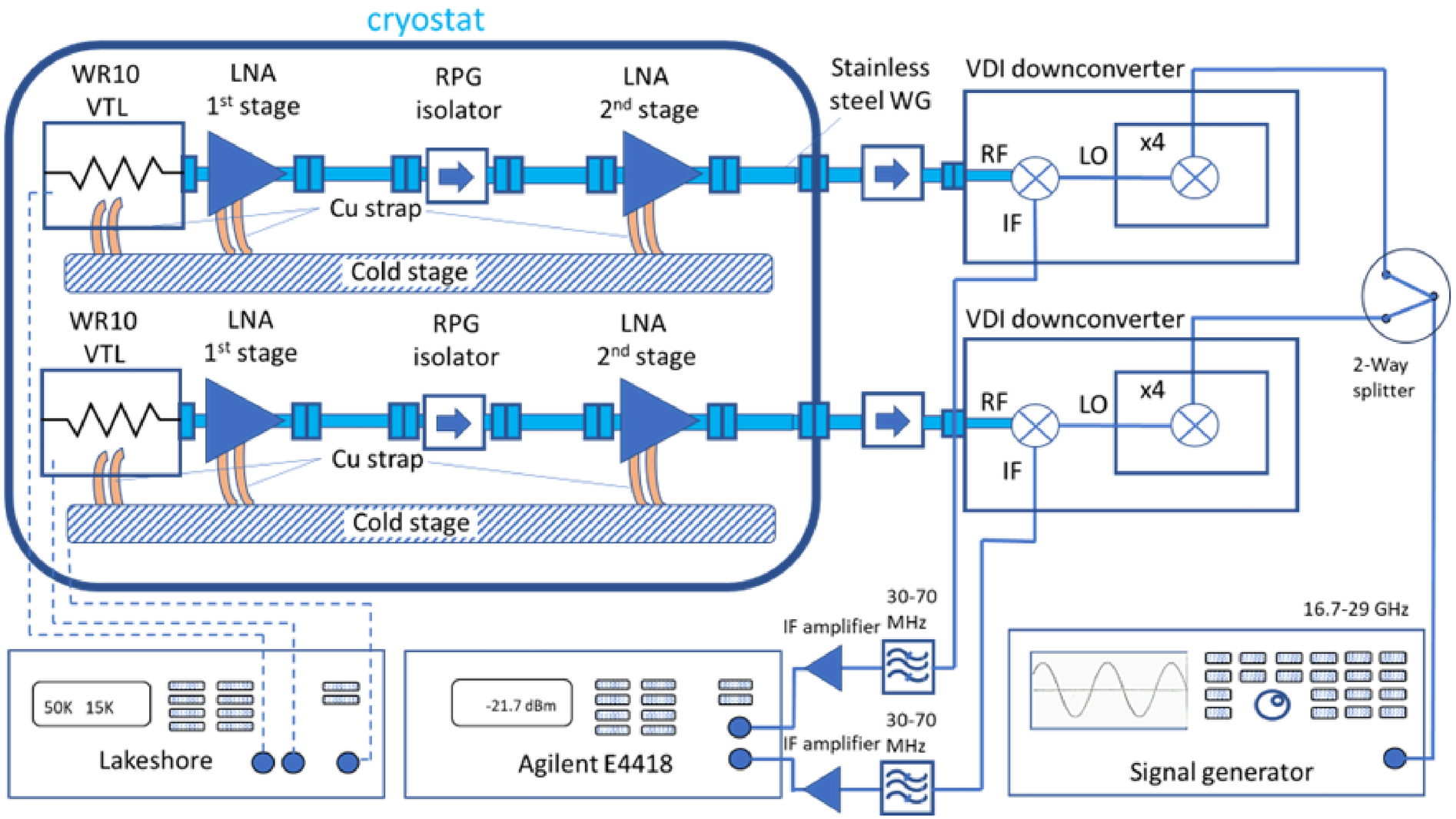
Test system, developed and installed at ESO, Garching, Germany



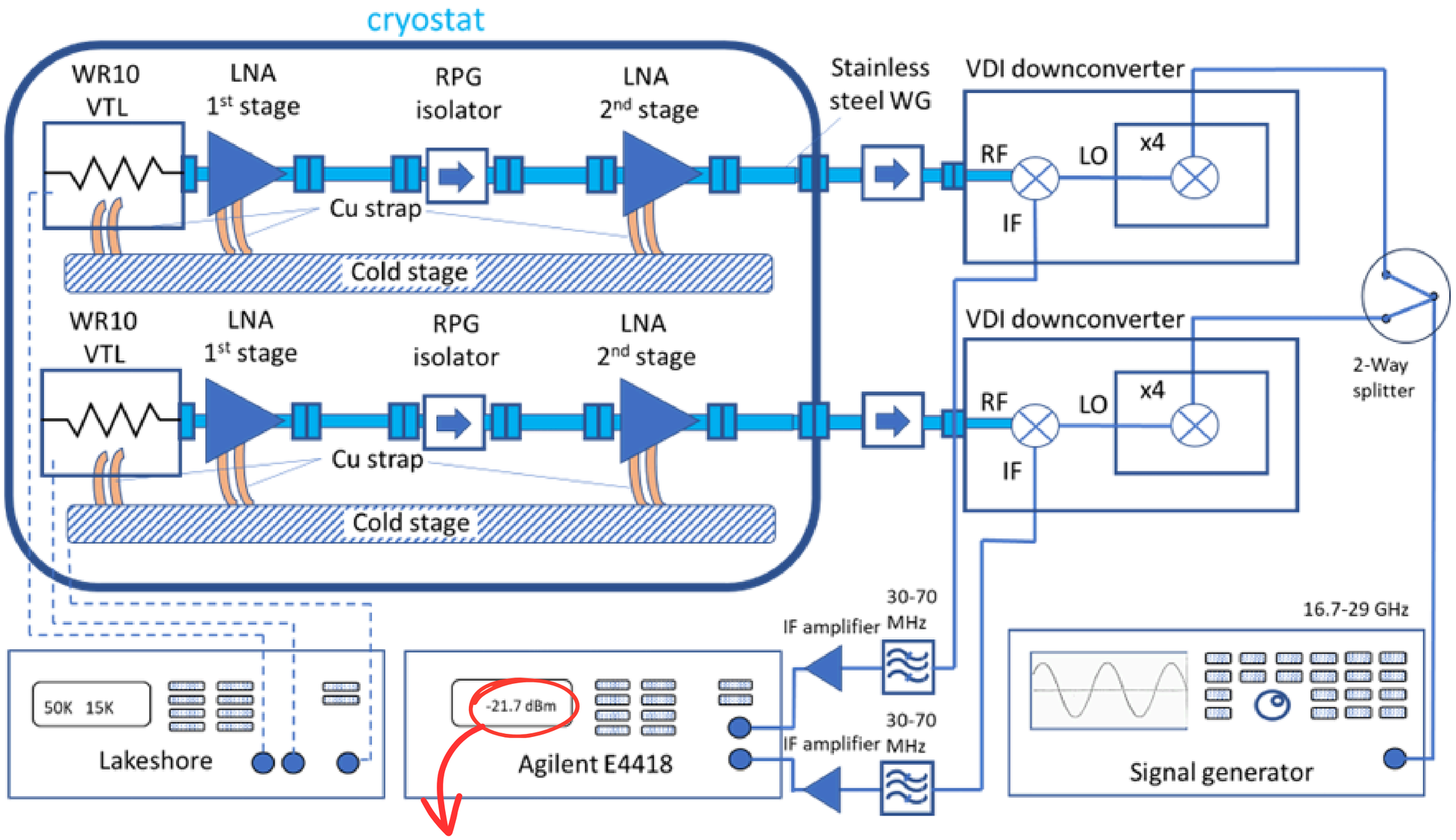




P. Yagoubov, LNA delivery report,2025

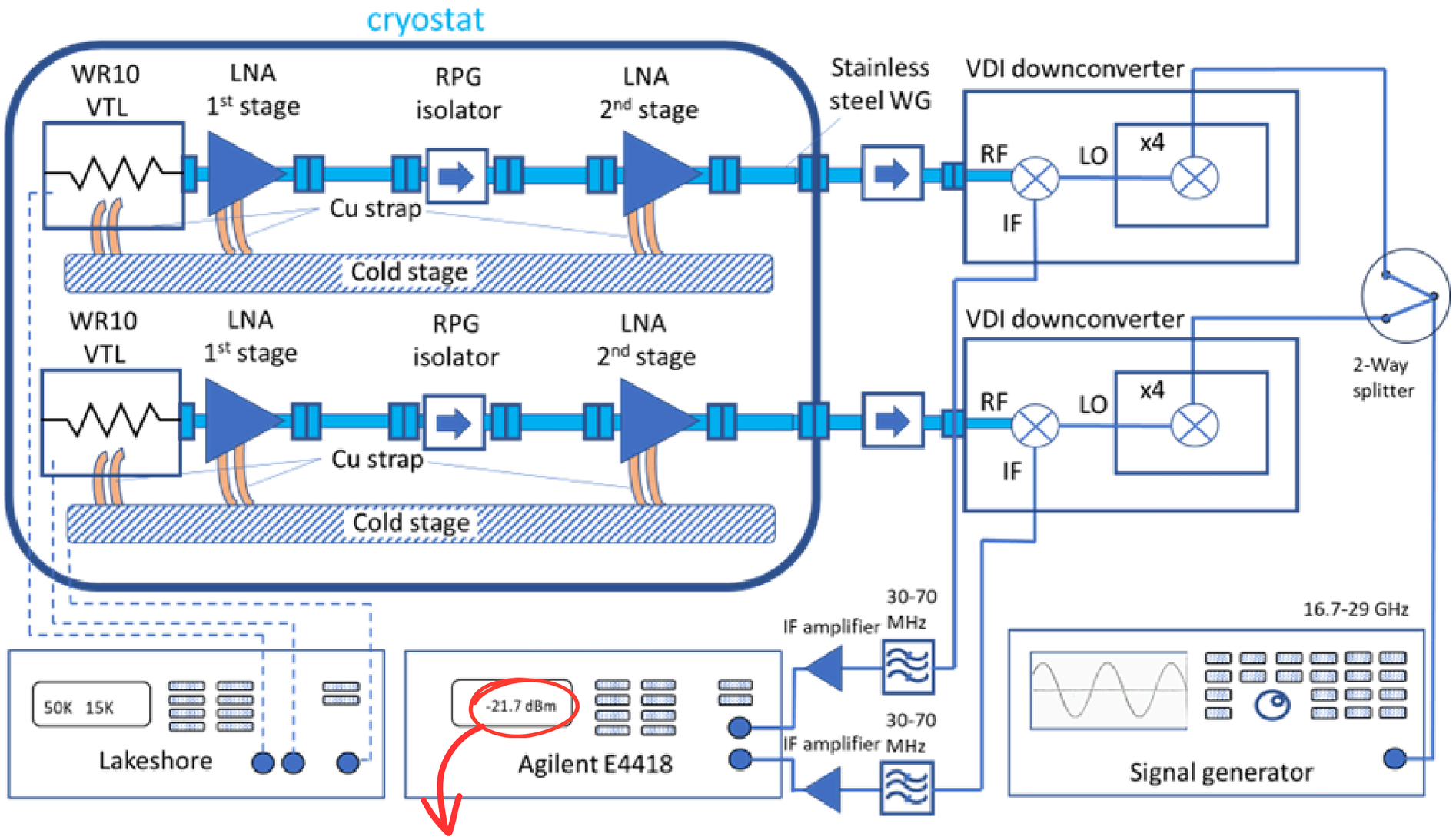


P. Yagoubov, LNA delivery report,2025



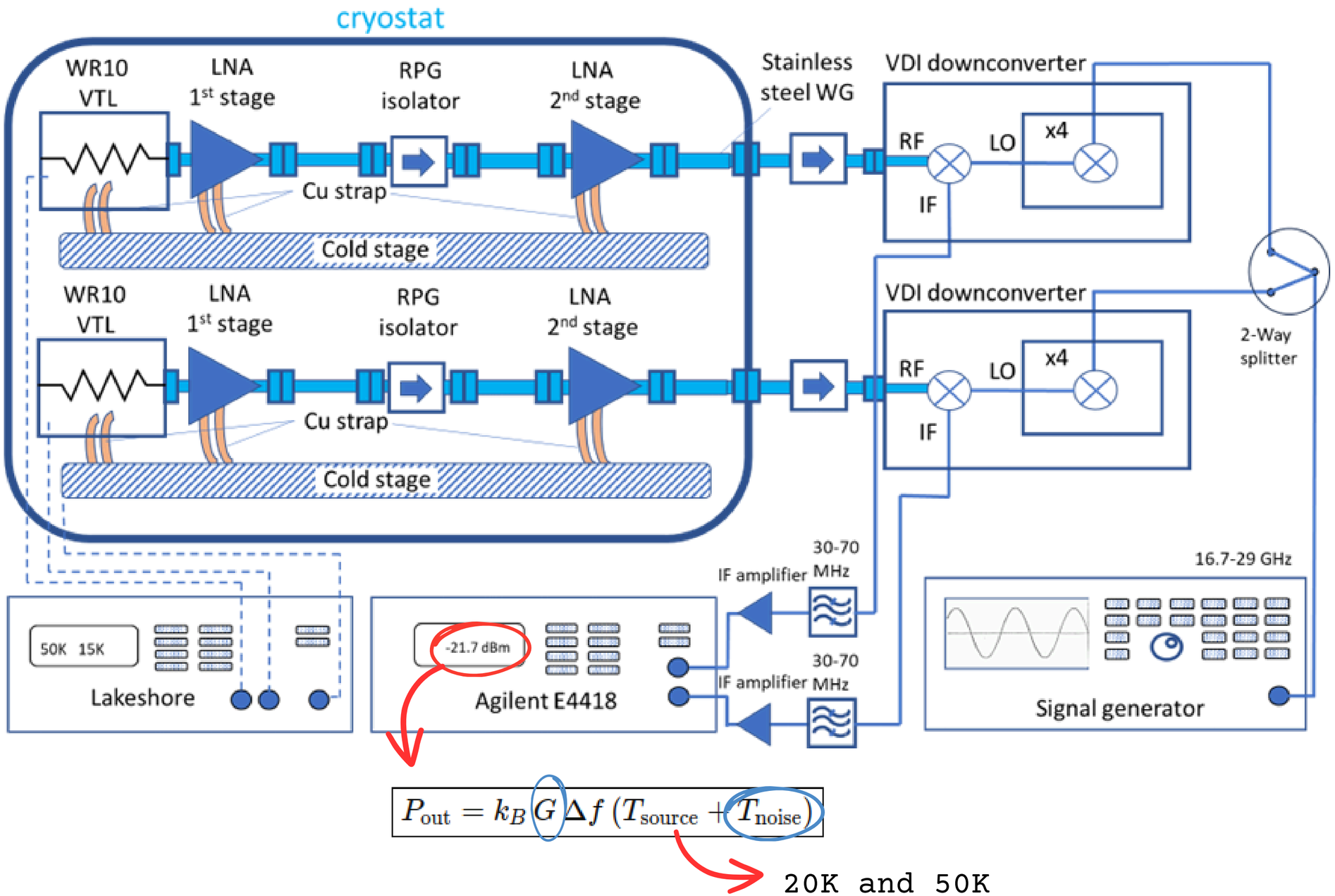
$$P_{\text{out}} = k_B \, G \, \Delta f \, (T_{\text{source}} + T_{\text{noise}})$$

P. Yagoubov, LNA delivery report,2025



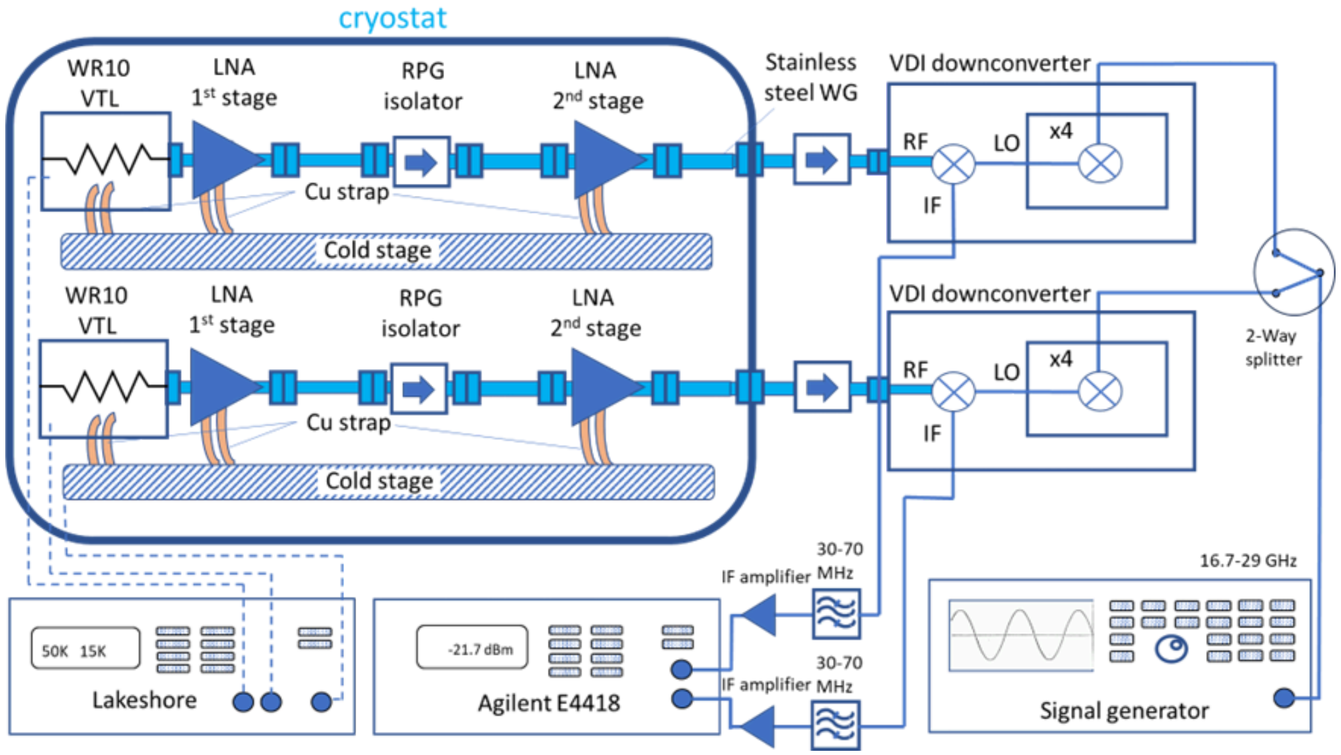
$$P_{\text{out}} = k_B G \Delta f \left(T_{\text{source}} + T_{\text{noise}}\right)$$

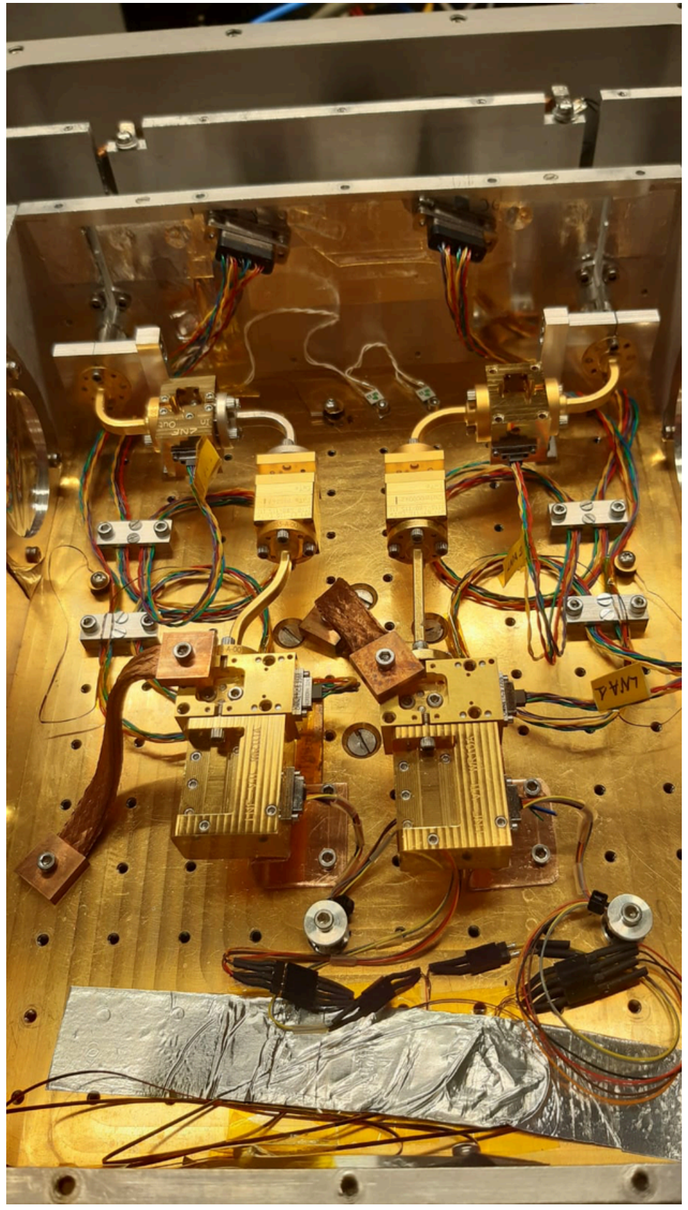
P. Yagoubov, LNA delivery report,2025

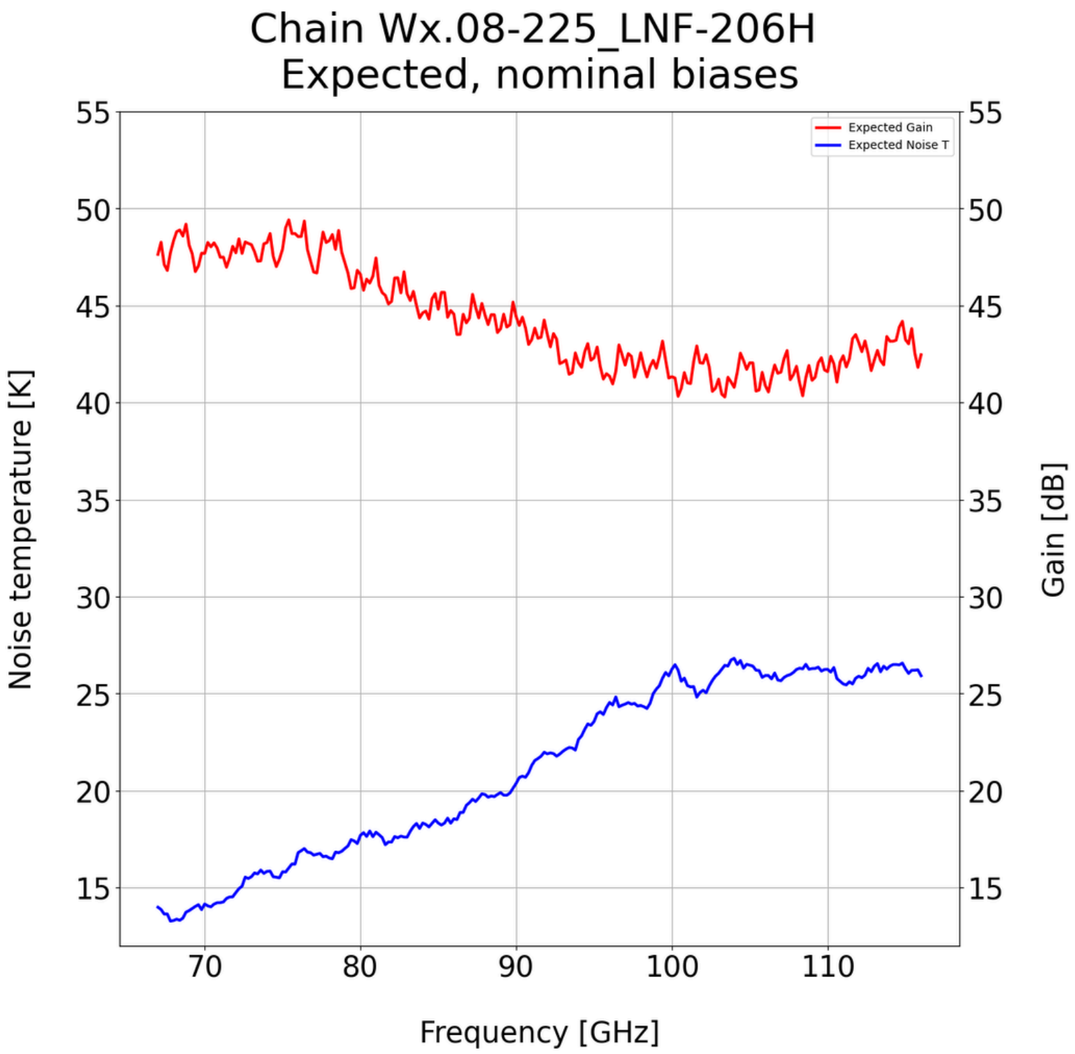


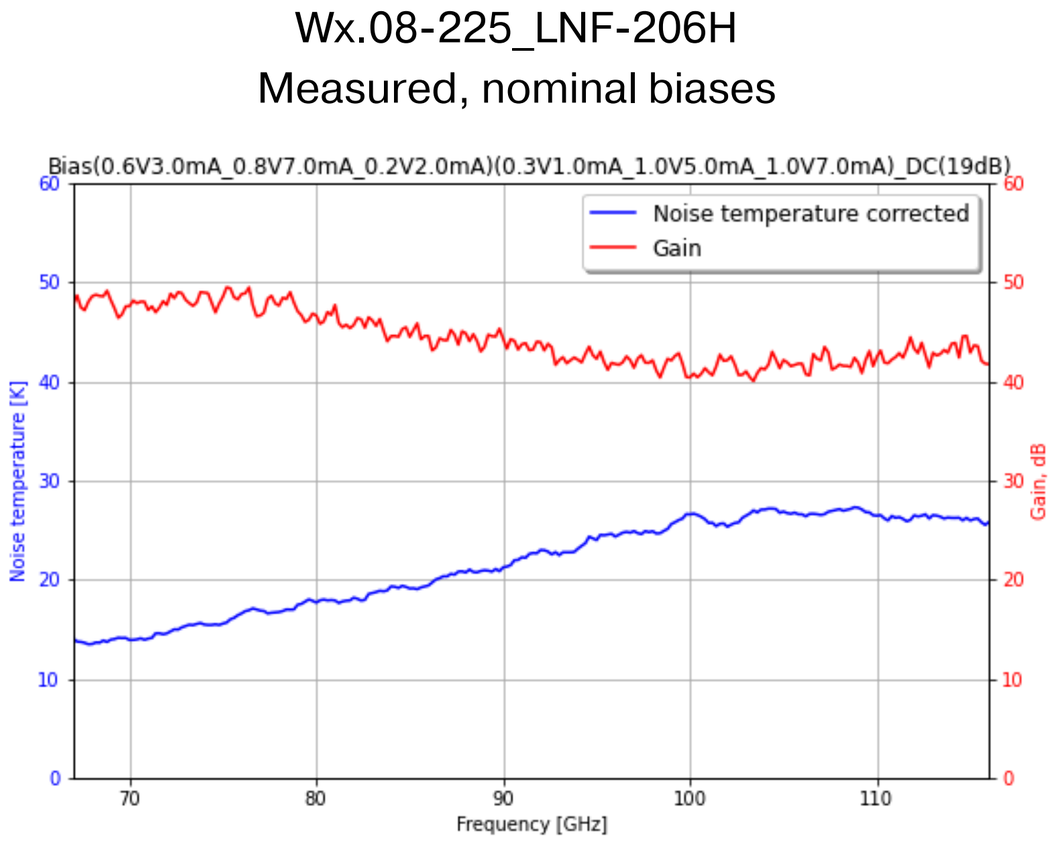
$$P_{\text{out}} = k_B G \Delta f \left(T_{\text{source}} + T_{\text{noise}}\right)$$

20K and 50K


cryostat
WR10
VTL
LNA
1st stage
RPG
isolator
LNA
2nd stage
Cu strap
Cold stage
WR10
VTL
LNA
1st stage
RPG
isolator
LNA
2nd stage
Cu strap
Cold stage
Stainless
steel WG
VDI downconverter
RF
LO
x4
IF
VDI downconverter
RF
LO
x4
IF
2-Way
splitter
30-70
MHz
IF amplifier
30-70
MHz
IF amplifier
16.7-29 GHz
50K 15K
Lakeshore
-21.7 dBm
Agilent E4418
Signal generator

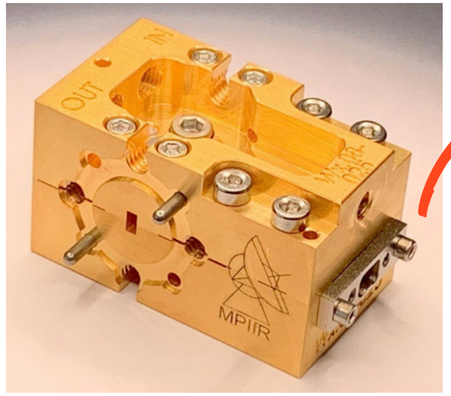


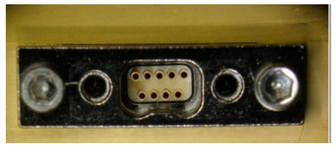

Chain Wx.08-225_LNF-206H
Expected, nominal biases
Expected Gain
Expected Noise T
Noise temperature [K]
Gain [dB]
Frequency [GHz]
55
50
45
40
35
30
25
20
15
70
80
90
100
110


Wx.08-225_LNF-206H
Measured, nominal biases
Bias(0.6V3.0mA_0.8V7.0mA_0.2V2.0mA)(0.3V1.0mA_1.0V5.0mA_1.0V7.0mA)_DC(19dB)
Noise temperature corrected
Gain
Noise temperature [K]
Gain, dB
Frequency [GHz]
60
50
40
30
20
10
0
70
80
90
100
110

3 Tuning amplifiers

Biases impact

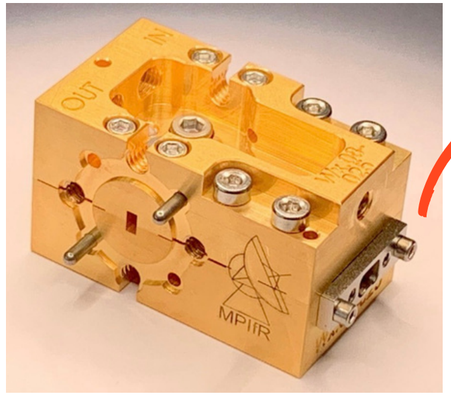


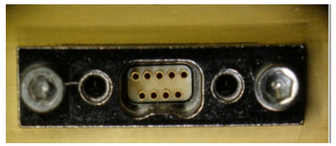


3 biases stages
each amplifier
(V&I)

3 stages x 2 variables x 2 aplifiers = 12 variables

Biases impact



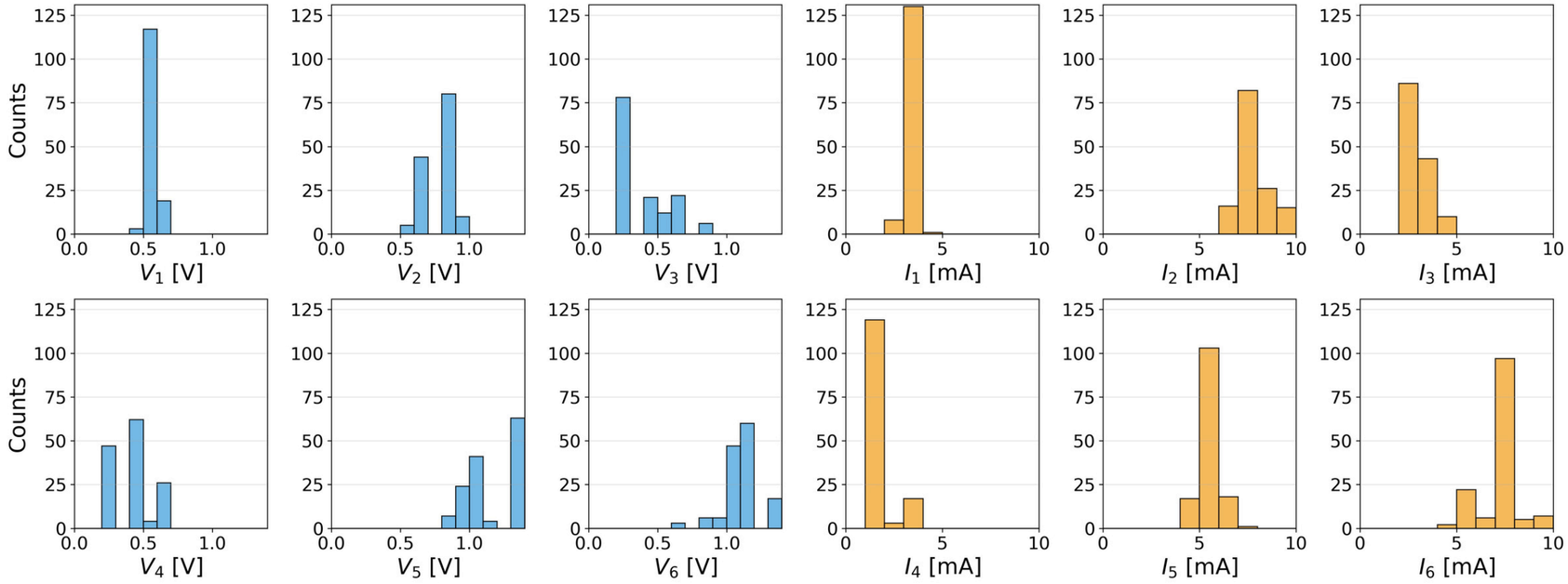


3 biases stages
each amplifier
(V&I)

3 stages x 2 variables x 2 aplifiers = 12 variables

1st stage amplifier

2nd stage amplifier

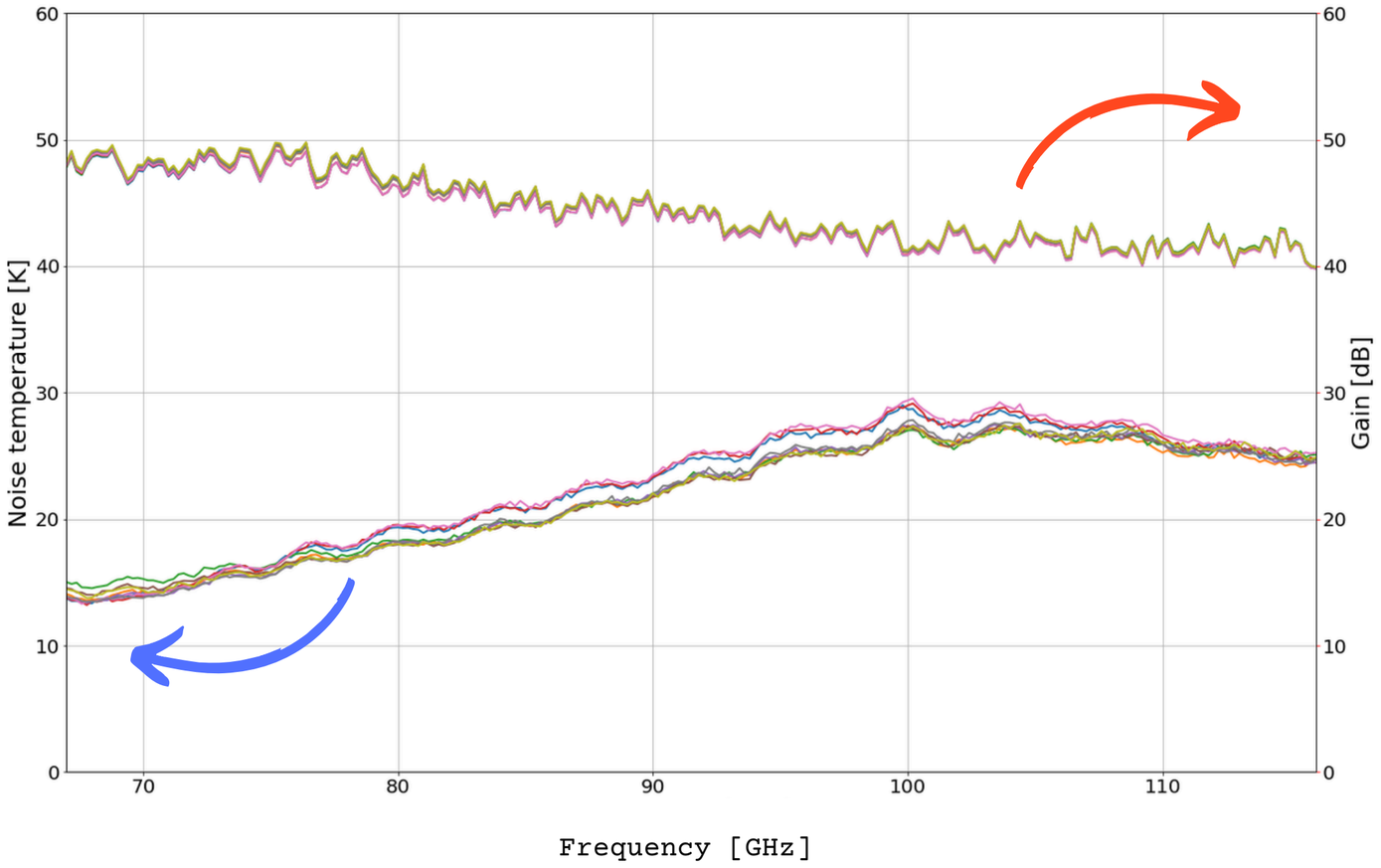


~5 possible values for each variable

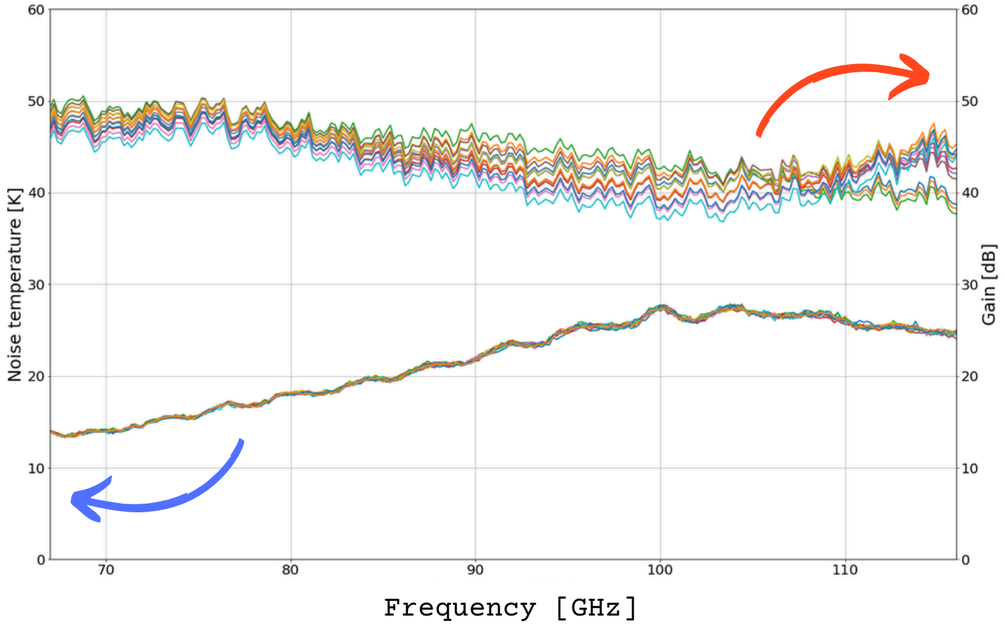
→ 5^{12} different configurations to be tested

~ 2300 years to run all tests!

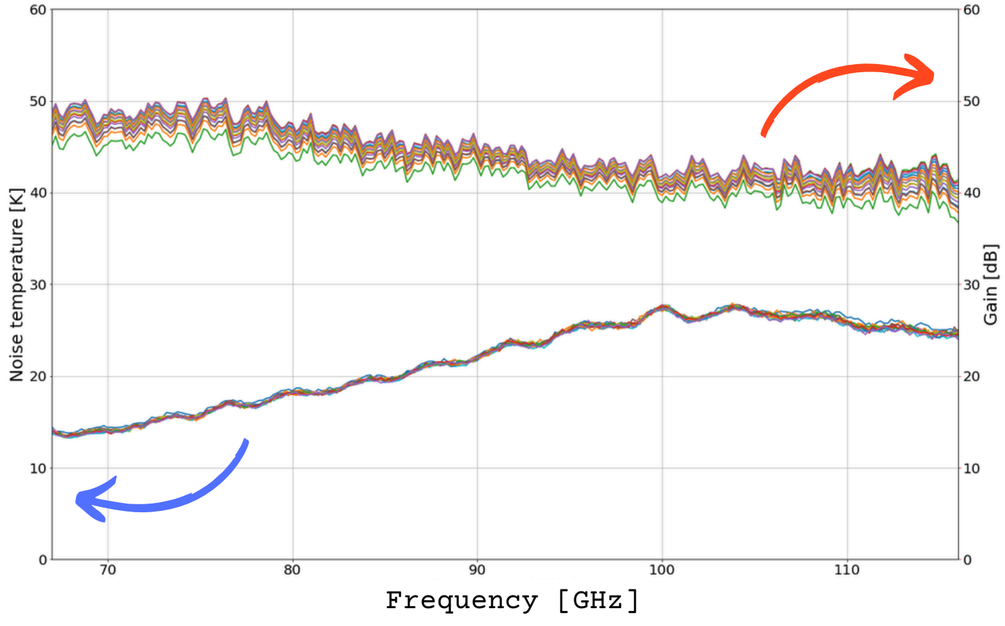
Difficult to predict, but there are some trends ...



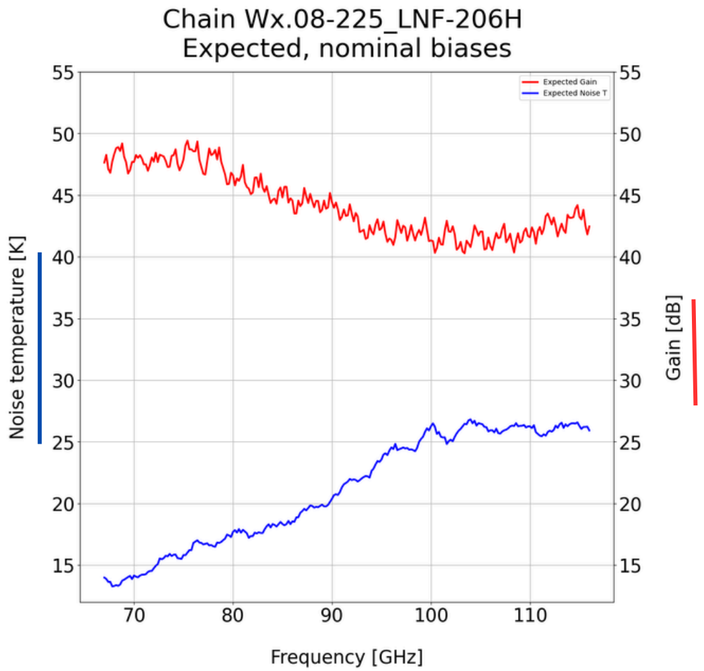
Changing the biases of the **1st stage** of the **1st amplifier** affects the **noise temperature**, but usually does not have a significant impact on the gain.

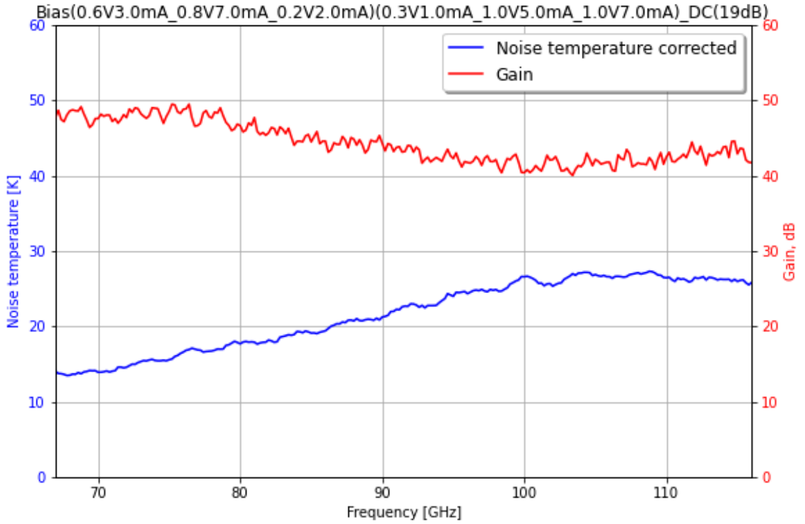


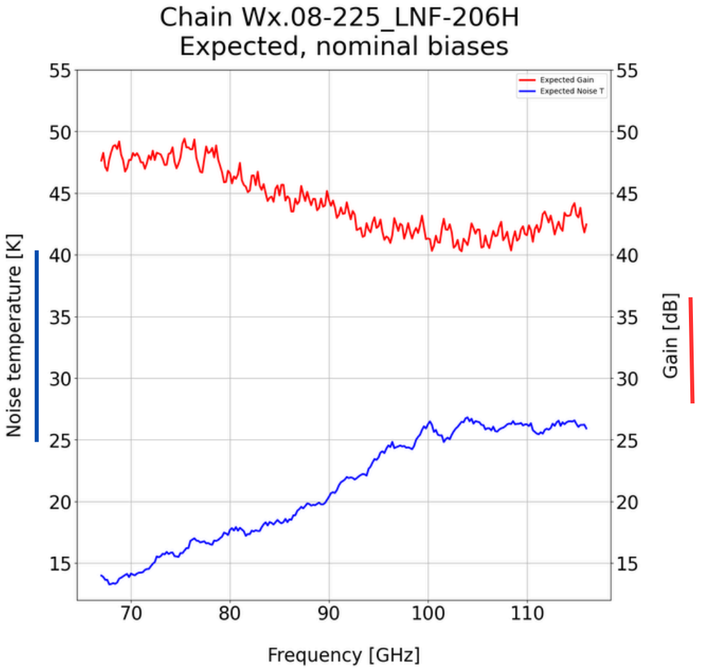
2nd stage, 2nd amplifier affects the **gain at high frequency**, no significant impact on the noise temperature (usually).

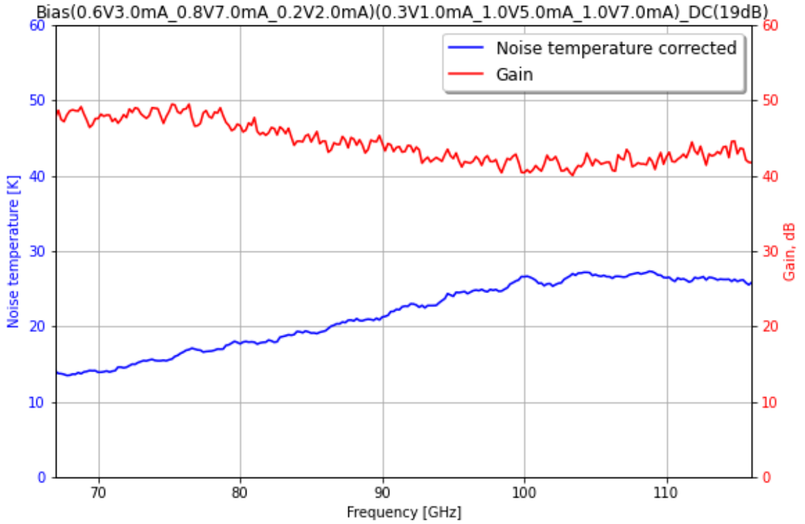


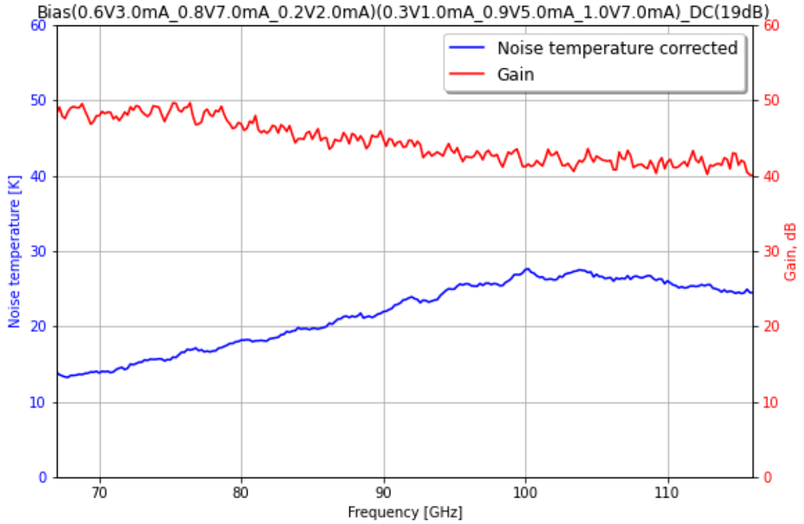
3rd stage, 2nd amplifier shift **gain up (or down)** no significant impact on the noise temperature (usually).

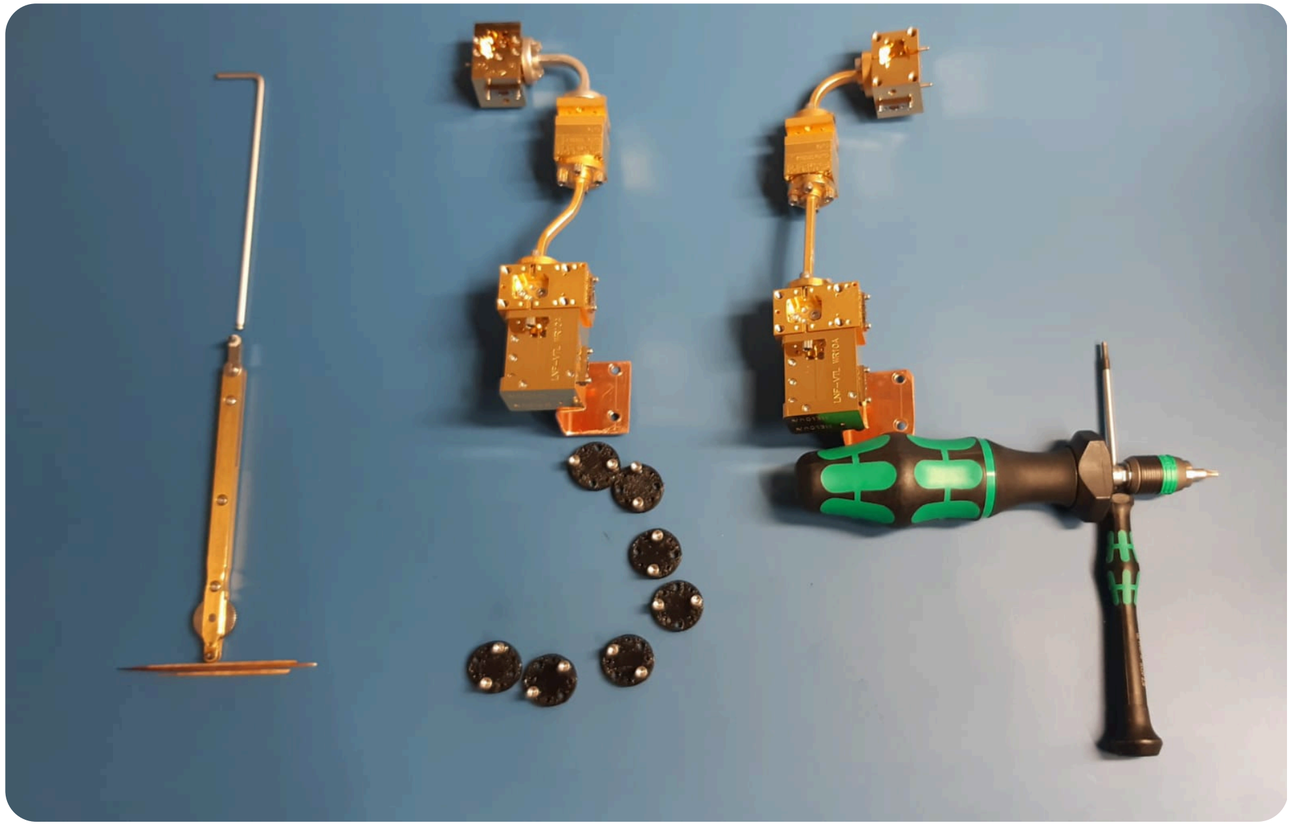

Chain Wx.08-225_LNF-206H
Expected, nominal biases
Expected Gain
Expected Noise T
Noise temperature [K]
Gain [dB]
Frequency [GHz]
55
50
45
40
35
30
25
20
15
70
80
90
100
110

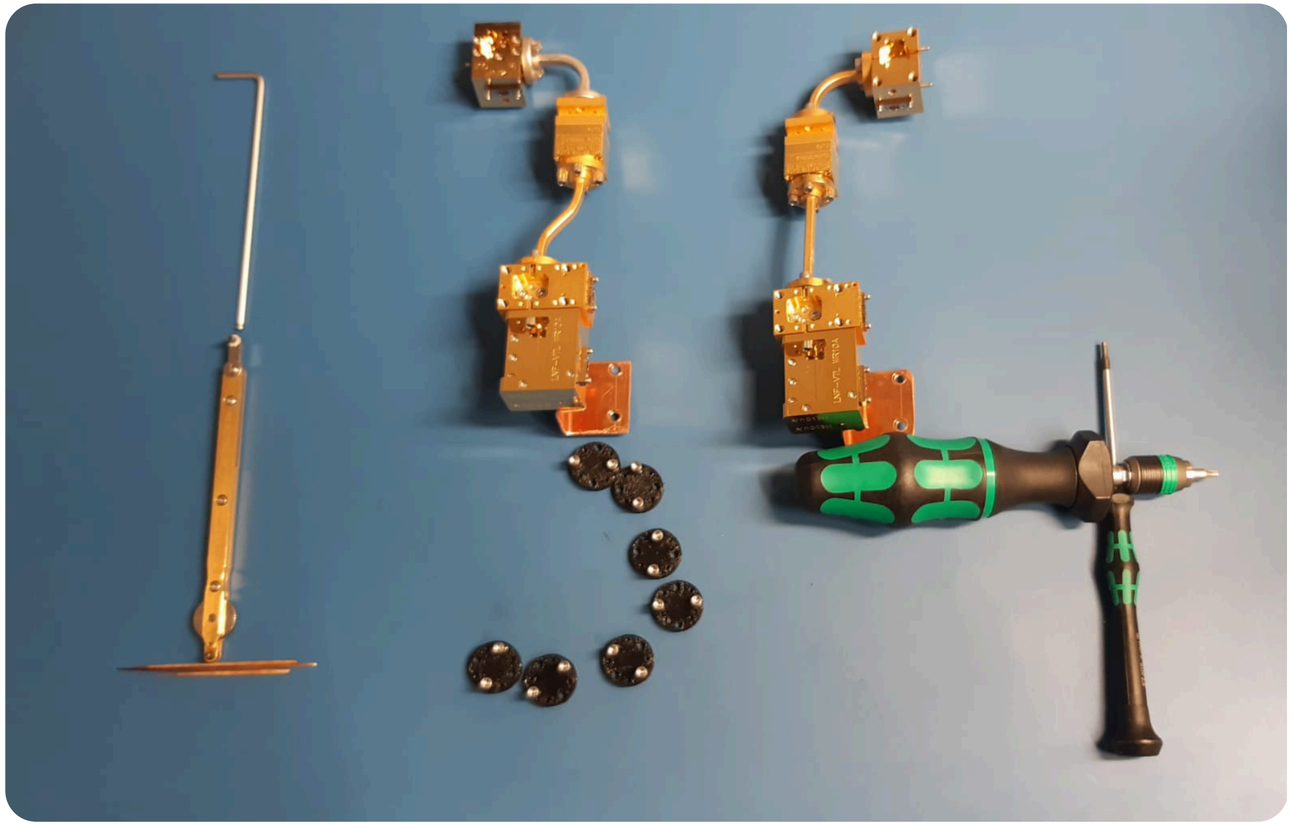

Bias(0.6V3.0mA_0.8V7.0mA_0.2V2.0mA)(0.3V1.0mA_1.0V5.0mA_1.0V7.0mA)_DC(19dB)
Noise temperature corrected
Gain
Noise temperature [K]
Gain, dB
Frequency [GHz]
60
50
40
30
20
10
0
70
80
90
100
110


Chain Wx.08-225_LNF-206H
Expected, nominal biases
Expected Gain
Expected Noise T
Noise temperature [K]
Gain [dB]
Frequency [GHz]


Bias(0.6V3.0mA_0.8V7.0mA_0.2V2.0mA)(0.3V1.0mA_1.0V5.0mA_1.0V7.0mA)_DC(19dB)
Noise temperature corrected
Gain
Noise temperature [K]
Gain, dB
Frequency [GHz]


Bias(0.6V3.0mA_0.8V7.0mA_0.2V2.0mA)(0.3V1.0mA_0.9V5.0mA_1.0V7.0mA)_DC(19dB)
Noise temperature corrected
Gain
Noise temperature [K]
Gain, dB
Frequency [GHz]





Thank you! ☺