IRAM receivers stability

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IRAM (Institut de RadioAstronomie Millimetrique), FRANCE

Outline

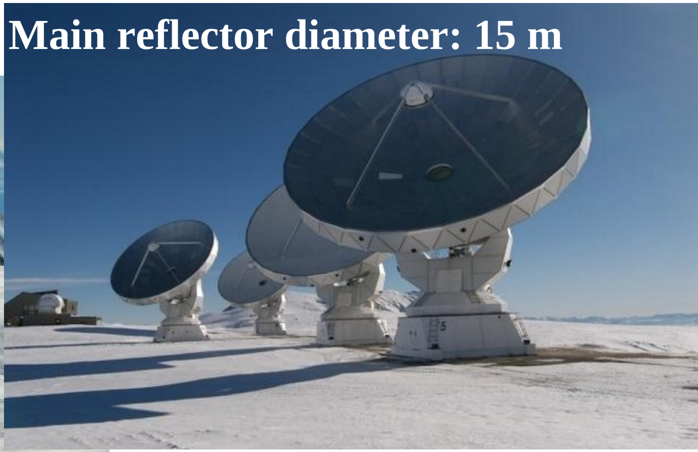
- IRAM observatories & instruments
- Receiver gain stability specifications
- IRAM 3mm HEMT receiver prototype description and stability measurements
- IRAM EMIR SIS receiver description and stability measurements
- ALMA band 7 cartridges description and stability measurements
- 4-12GHz amplifiers stability measurements

IRAM Plateau de Bure observatory

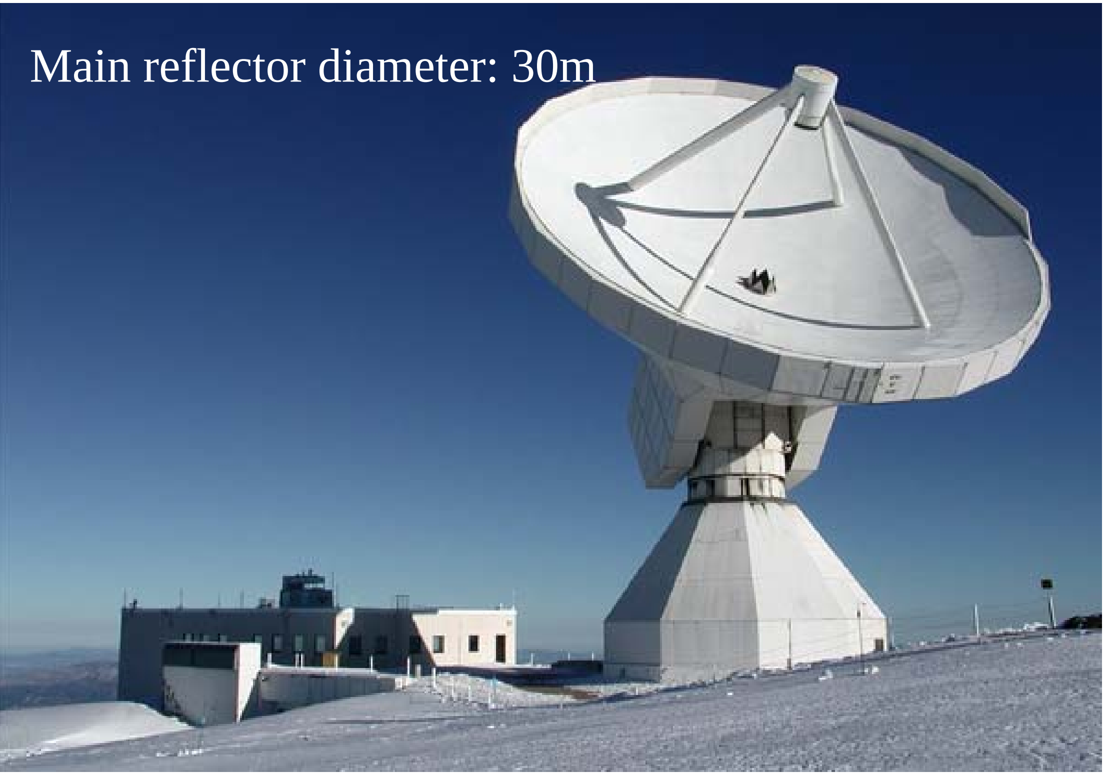
Altitude: 2550 m

Localization: Plateau de Bure (Hautes-Alpes, France)

Heterodyne SIS Receivers covering from 84GHz to 375GHz



IRAM Pico Veleta Telescope



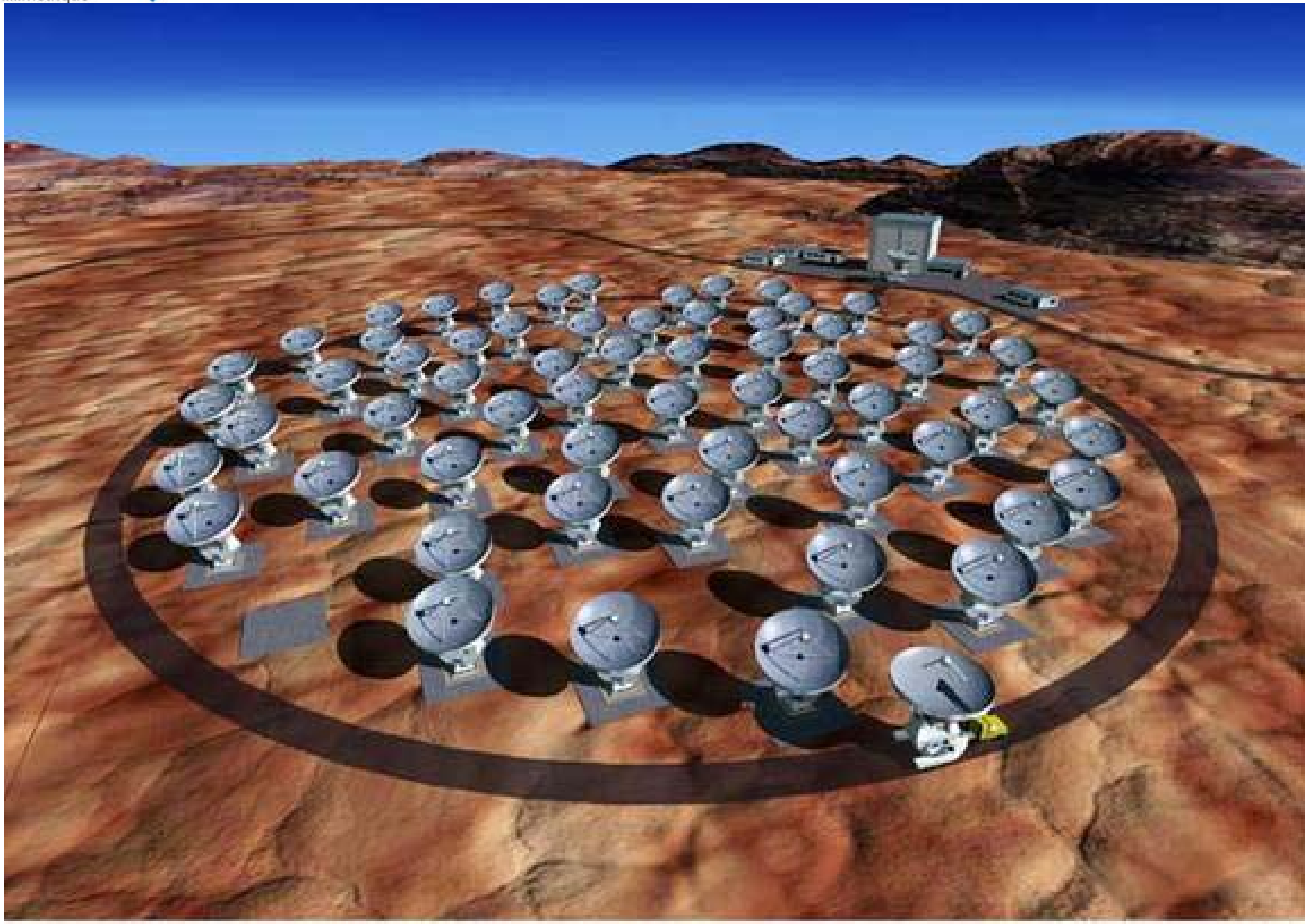
1 single-dish telescope

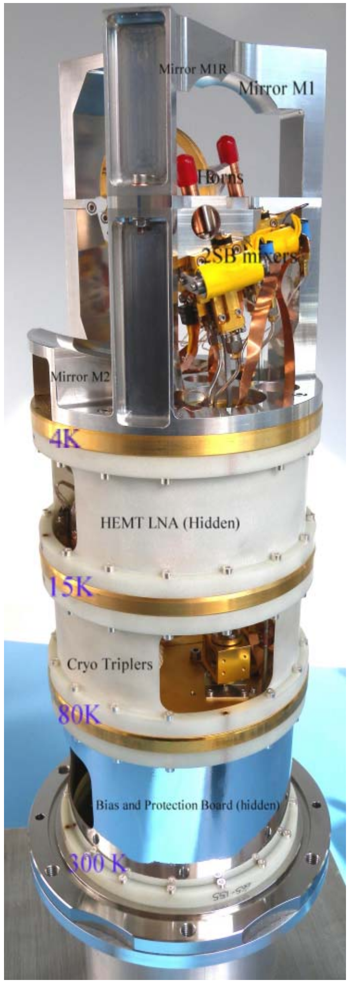
Altitude: 2850 m

Localization: Sierra Nevada (Andalusia, Spain)

Heterodyne receivers covering from 84GHz to 365GHz (both HEMT and SIS technology)

IRAM involvement in ALMA: band 7 receivers development & production





IRAM has to produce ~ 60 SIS receivers covering 275GHz to 370GHz (Band 7)

Gain Stability specifications

- **For a single dish telescope, the Amplitude gain stability specification depends on:**

  -The fluctuations of atmospheric emission.

  -The frequency bandwidth.

  -The observation mode.

  - …

  (note that the phase stability is not critical)

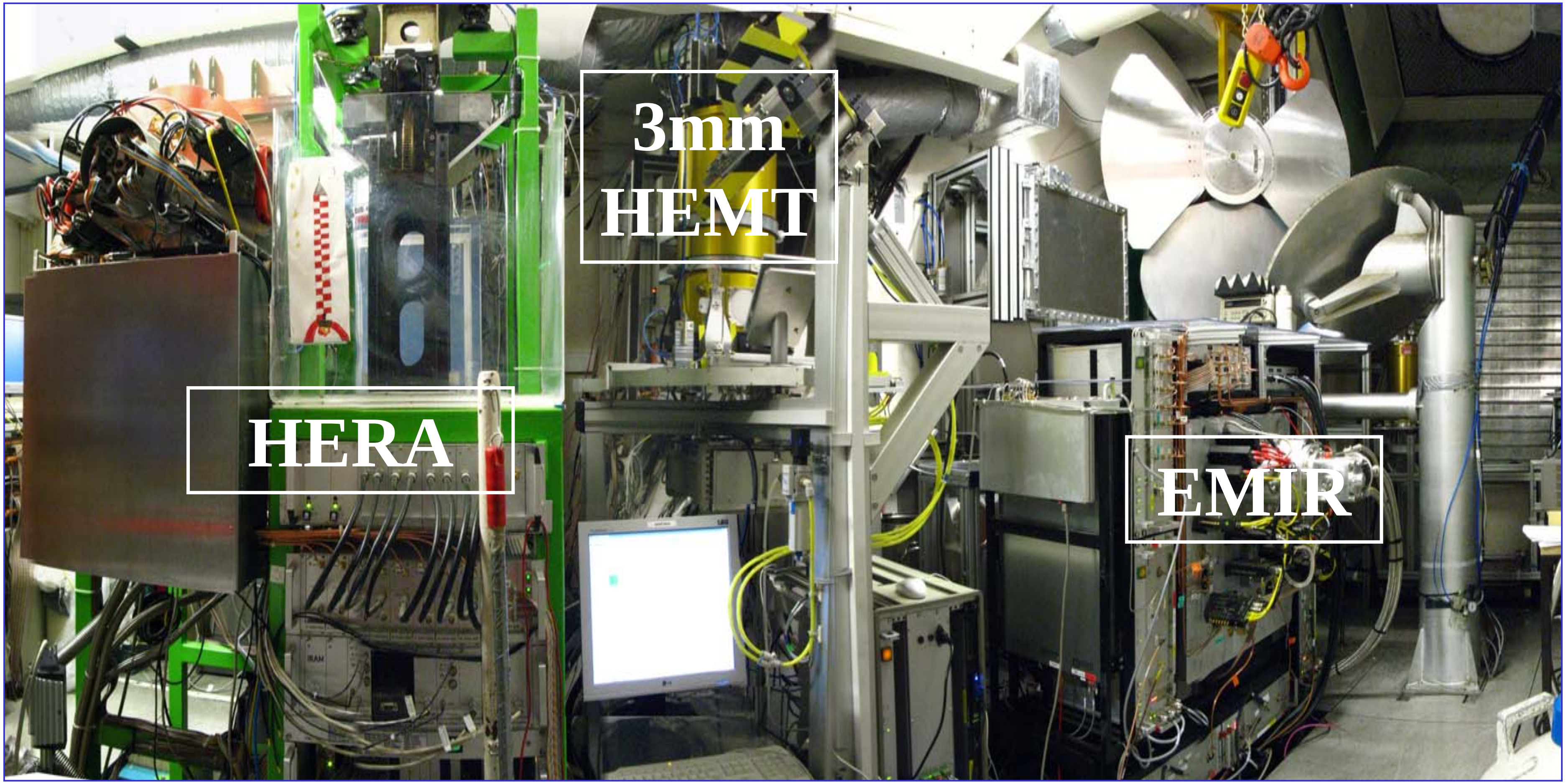
- **For ALMA Band 7, σ < 6.10-4 for 0.05<τ<100s & σ < 1.8.10-3 for 100<τ<300s.**

- **For an interferometer, the receiver phase stability is also important.**

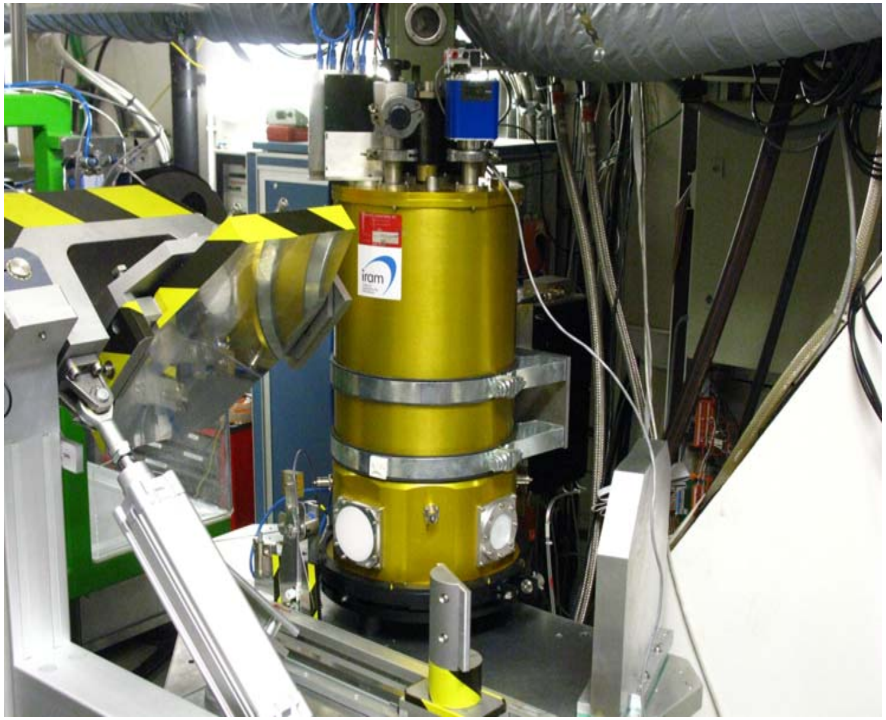
To not limit the interferometer performances the receiver phase instability must be negligible compare to the atmosphere phase fluctuations.

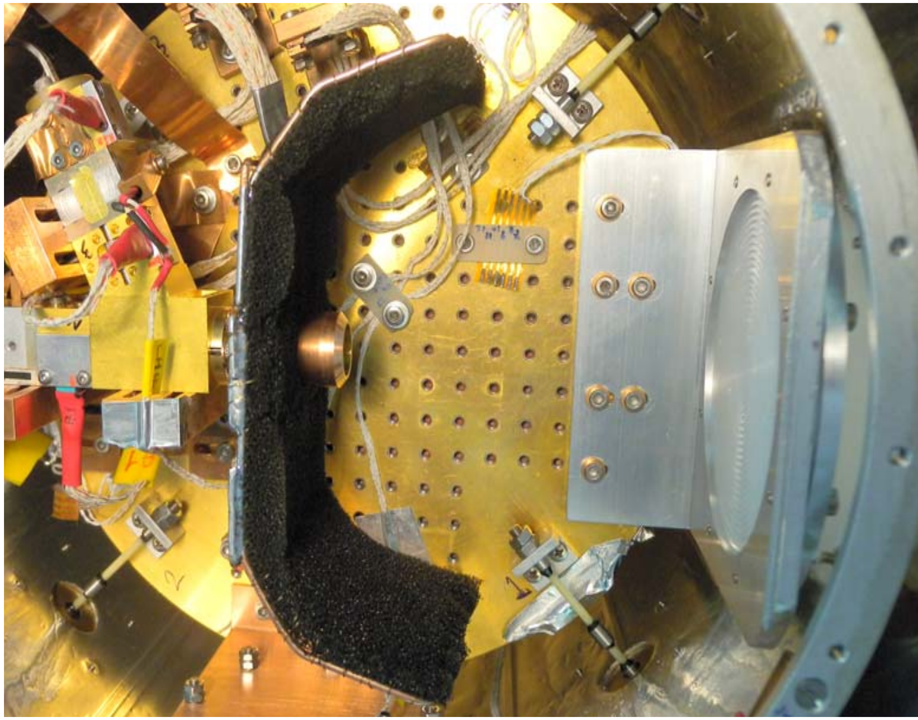
For ALMA Band 7, $\sigma < 0.6^{o}$ @ LO =283GHz, $\sigma < 0.7^{o}$ @ LO =323GHz, $\sigma < 0.8^{o}$ @ LO =365GHz for 1<τ<300s.

Pico Veleta receivers

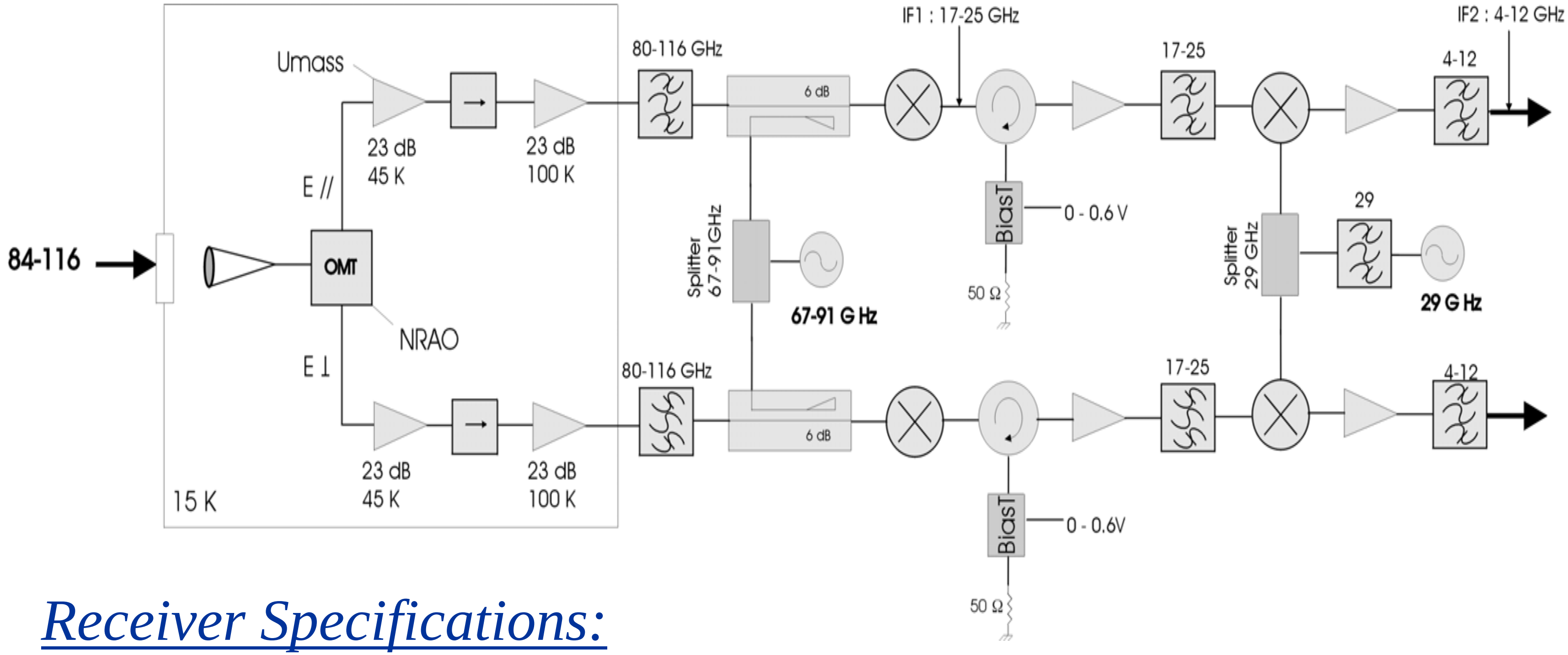


3mm HEMT receiver prototype





3mm HEMT receiver block diagram



Receiver Specifications:

-Single pixel with two linear polarizations.

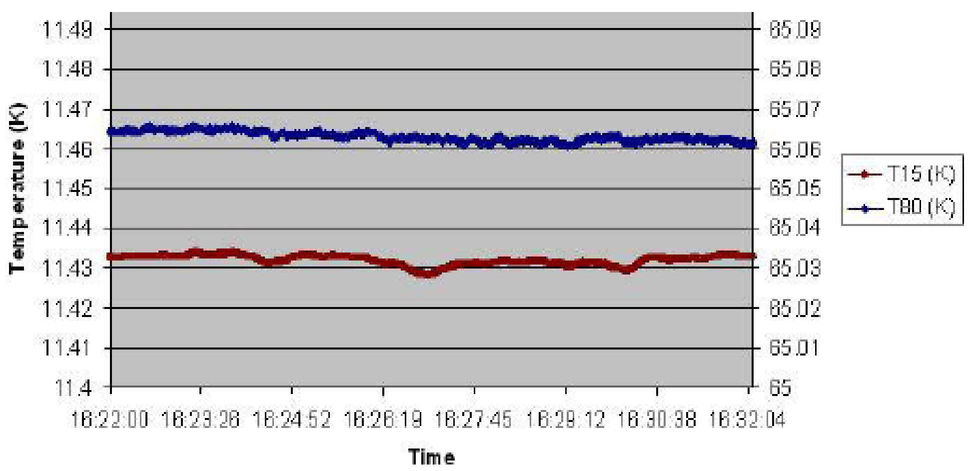
-Signal frequency band : 84-116GHz.

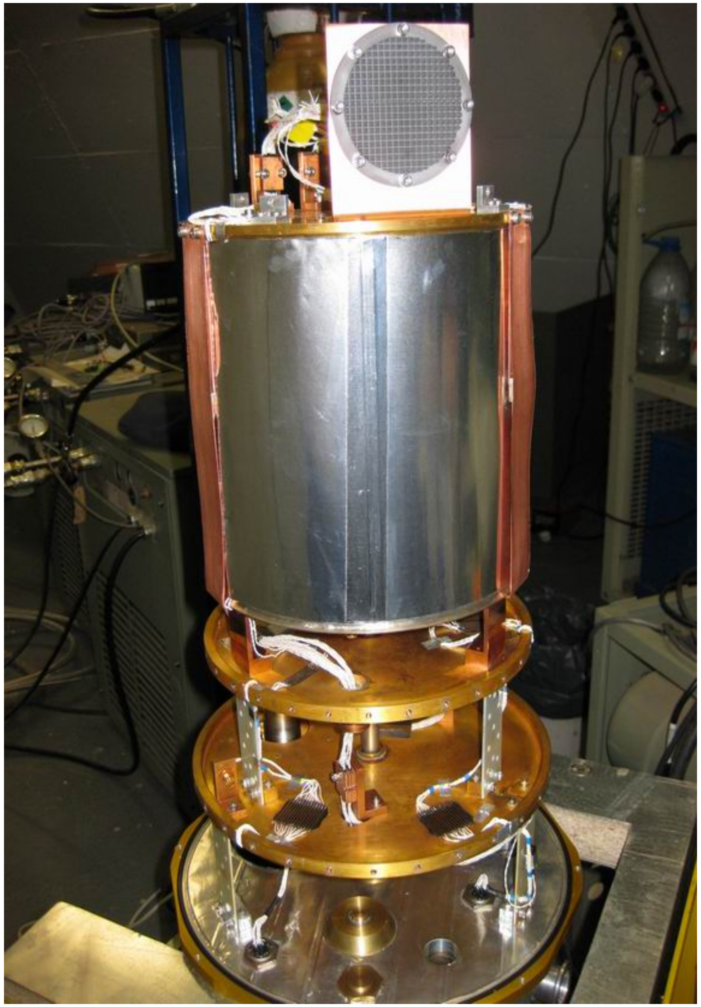
-Intermediate frequency band : 4-12GHz.

3mm HEMT receiver cryogenic part

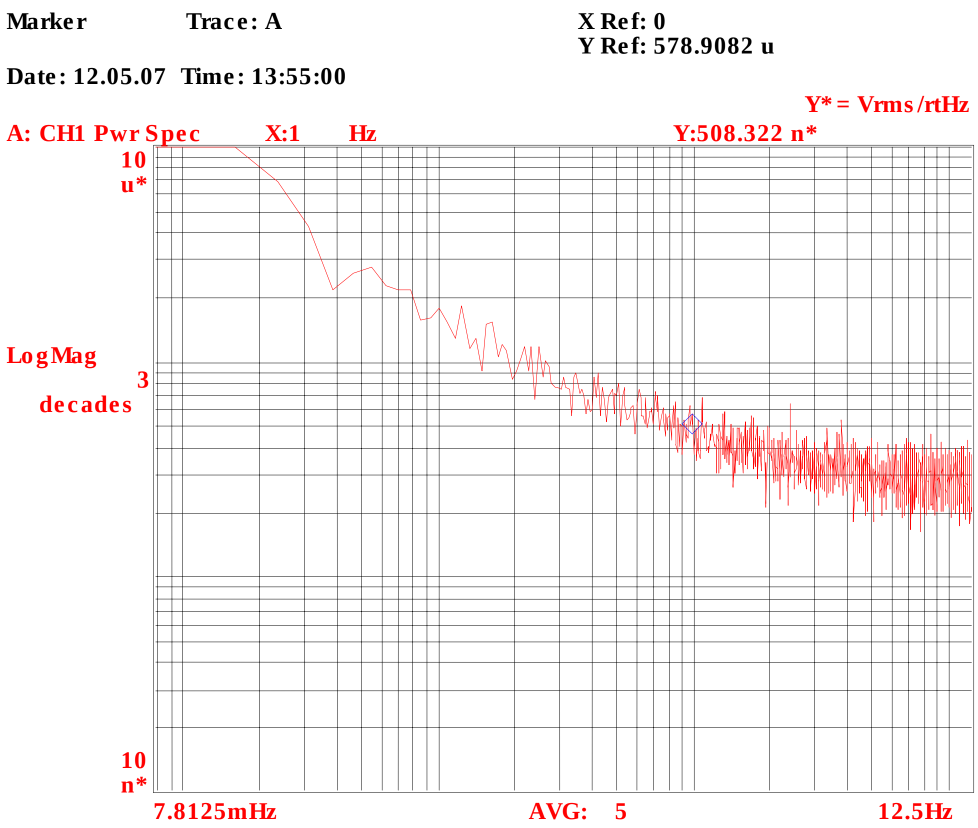
- HDV10 cryostat modification:
  - 4K plate -> 15K with copper strap.
  - 15K thermal screen was removed.
  - Vacuum in the Helium tank.
- Cryostat vacuum: $3{,}5.10^{-7}$ Torr.

if $\Delta G \sim 0.05$dB/K $\Delta T = 10$mK -> $\Delta G/G \sim 1.10^{-4}$



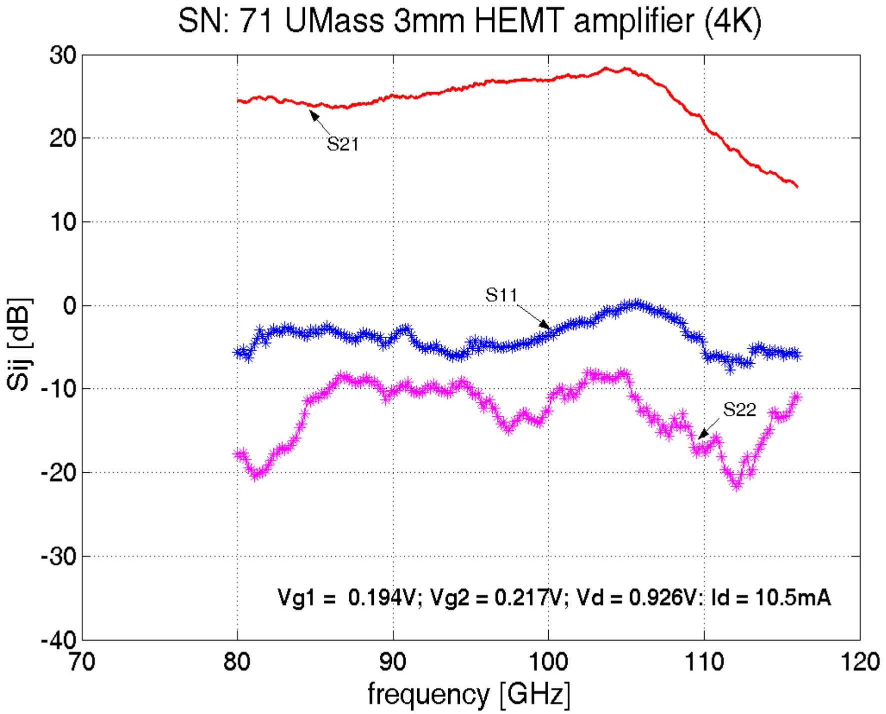


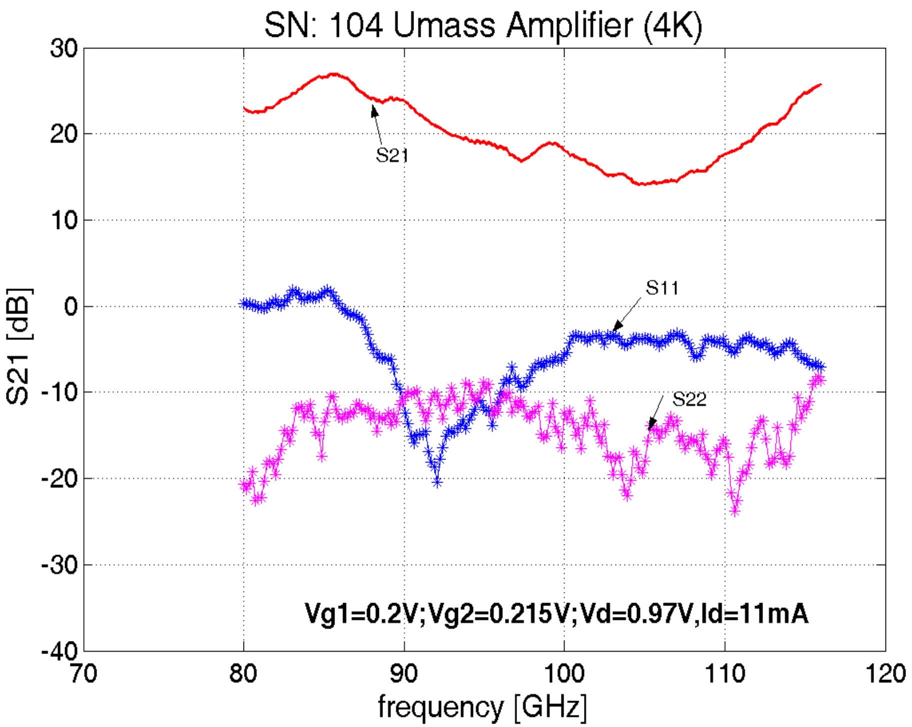
Amplifier bias Stability



- Measurement made with a Dynamic Signal (HP 35670A) Analyzer.
- Noise ~ 500nV/Hz$^{0.5}$ @1s.
- Below 1Hz the analyzer drift is not negligible.

Amplifiers Input reflection issues



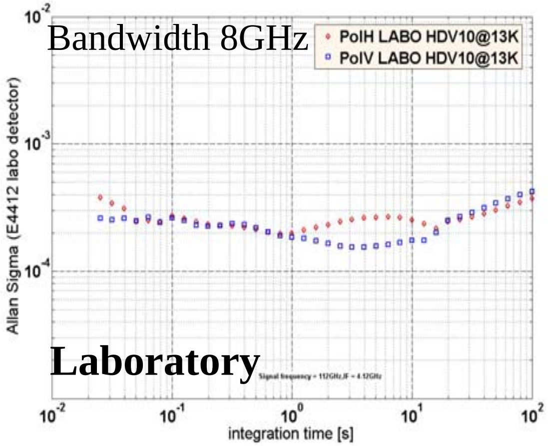


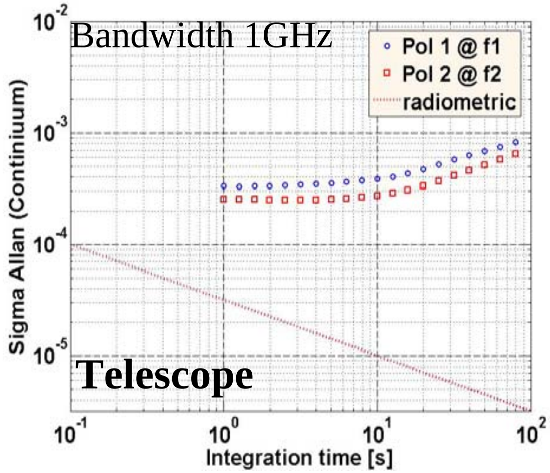
Noise temperatures are about 50K (with HEMT @ 15K) in the 84-116GHz range

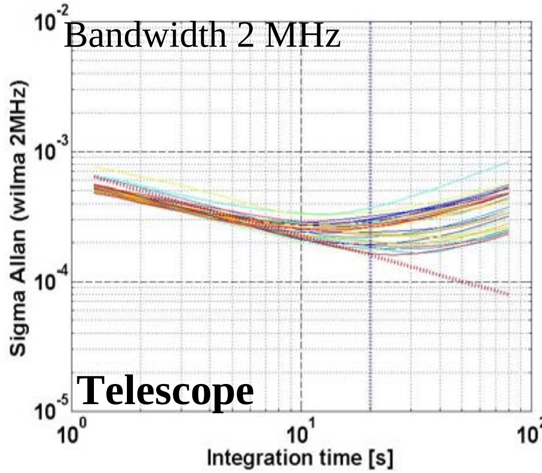
Total power Stability measurements test set (in the laboratory)

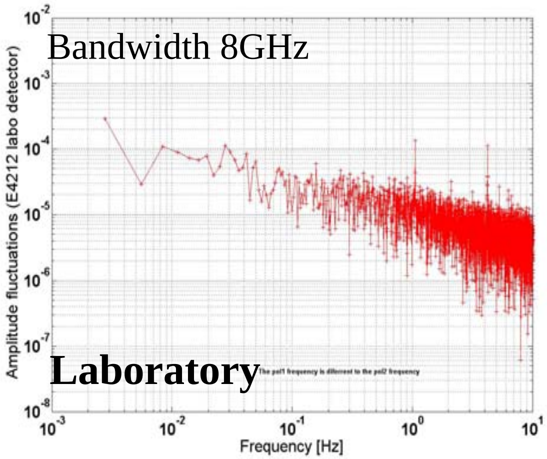
- E4412A Agilent power sensors
- E4419B Agilent dual channel power meter
- Sampling with GPIB Bus (100samples/s, managed by labview)
- Frequency bands :4-12GHz
- Measurement made with an ambient load in front of the receiver
- Allan variance and Fourier transform are calculated on normalized ($\delta P_{RMS}/P_{avg}$) output power.

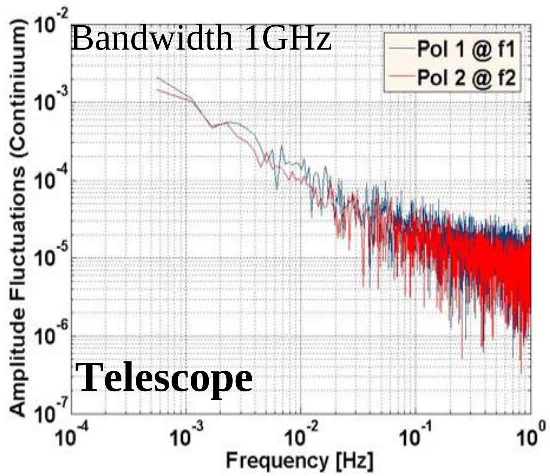
3mm HEMT receiver total power stability

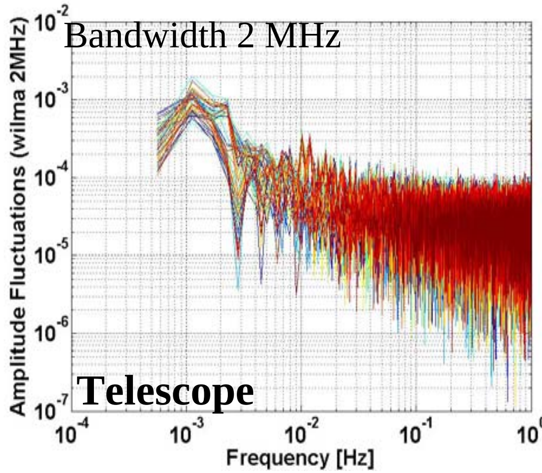




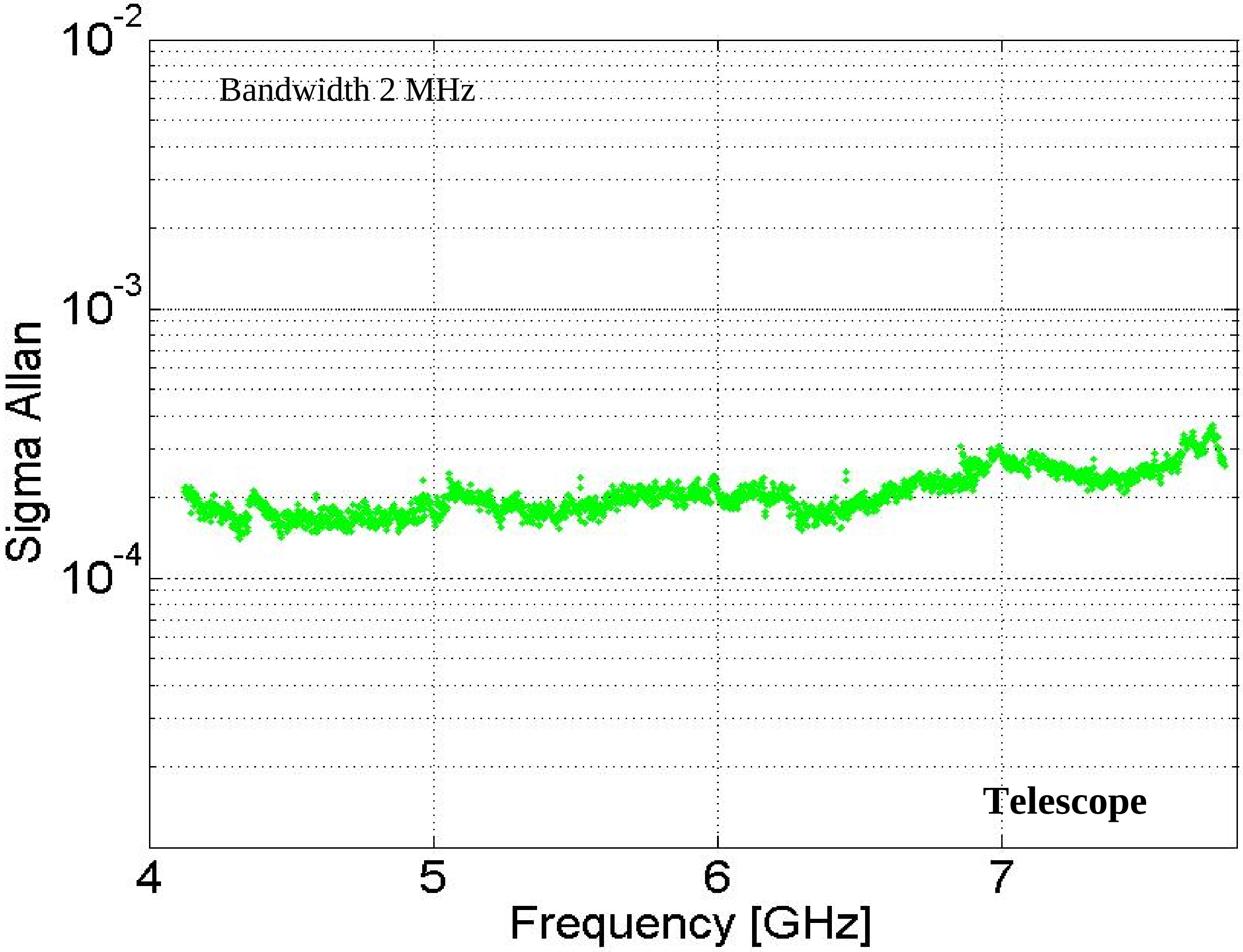






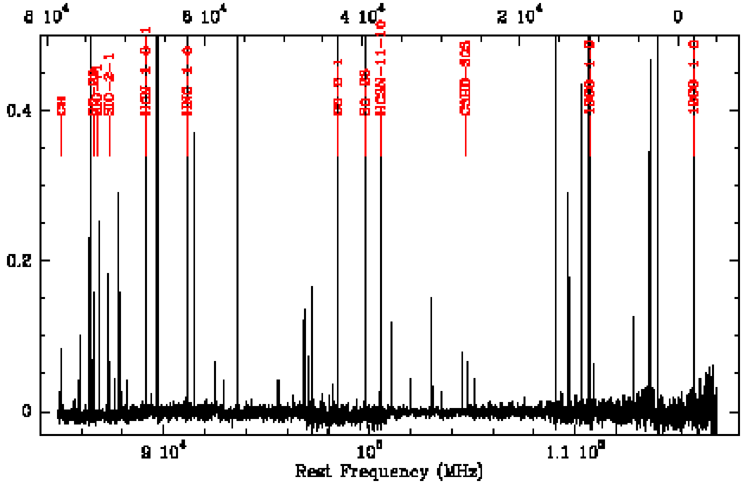


3mm HEMT receiver Spectroscopic stability

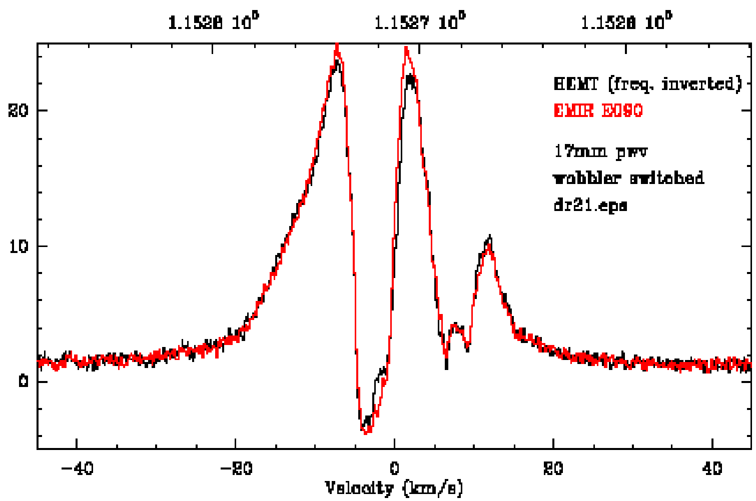


3mm HEMT receiver, first measurements on the sky

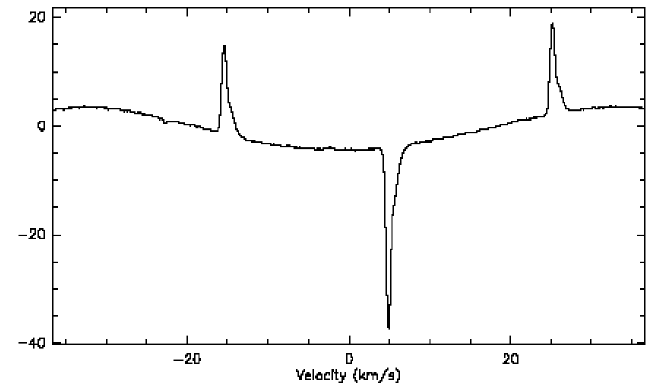
Frequency survey (Galactic star forming region S140)



Bright massive star (forming region DR21)



Frequency switching mode (^{12}CO on Ced201)

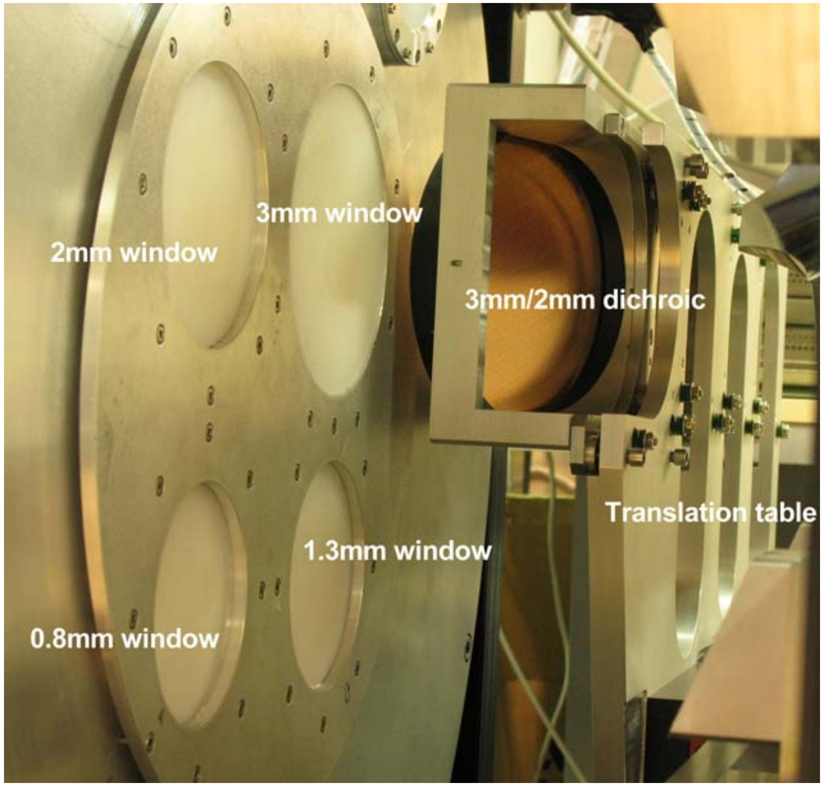


EMIR receiver

Band#	RF coverage (GHz)	Mixing scheme	IF config. Pol× Sb× BW(GHz)
B1	83 – 117	2SB	$2 \times 2 \times 8$
B2	129 – 174	SSB	$2 \times 1 \times 4$
B3	200 – 267	SSB	$2 \times 1 \times 4$ [a]
B4	260 – 360	2SB	$2 \times 2 \times 4$ [b]

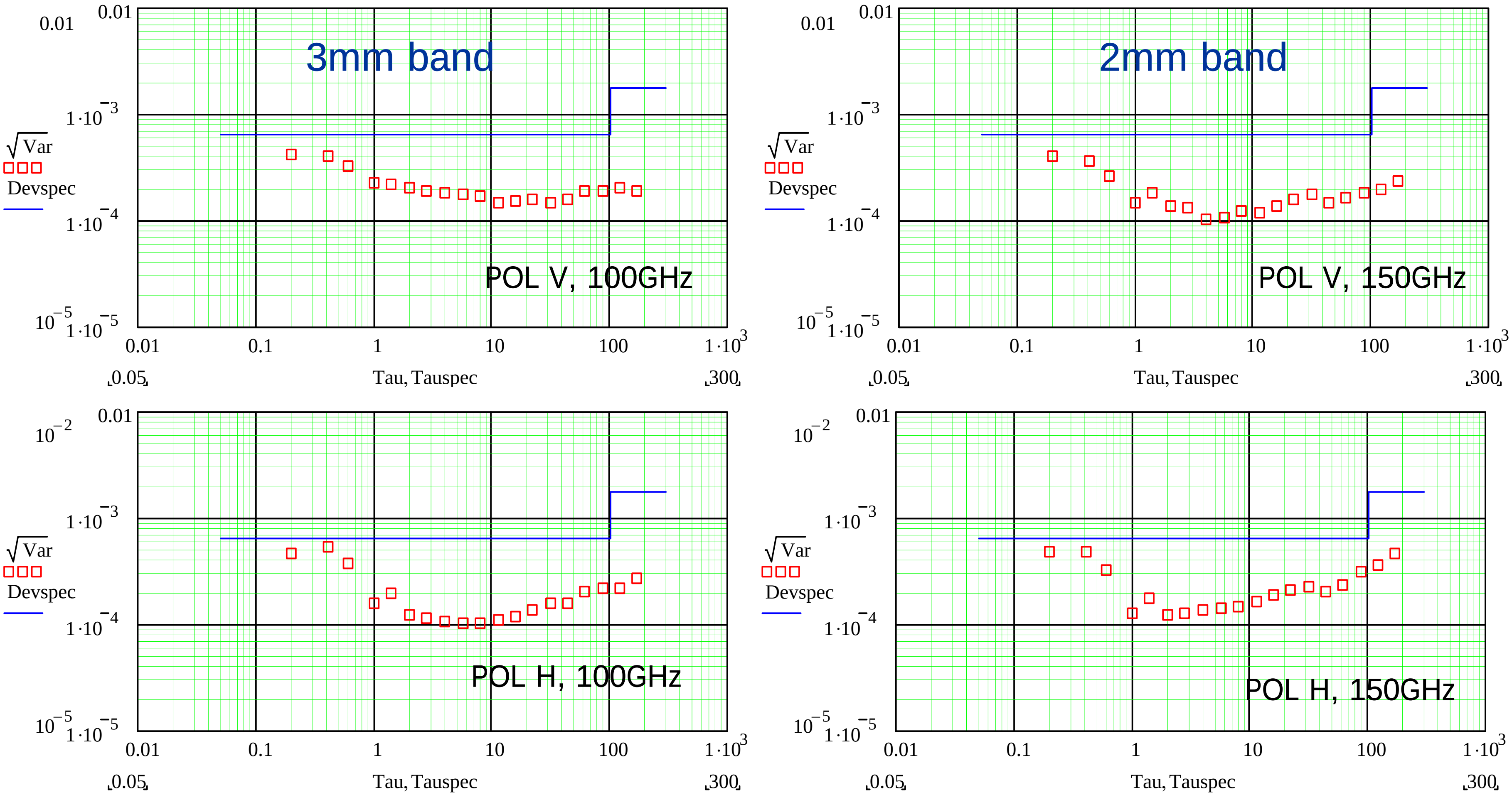
Notes. The following upgrades to the mixing and/or IF capability are planned in 2011:
[a] Band 3: 2SB mixers, $2 \times 2 \times 8$GHz
[b] Band 4: $2 \times 2 \times 8$GHz

A switching table of dichroic filters also allow dual band observations for
B1 + B2
B1 + B3
B2 + B4



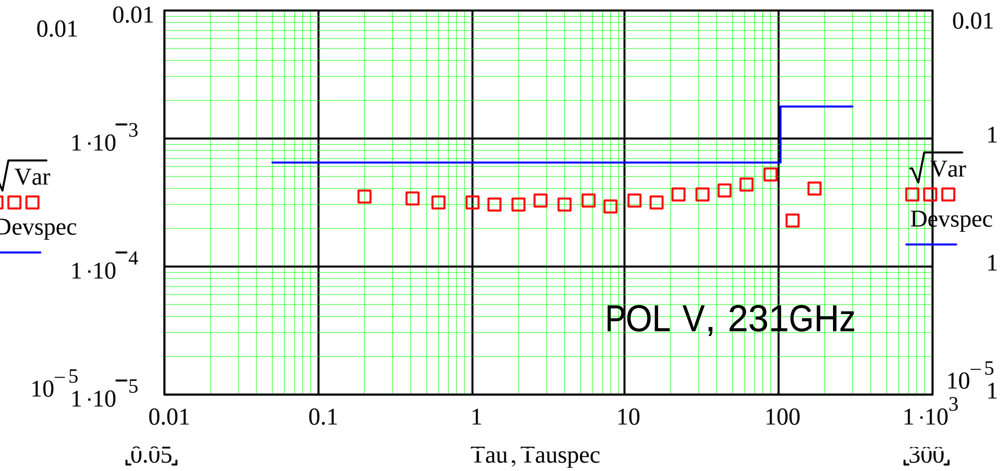
Plateau de receivers ~ EMIR (except for dual band modes) -> Only EMIR results are presented

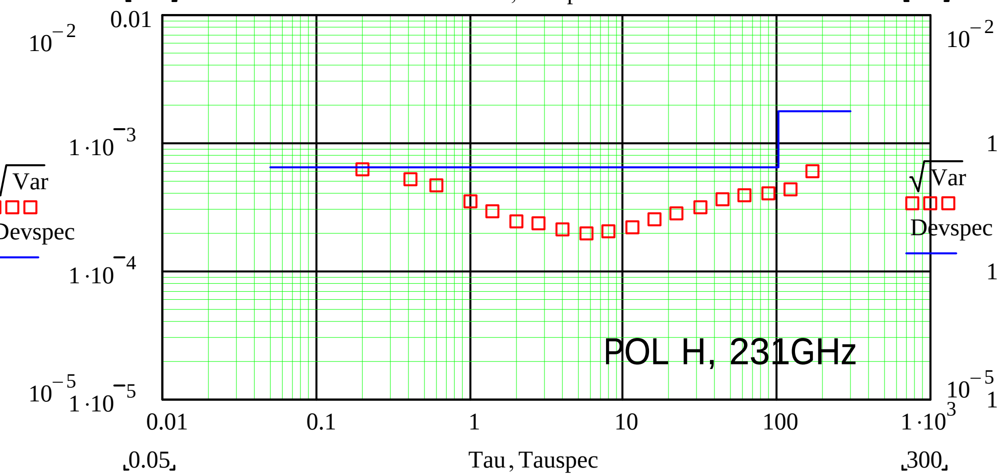
EMIR receivers, total power stability measurements



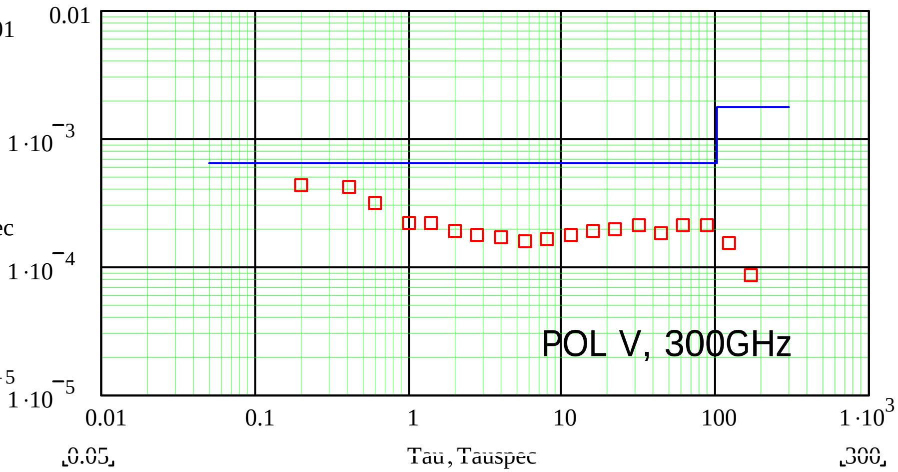
EMIR receivers, total power stability measurements

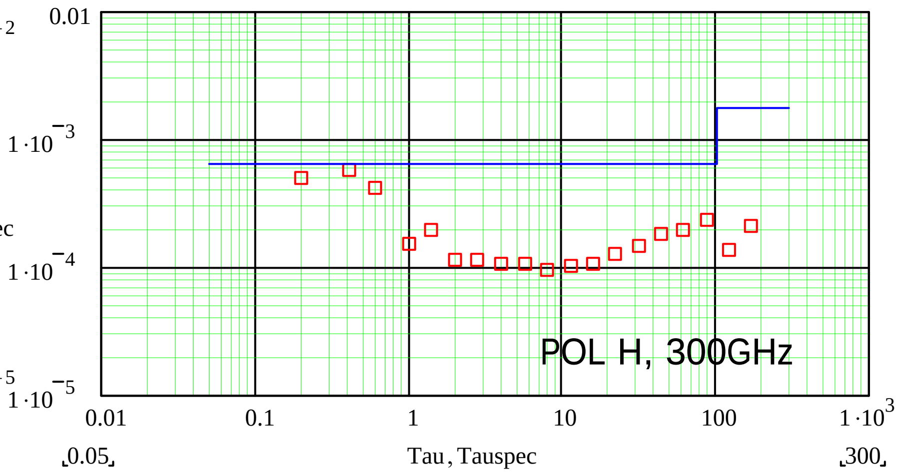
1.3mm band



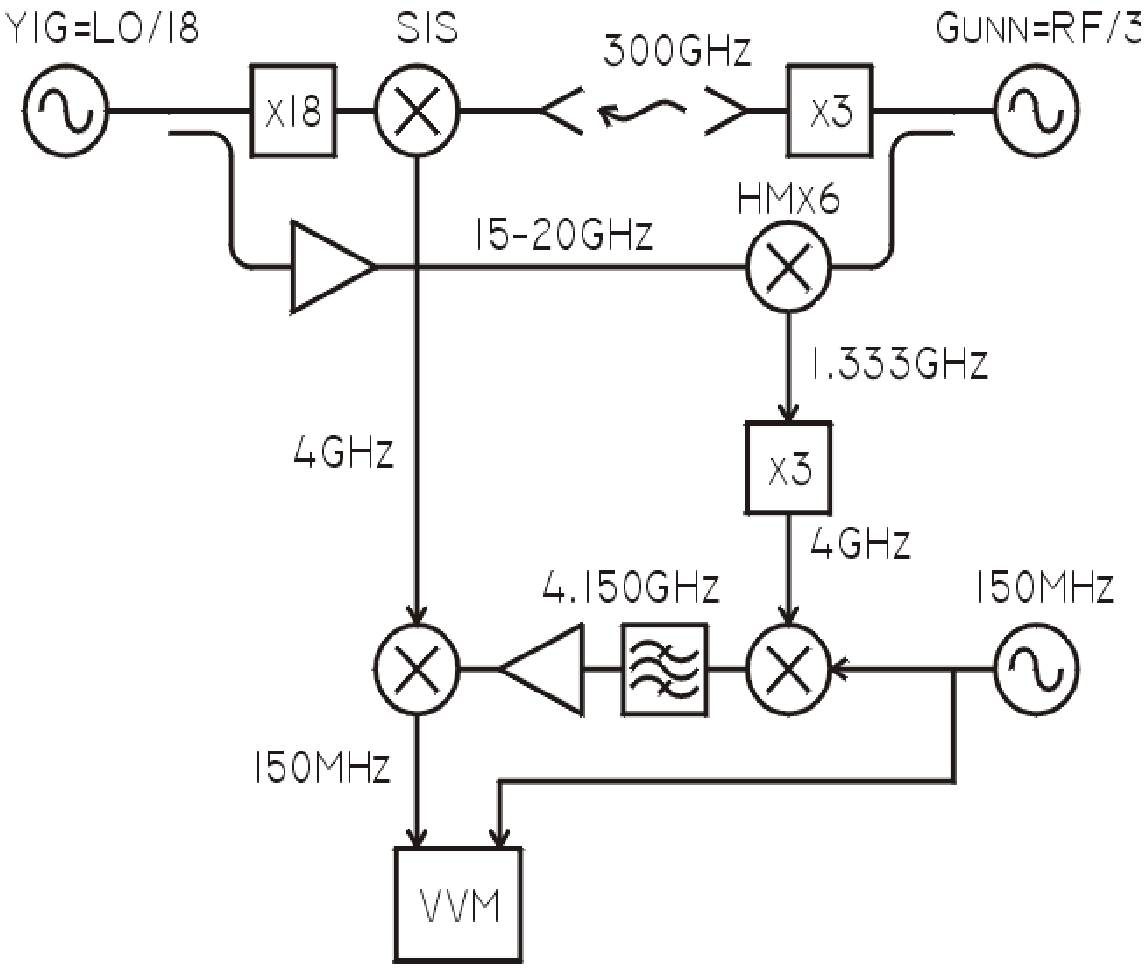


0.8mm band

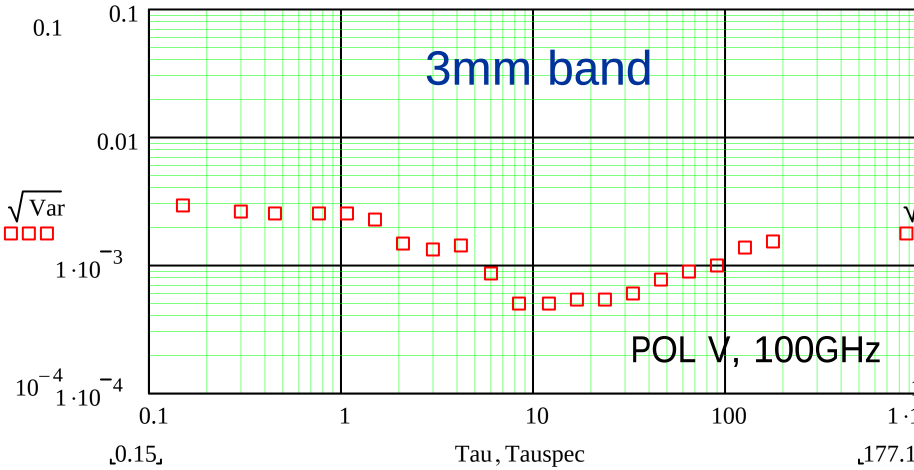


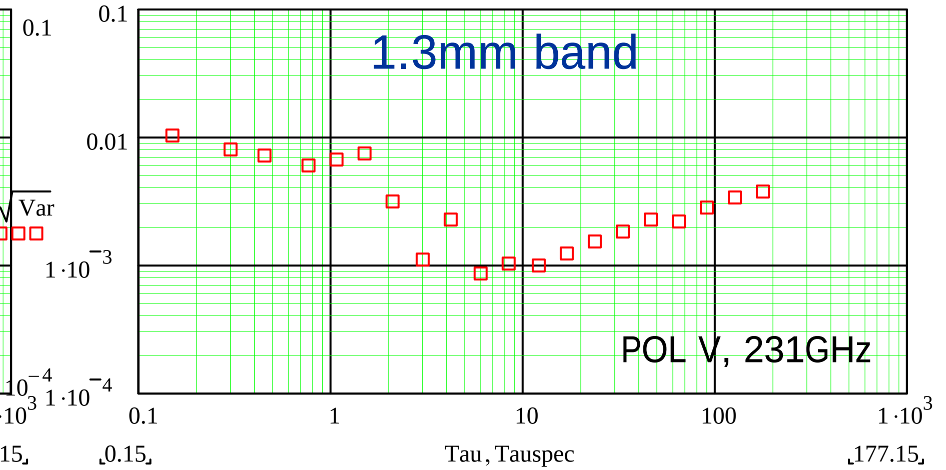


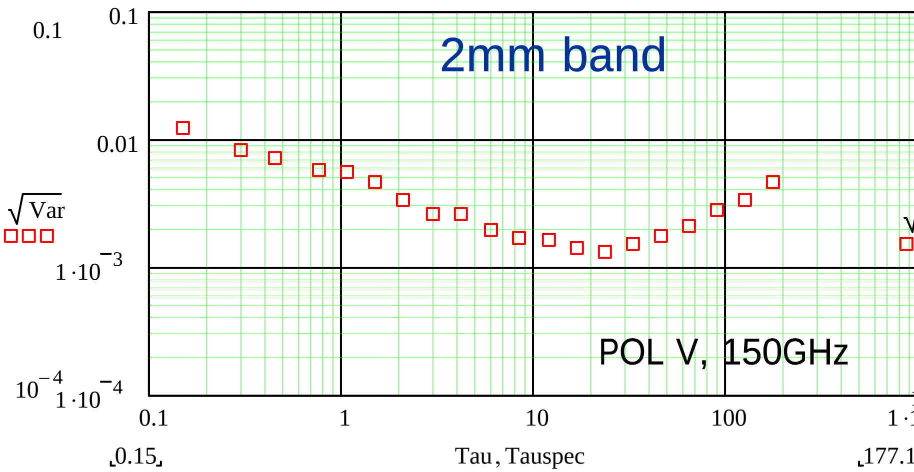
Phase Stability measurements test set (homodyne system)

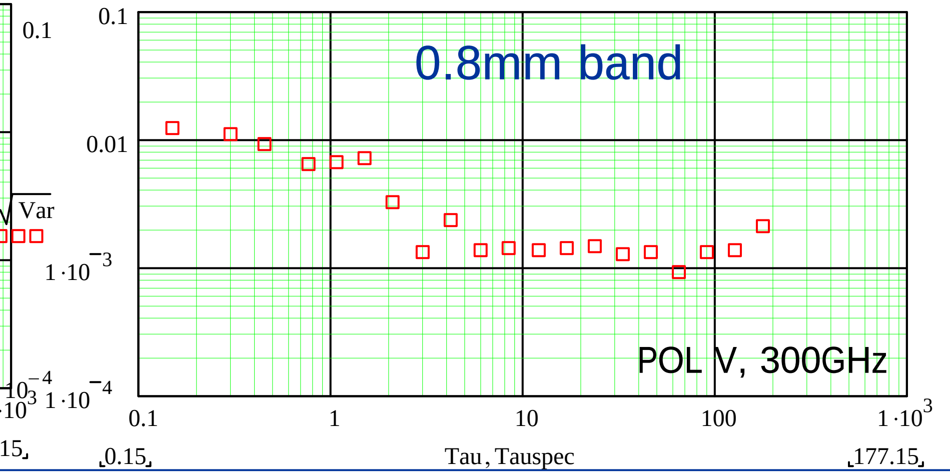


EMIR receivers, phase stability measurements

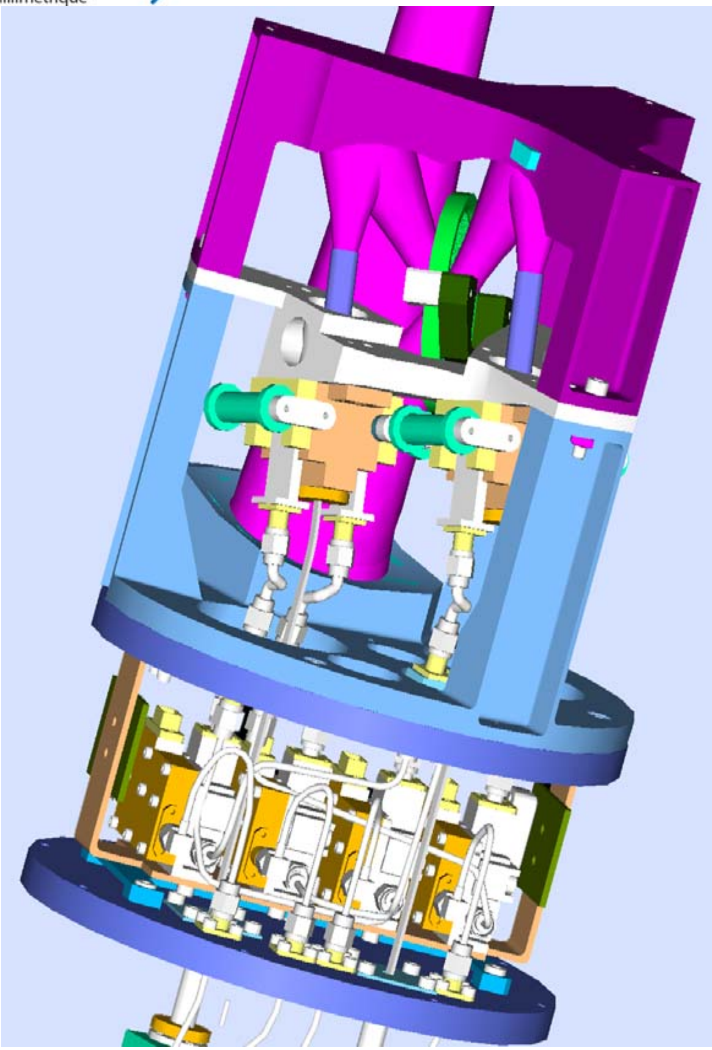


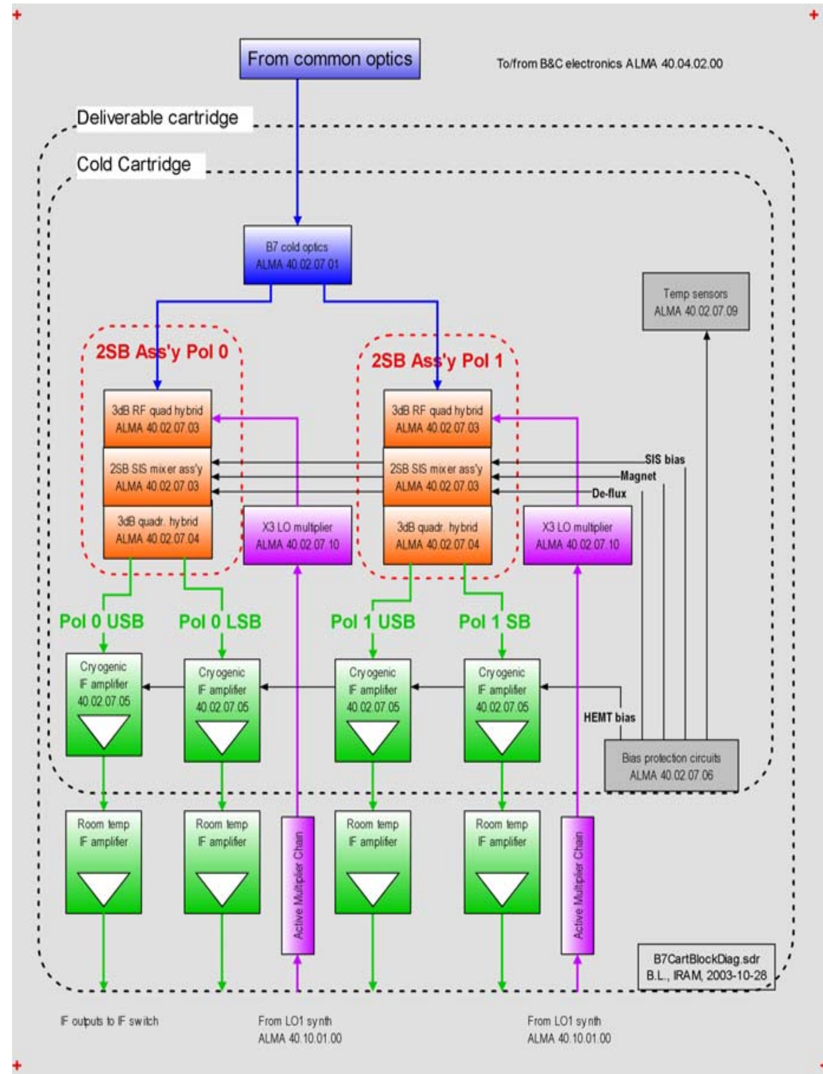




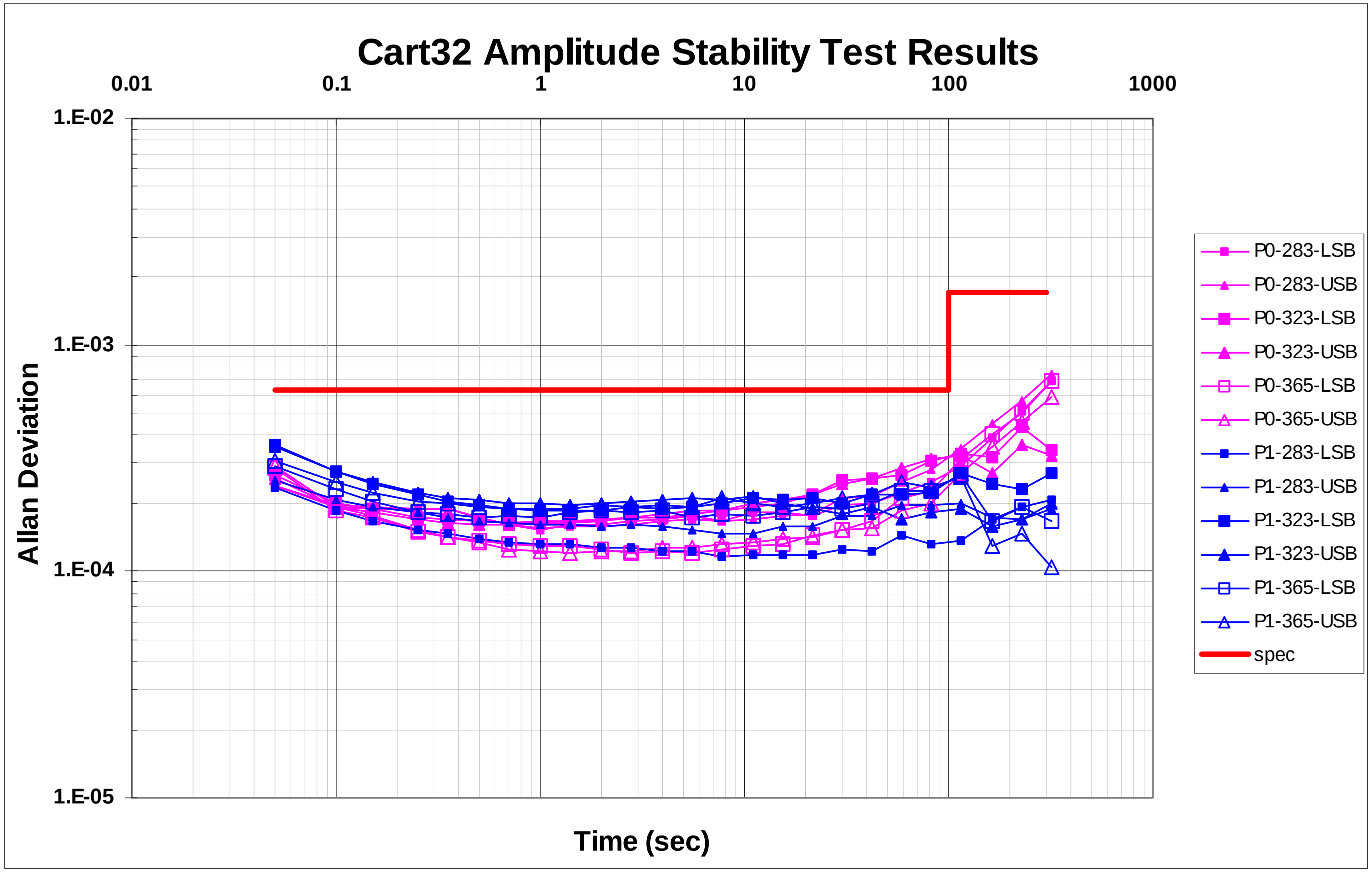


Band 7 Cartridge overview

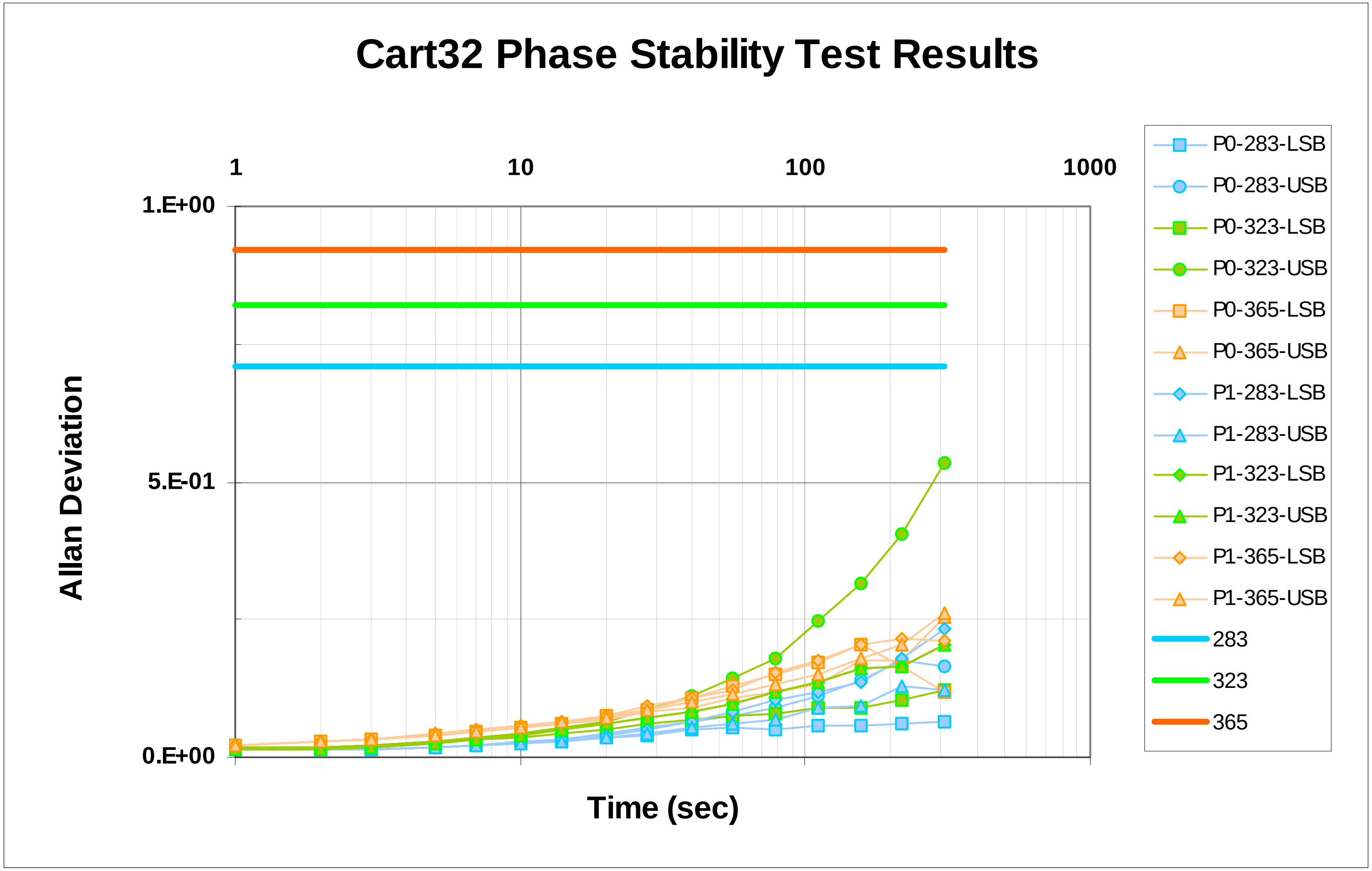




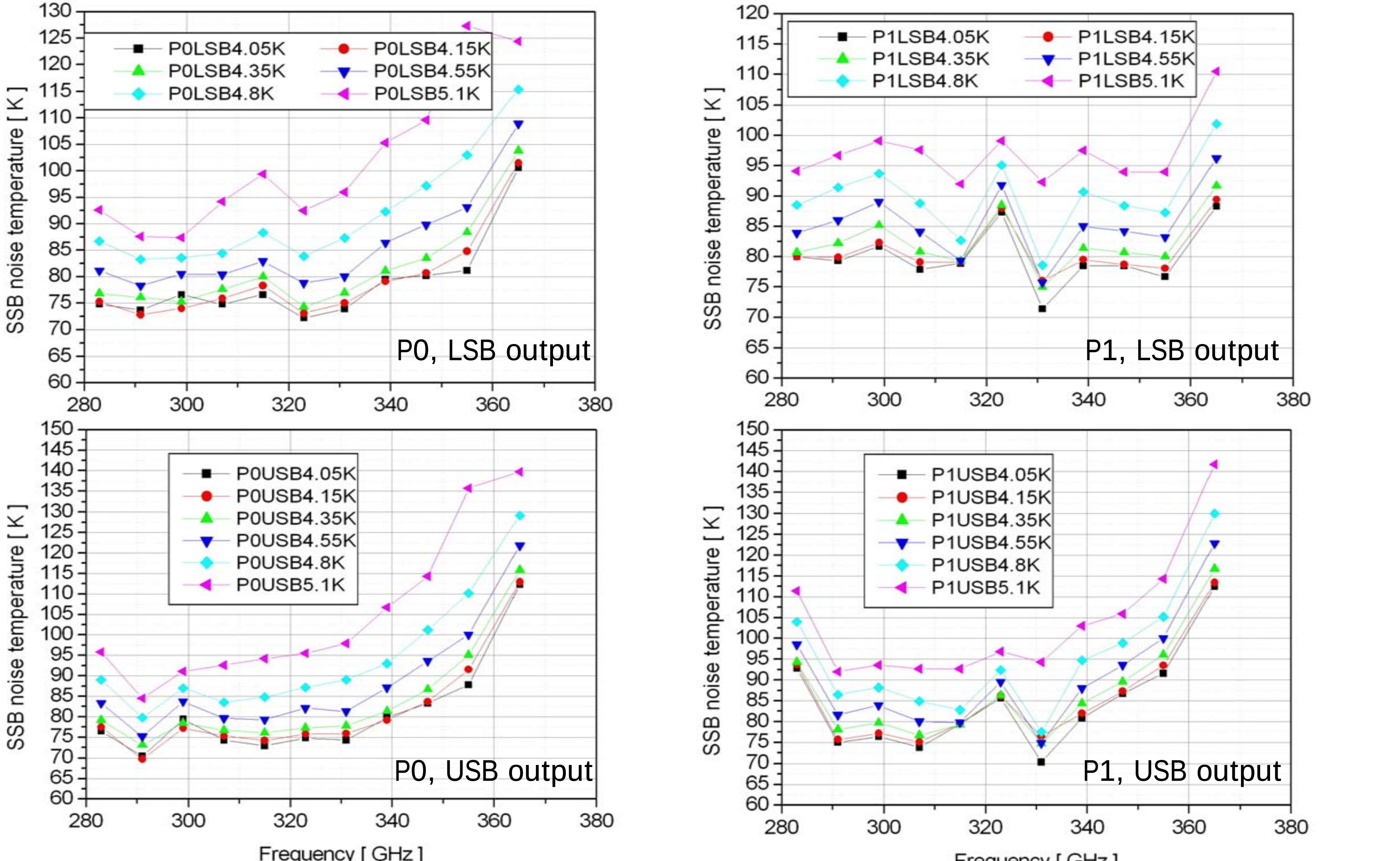
Total power stability measurements results (ALMA Band 7)



Phase stability measurements results



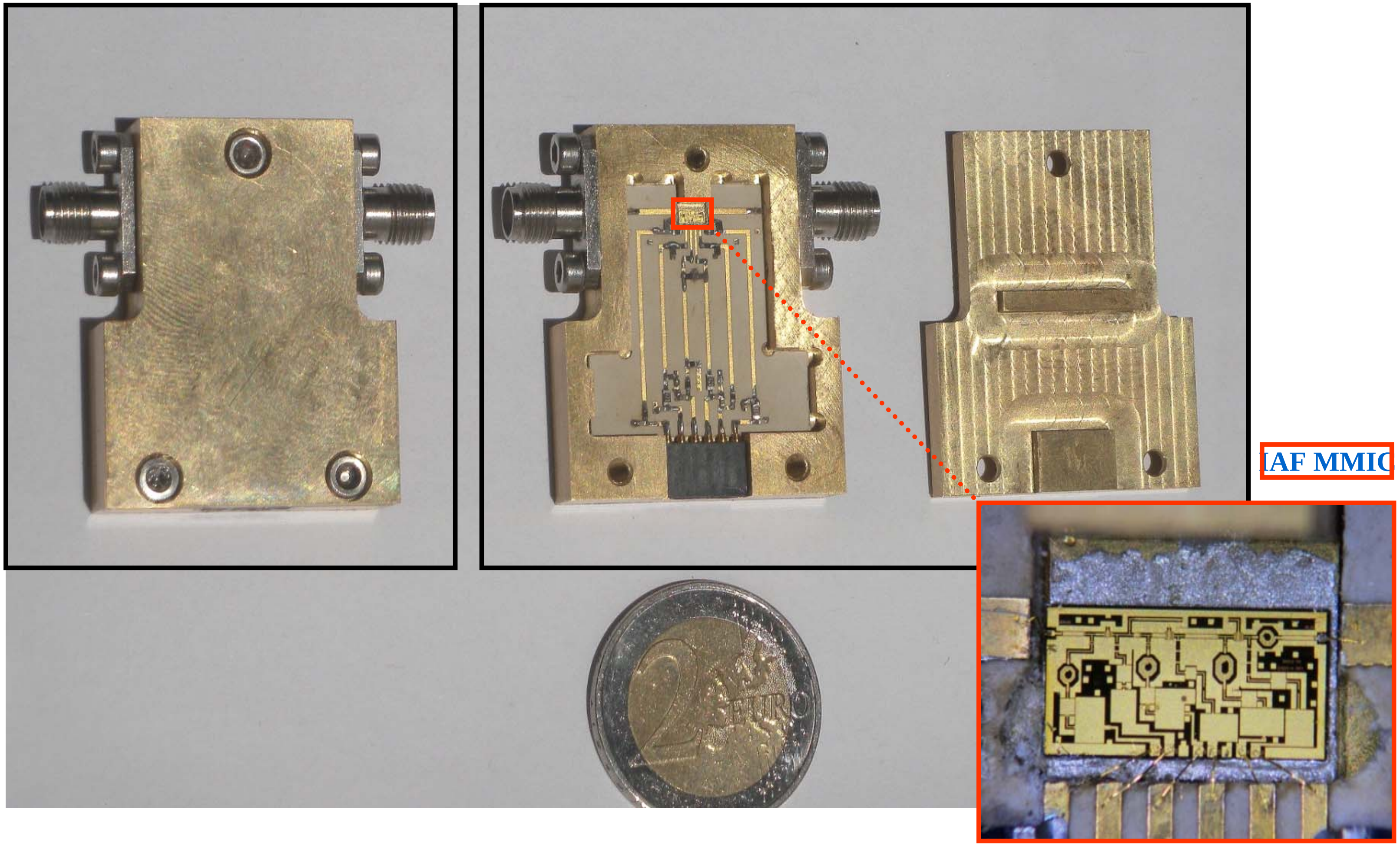
ALMA band 7: Noise temperature versus Mixer block temperature



4-12GHz Cryogenic HEMT Amplifier (AMSTAR+)

Assembled LNA

LNA with cover lid removed



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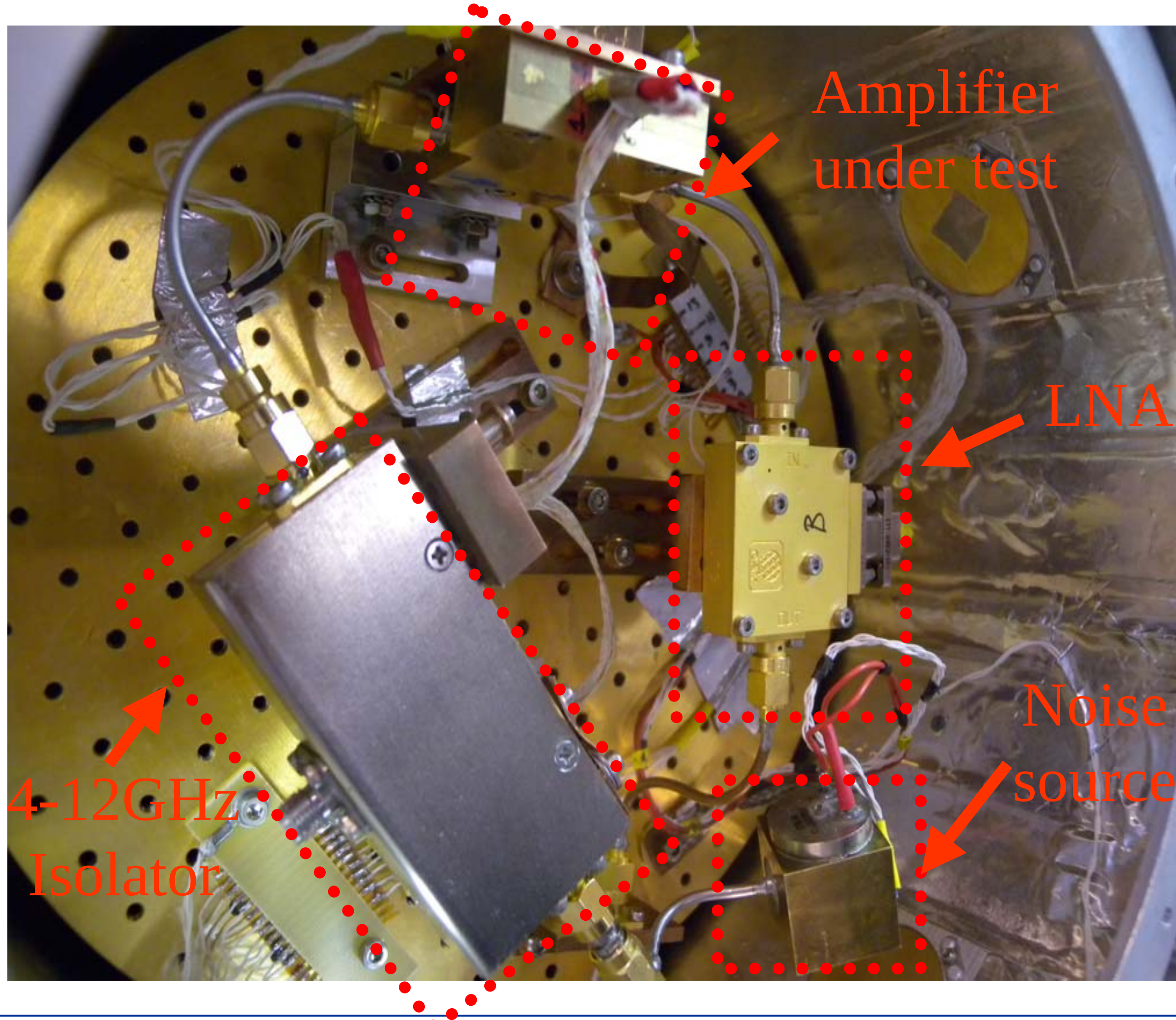
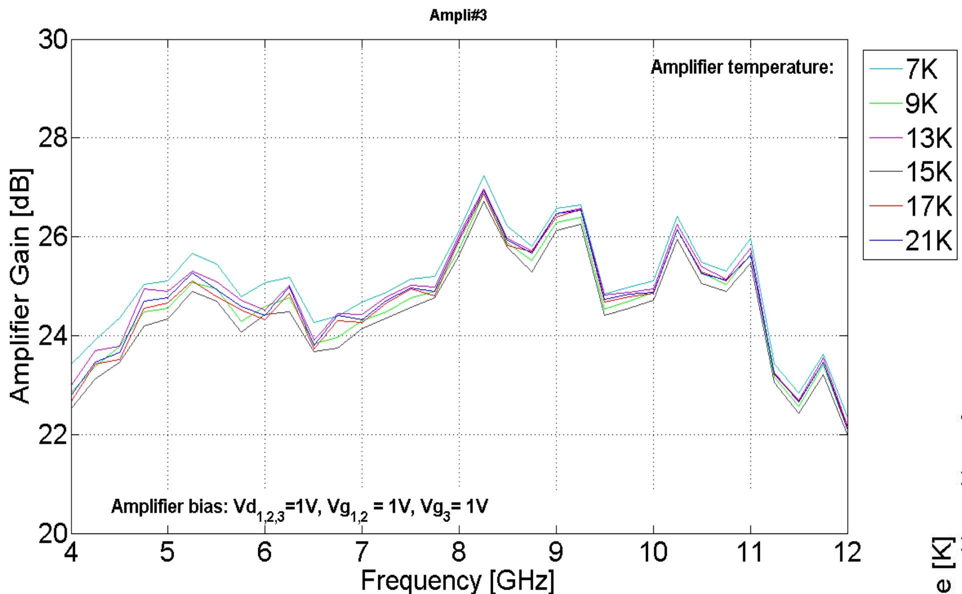
Noise and gain measurement



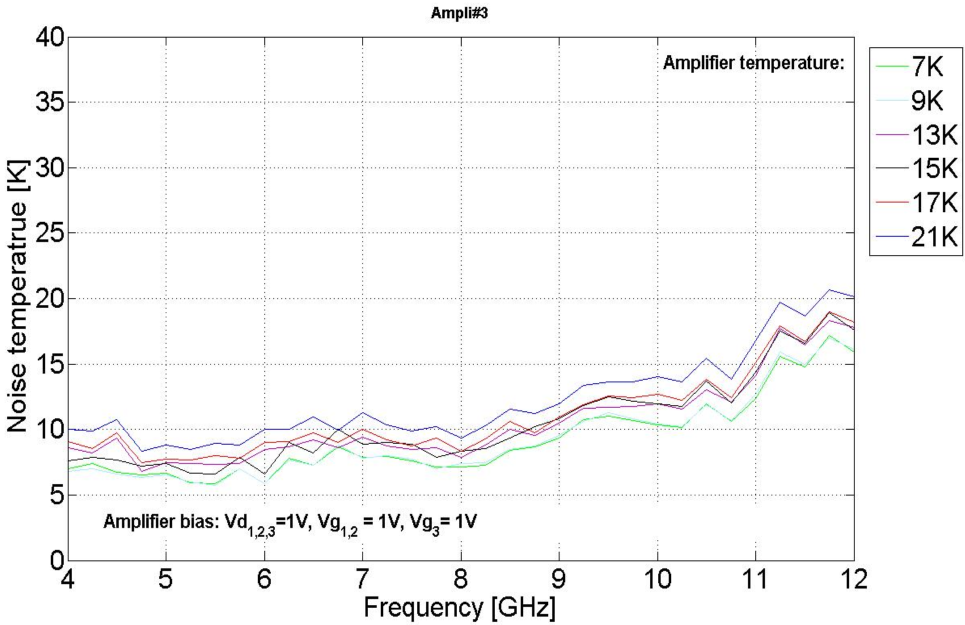
Dependence of LNA performance on physical temperature variation (AMSTAR+)



•No correlation between the gain fluctuations and the physical temperature variations was observed with this measurement.

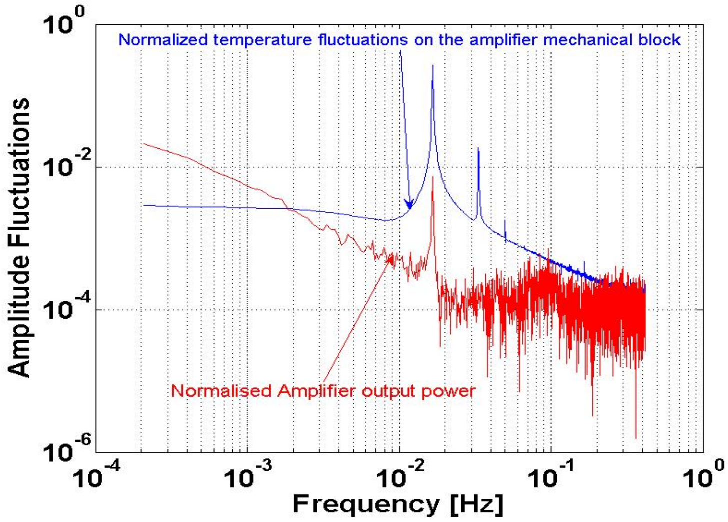
• Measured gain variations are principally due to the thermal drift of the measurement bench

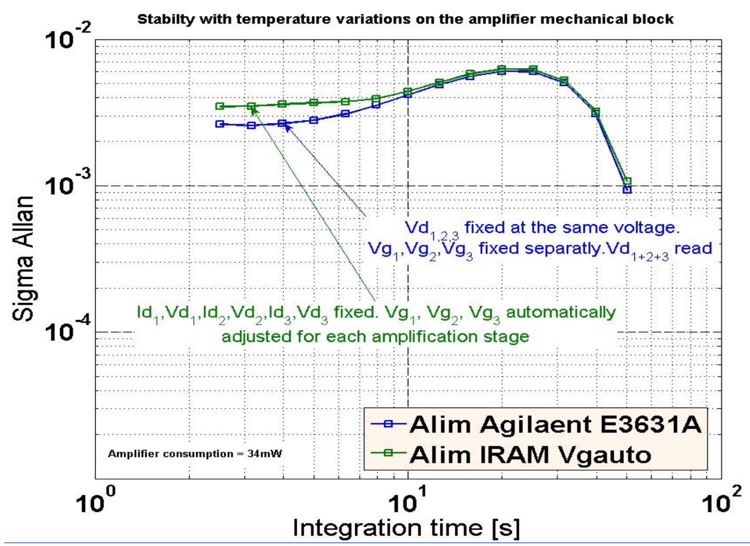
•2K are added to the noise temperature for 7K increase to the physical temperature.



Amplifier Temperature fluctuations

@~15K, 8GHz





- Temperatures fluctuations on the amplifier cause instability on the output power.
- The drain voltages can be whole connected without important difference on the noise temperature.
- It is not necessary to bias the amplifier with a gate voltage control (to keep the drain current constant) on each amplification stage.
- This measurement allows to appreciate the temperature stability needed on the (15K or 4K) cryogenic stage.

Thank you for your attention