APRICOT Kick-off
Cryogenic Amplifier and MMIC Projects at CAY
T4: Establishing accurate performance of LNAs

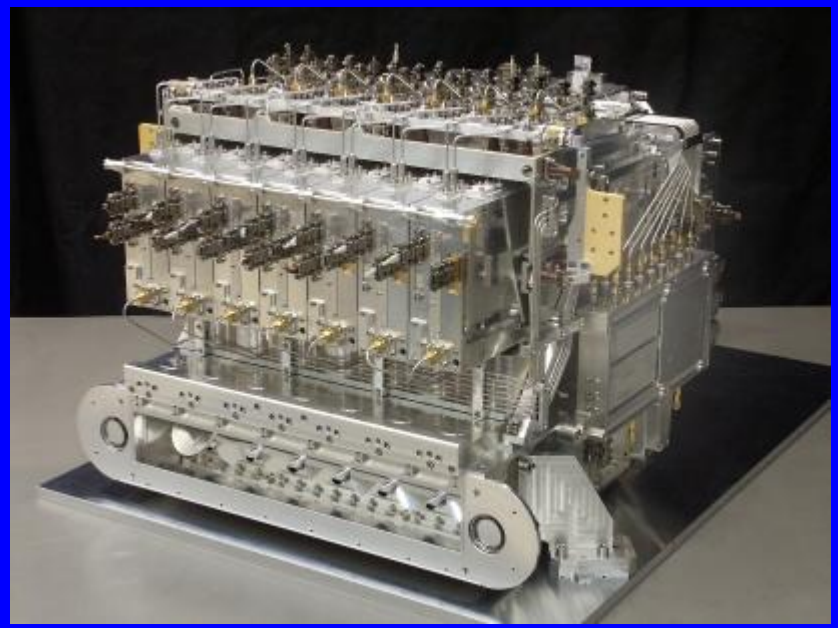
March 2009

RECENT PROJECTS

- HERSCHEL (HIFI) → TRW
- IRAM → ETH + HRL
- RT 40 m CAY (bands from 2.2 GHz to 26 GHz) → ETH + HRL + TRW
- ALMA (4-8 and 4-12 GHz) → HRL
- ESA (ESOC)
  - X-Band → ETH
  - Ka-Band (25.5- 34 GHz) → ETH
- EUROPEAN PROJECTS
  - FP6: AMSTAR (IFs for IRAM & SRON) → HRL
  - FF7: AMSTAR+, APRICOT → UMANCHESTER + IAF + OHMIC?

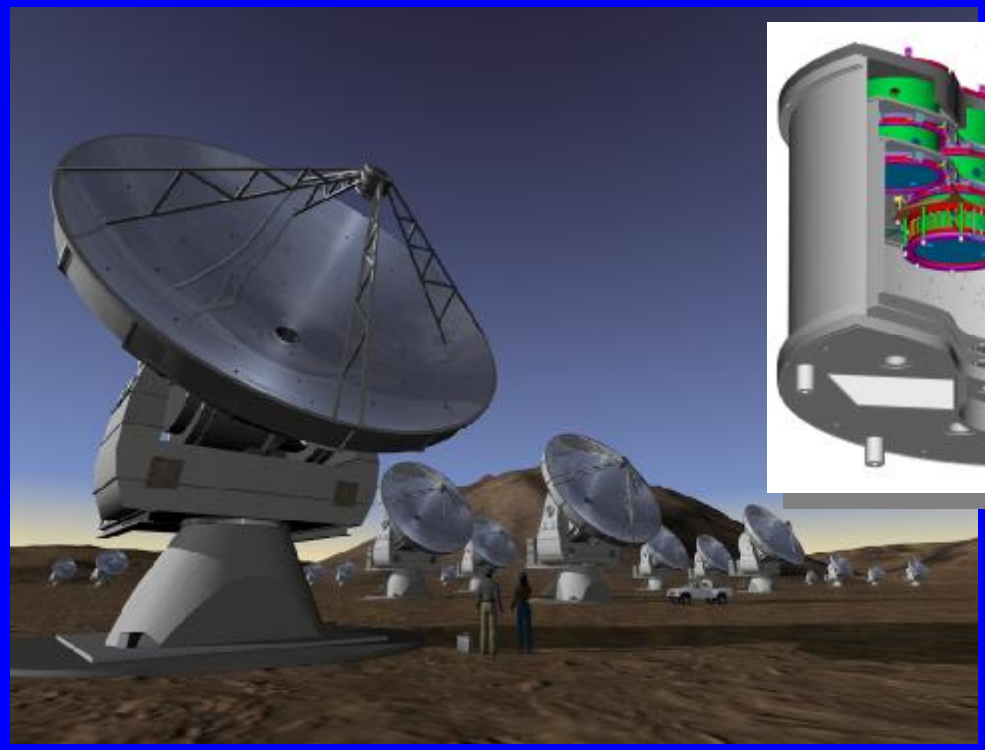
HERSCHEL (HIFI)

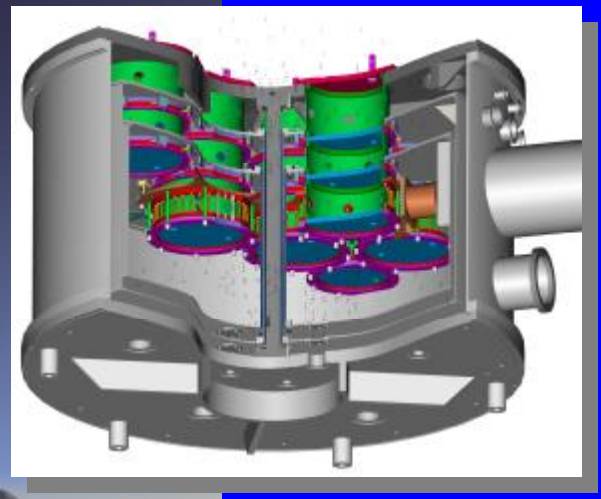
To be launched April 16 2009!

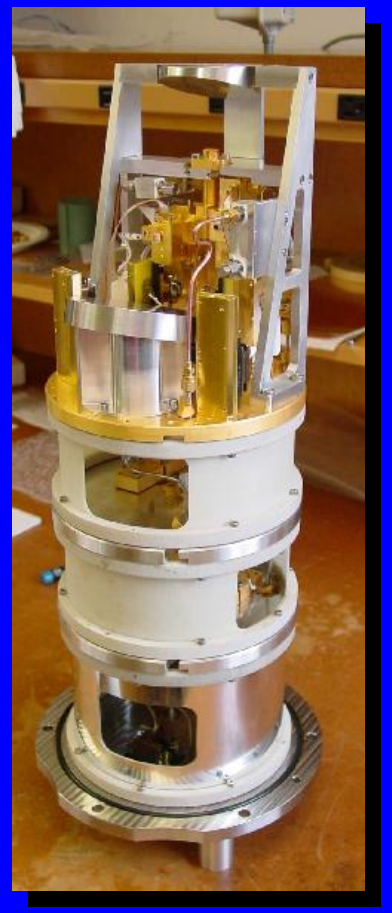


ALMA

- Array of 50×12 m antennas in Atacama, Chile with up to 10 km baseline
- Covers all atmospheric windows up to 1 THz
- **CAY contribution**: Cryogenic IF amplifiers for all European channels (IRAM, Band 7 and NOVA, Band 9)







ESOC (ESA)

- Deep Space Network
- Needed for missions like:
  - Venus express
  - Mars express
  - Rosetta
  - Herschel
  - Plank

FP6 (AMSTAR)

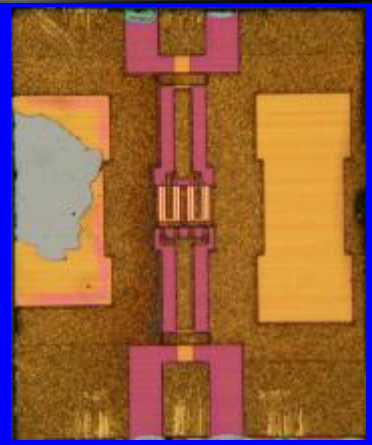
- Not much funding but interesting subjects and cooperation between top quality groups
- GOAL: to develop the future technology for Radio Astronomy
  - Example: Array of SIS mixer receivers driven by photonic LOs
  - 120-180 GHz Tn=60K DSB

IRAM

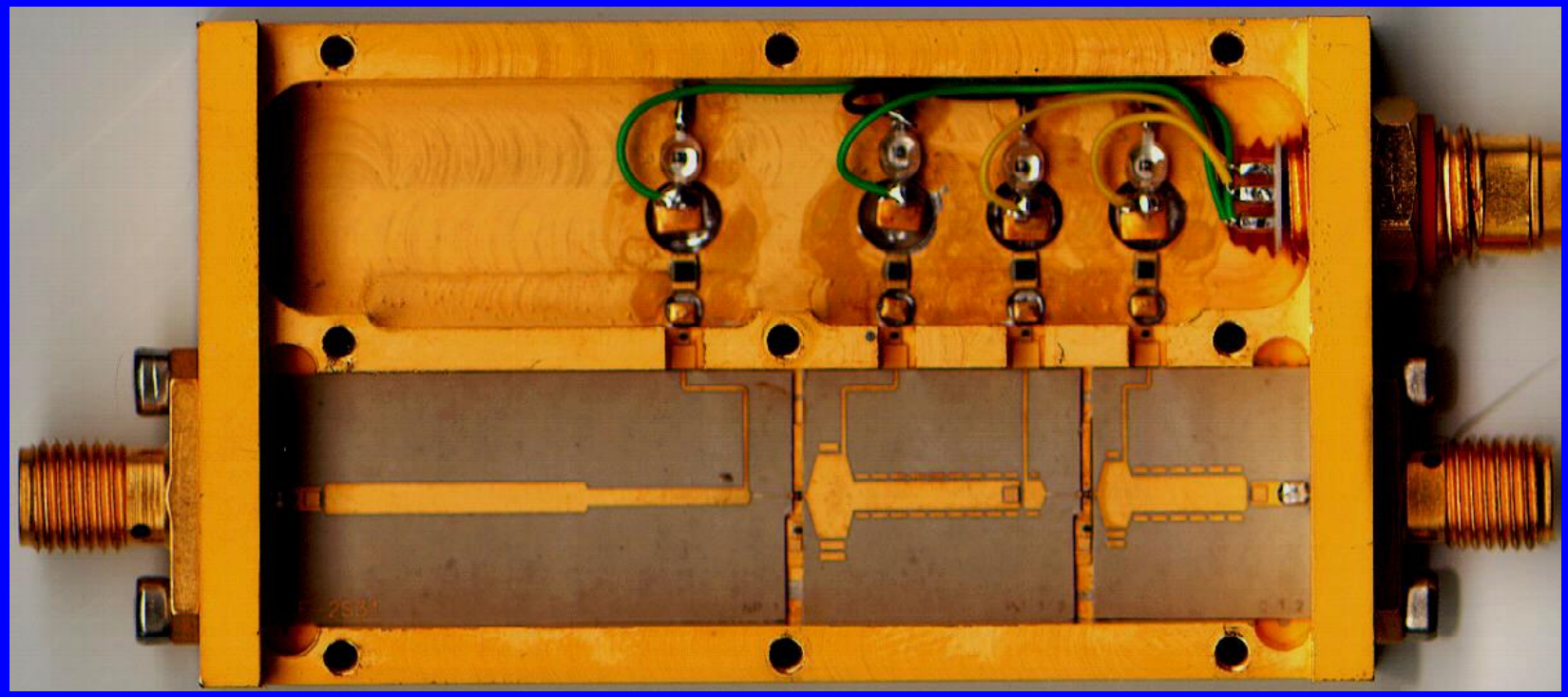
- 30m mm Antenna in Pico Veleta (Granada)
- Plateau de Bure Interferometer (France)

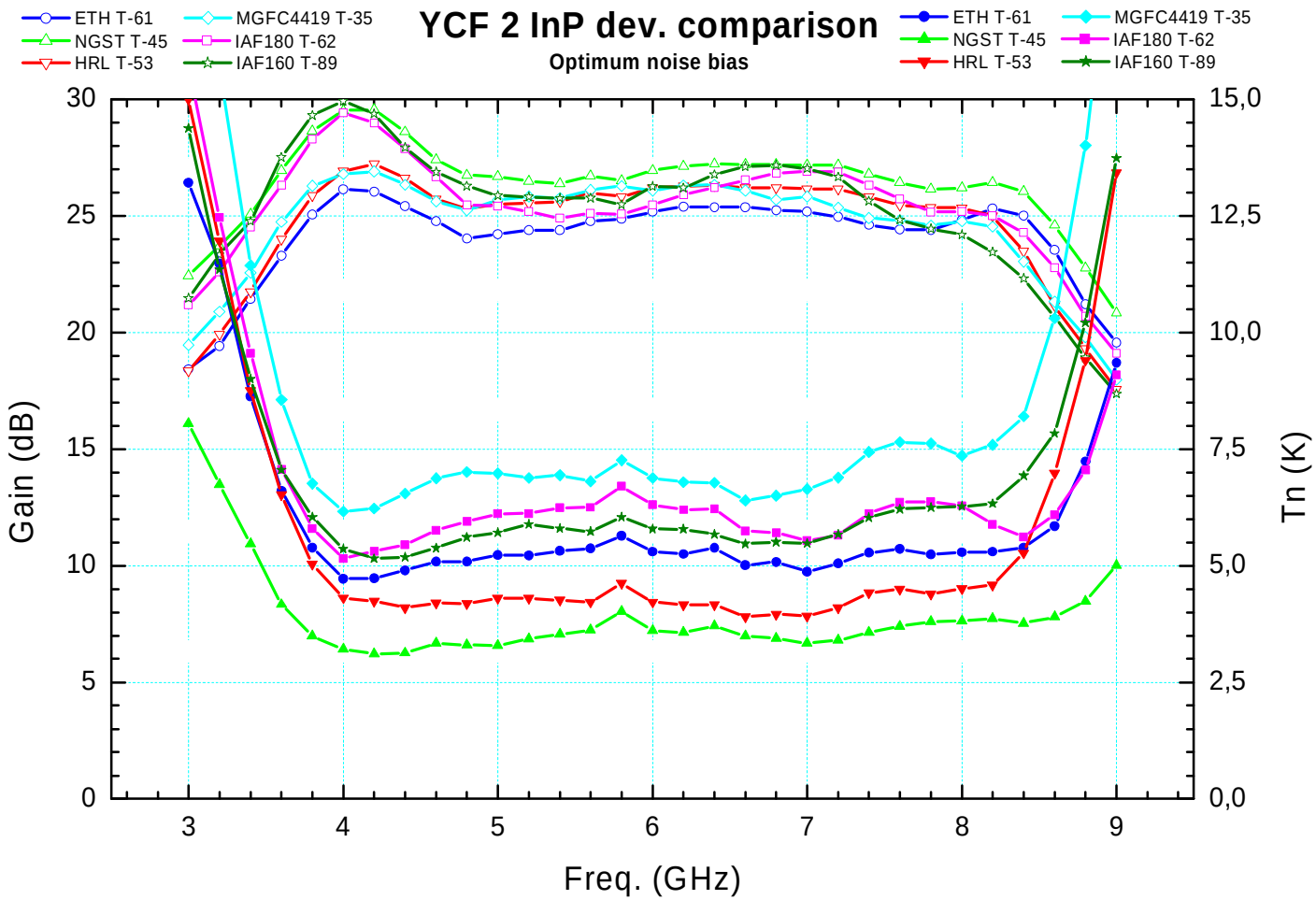
Experience with IAF devices

Tested for noise at 15 K in a 4-8 GHz and 18-26 GHz amplifiers

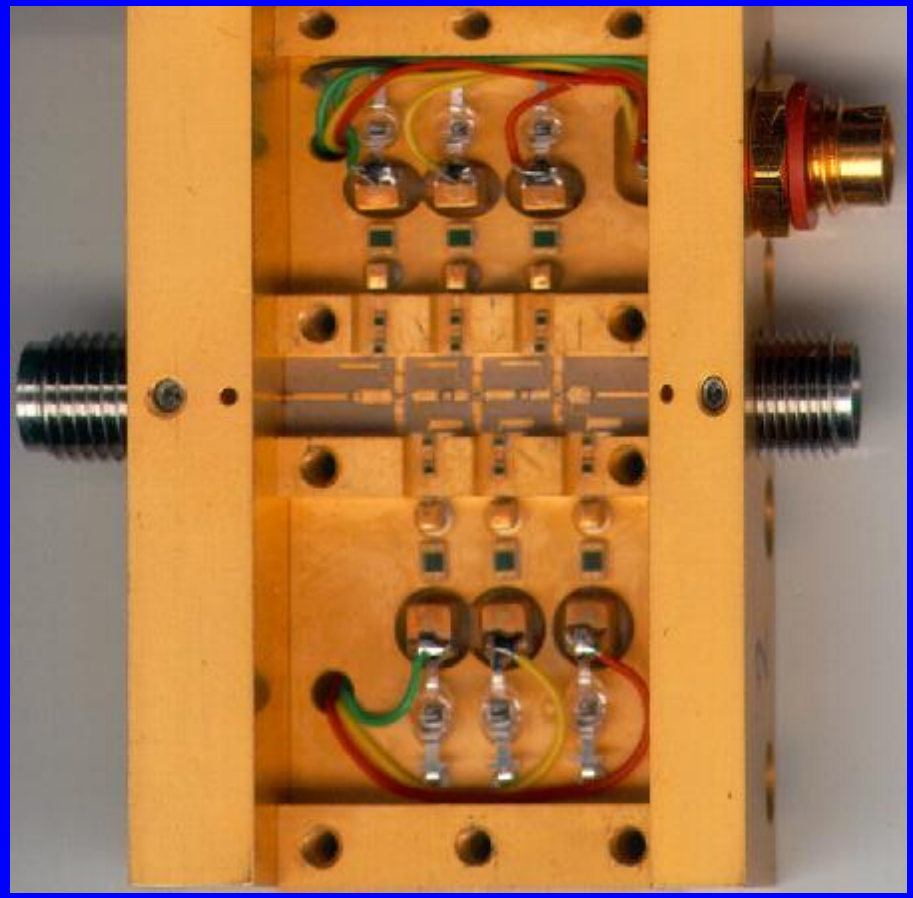


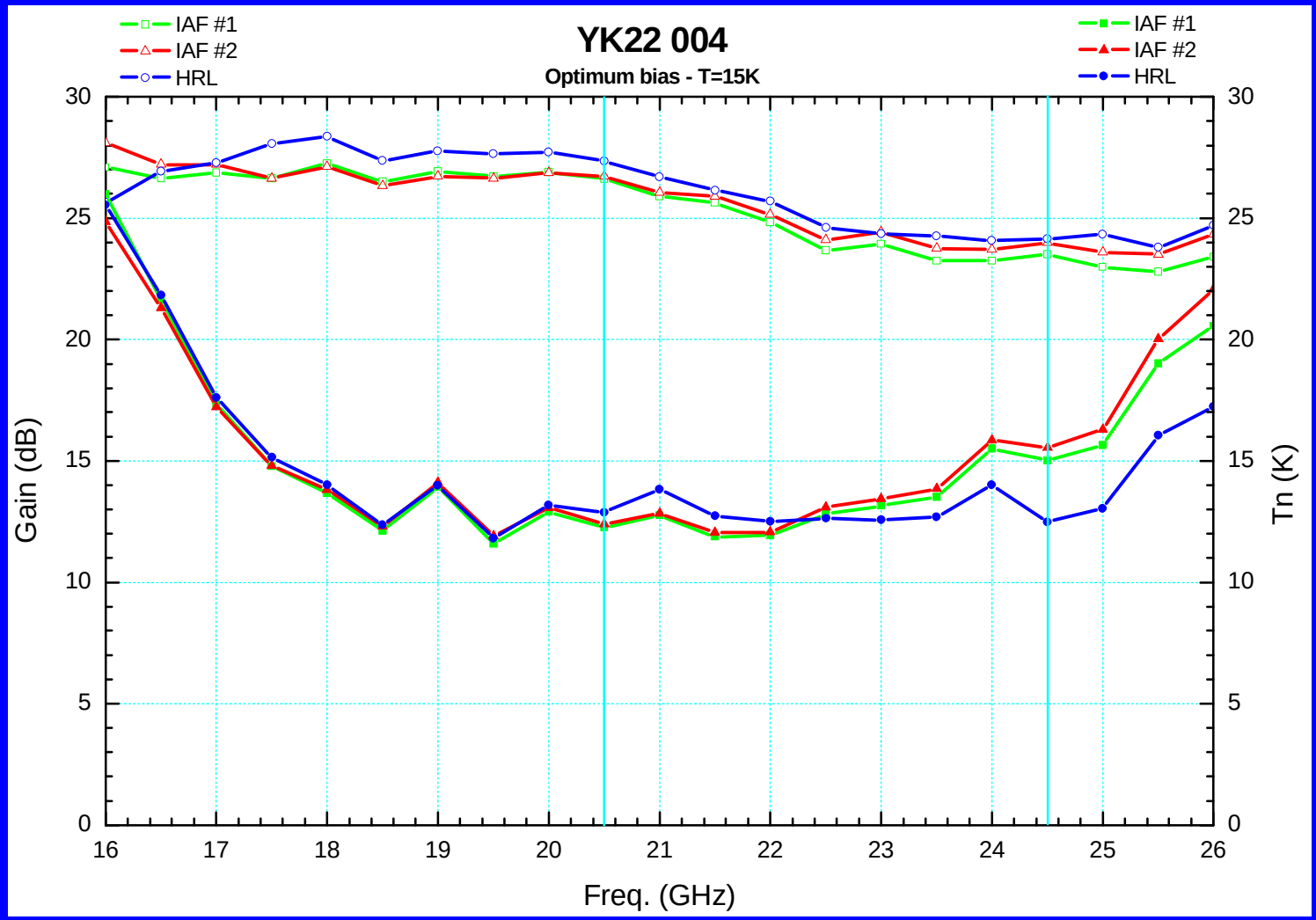
4-8 GHz “test” amplifier




YCF 2 InP dev. comparison
Optimum noise bias
ETH T-61
MGFC4419 T-35
NGST T-45
IAF180 T-62
HRL T-53
IAF160 T-89
Gain (dB)
Tn (K)
Freq. (GHz)
0
5
10
15
20
25
30
0,0
2,5
5,0
7,5
10,0
12,5
15,0
3
4
5
6
7
8
9

K-BAND (20.5-24.5) VLBI




YK22 004
Optimum bias - T=15K
IAF #1
IAF #2
HRL
IAF #1
IAF #2
HRL
Gain (dB)
Tn (K)
Freq. (GHz)
0
5
10
15
20
25
30
16
17
18
19
20
21
22
23
24
25
26

Agreement UC-CAY-IAF

- 4 years, (mid 2008 - mid 2012)
- Investment (own funds): 260 + 120? = 380 K€

- Main goals:
  - Funding one post-doc level position for a person working at IAF
  - Improvement of Metamorphic technology for cryogenic LNAs competitive with InP
    - Discrete
    - MMIC
  - MMIC development in the 25.5-34 GHz band (ESOC K-Ka)
  - MMIC development for 4-12 GHz (ALMA-IRAM IF)
  - Other projects of interest for RA if time and funding is available

Yebes view of Technology Development at IAF (1)

- Very ambitious goal: 13 K in Q band
- Competing with long and expensive developments in cryogenic InP: NGST (TRW) and HRL
- The devices should be optimized for Low Noise at Cryogenic Temperature. A rational and effective approach is needed. Ideally:
  1. Development of technology (devices)
  2. Establish good device models based on measurements (needed for MMIC design)
  3. Design of MMICs
- Direct way to FAILURE: Designing a MMIC based on ambient temperature models to see how it performs at cryogenic temperature

Yebes view of Technology development at IAF (2)

- PHASE 1 (6-12 months?):
  - Establish “canonical” transistors
  - Characterize several runs
  - Measure them at Tcryo
    - On Wafer (SPAR)
    - On MIC Amps
  - Establish Transistor Models
  - Design “validating” MMICs (AMSTAR+ & APRICOT)

- PHASE 2:
  - Each institute prepares its own design. Selection of priorities and distribution of wafer space by APRICOT internal agreement (2 months?)
  - Decision of the procedure to produce the final MMICs (multi-project runs, joining AMSTAR and ordering a complete wafer….)

T4: Establishing accurate performance of LNAs

- Based on long experience in building and testing cryogenic amplifiers with many different devices
- Measurement of discrete devices mounted in a “test” amplifier for “fair” comparison (4-8 GHz or 18-26 GHz)
- Dedicated measurement cryostats already in place
- Measurement of gain fluctuations of devices (based on the experience and procedures used used for HERSCHEL & ALMA)
- Transfer standard for circulating between partners
- Problem: Budget constraints may limit upgrading measurements capabilities up to Q band.

Measurement Cryostat

Recent experience on Gain Fluctuations

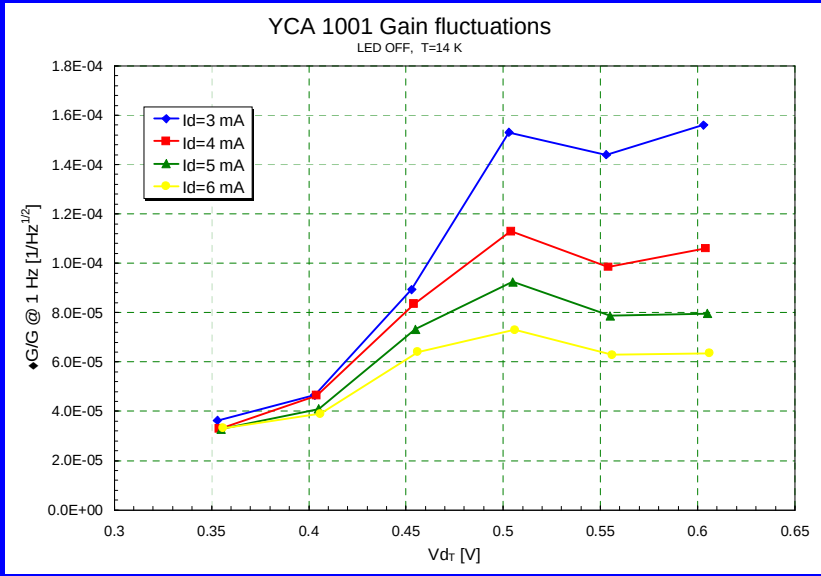
- Gain fluctuation should be specified in terms of spectrum (SNGF) or Allan Variance. (corner freq. is dependant on IF BW)
- Method of measurement of SNGF and AVAR defined in:
  ALMA memo #560 (Oct 2006)
- Specs for ALMA:

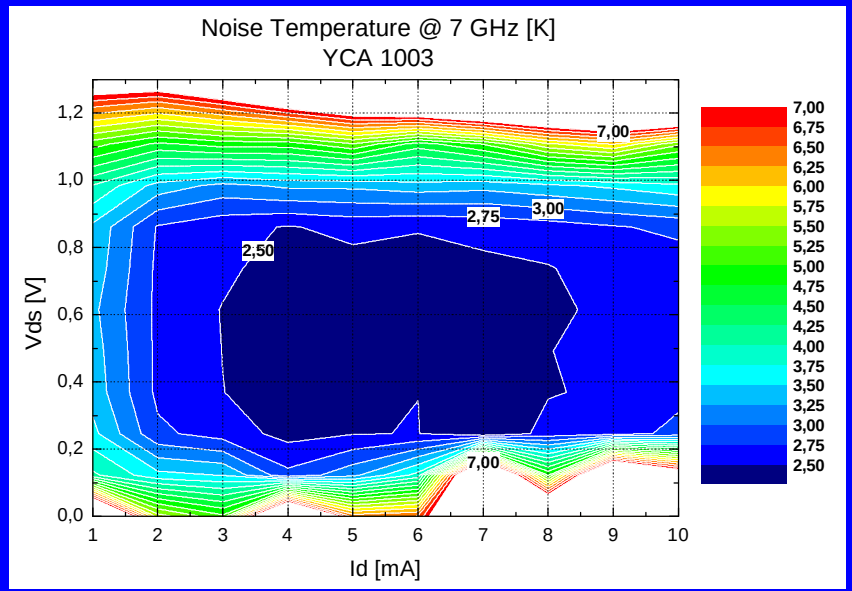
$$\begin{cases} \sigma^2(\tau) \le 2 \cdot 10^{-8} & 0.05 \le \tau \le 100 \quad (\text{sec}) \\ \sigma^2(\tau) \le 2 \cdot 10^{-9} & 100 < \tau \le 300 \quad (\text{sec}) \end{cases}$$

- Specs for HERSCHEL:

$$\Delta G_n = 1.4 \cdot 10^{-4} \; {}^{1}\!/\!_{\sqrt{Hz}} \quad @1 \cdot Hz$$

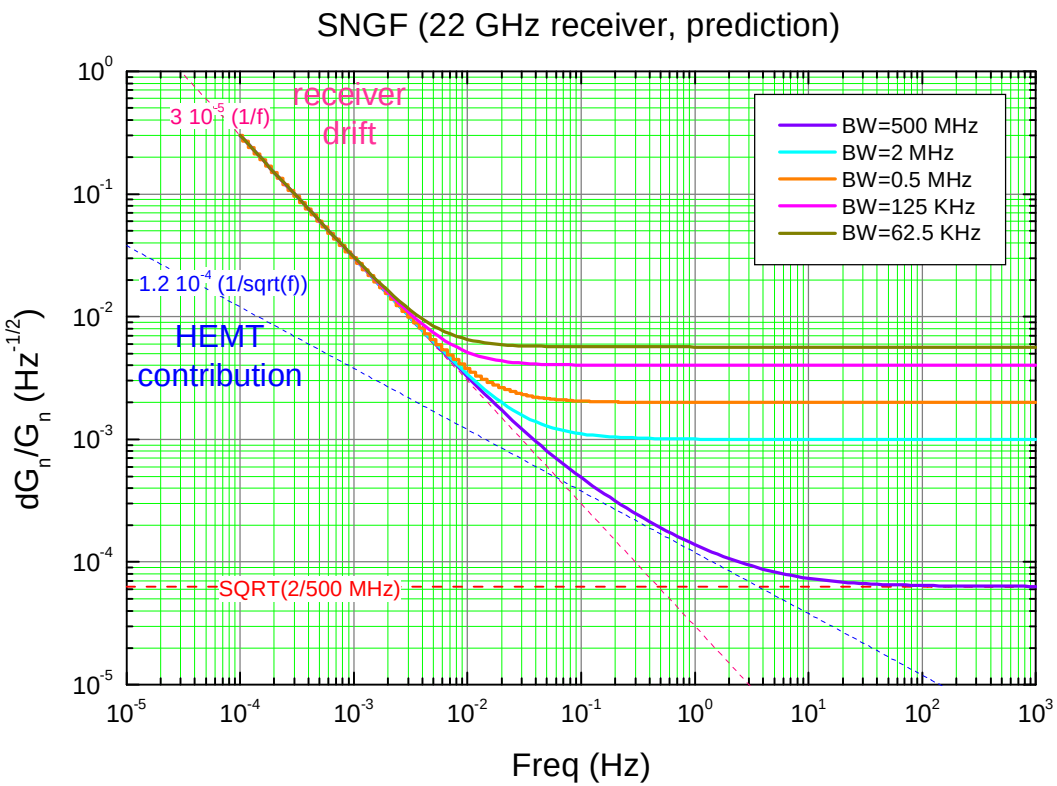
Gain fluctuations of LNAs should be characterized





- Bias dependence of Gain Fluctuations and Noise follow a different law!
  - Noise (and gain) are much more insensitive to bias changes
  - High fluctuation zones could be avoided with no penalty in noise or gain

Example: 22 GHz receiver, InP devices



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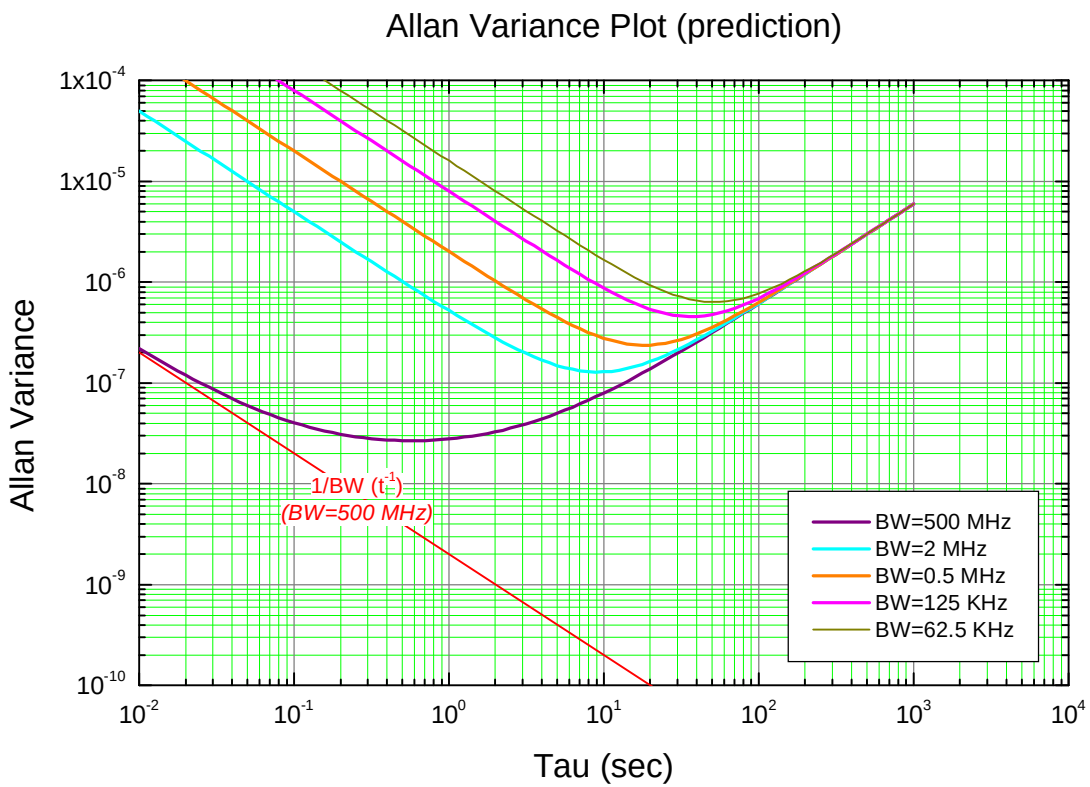

Deliverables:

- Tests of Noise & Fluctuation performance of discrete devices (month 18 and month 30)
- Transfer Amplifier Standard (month 24)
- Test of Noise & Fluctuation performance of MMICs (month 24 and month 35)

Deliverables to EC are reports on these subjects

Use of FP7 funds by FG-IGN

- A person (recent graduate, PhD student) will be hired. The founding comes from:
  - 1/3 APRICOT
  - 1/3 AMSTAR+ (IRAM WP)
  - 1/3 AMSTAR+ (SRON WP)

- Travel reimbursements (meetings, etc)