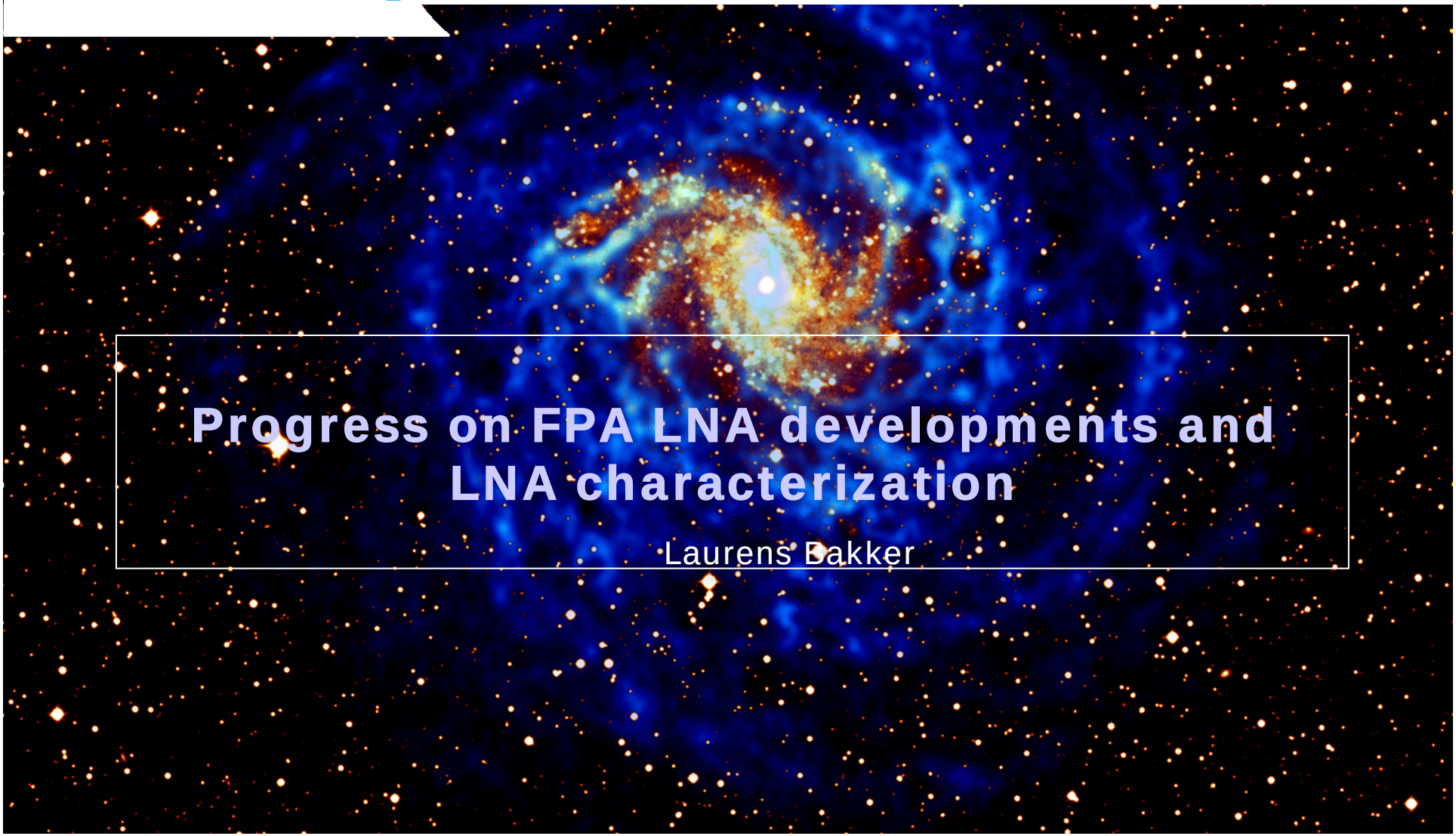
ASTRON



# Progress on FPA LNA developments and LNA characterization

Laurens Bakker

# Outline

- Brief introduction APERTIF
- Focal Plane Array LNA developments
- Noise measurements
- Future work

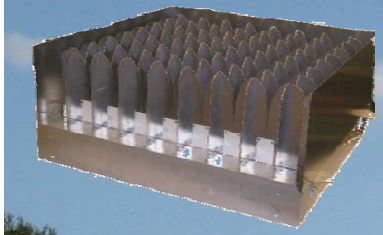
# APERTIF (APERture Tile In Focus)

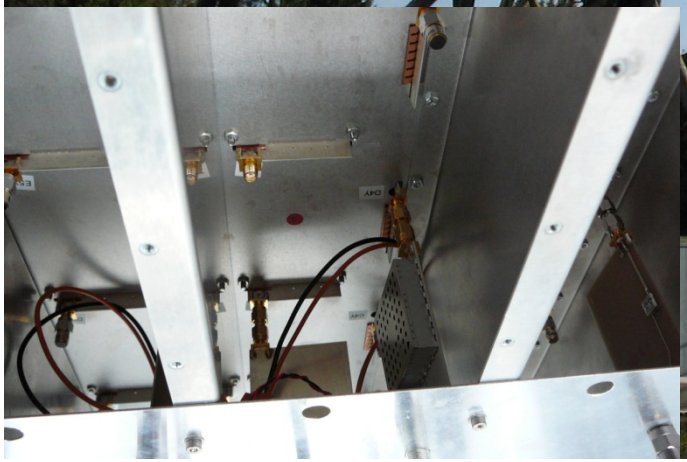
- APERTIF aims to increase the field of view of the WSRT with a factor 25
  - survey speed increase with factor ~20.
- Enables new astronomical science, especially large surveys
- Operational in 2012
- Only feasible with dense Phased Array Feed (PAF) technology

| | |
|---|---|
| • Frequency range | **1000 – 1750 MHz** |
| • Instantaneous bandwidth | 300 MHz |
| • System temperature | **< 55 K** |
| – Couple of thousand LNAs required | |
| • Aperture efficiency | 75% |
| • Polarization | Dual linear |
| • Beamforming | All digital |
| • Number of simultaneous beams | 25 dual pol |
| • Field of view | 8 deg$^2$ |
| • Dish | |
| – diameter | 25 m |
| – f/D | 0.35 |
| – equatorial mount | |

# APERTIF prototype

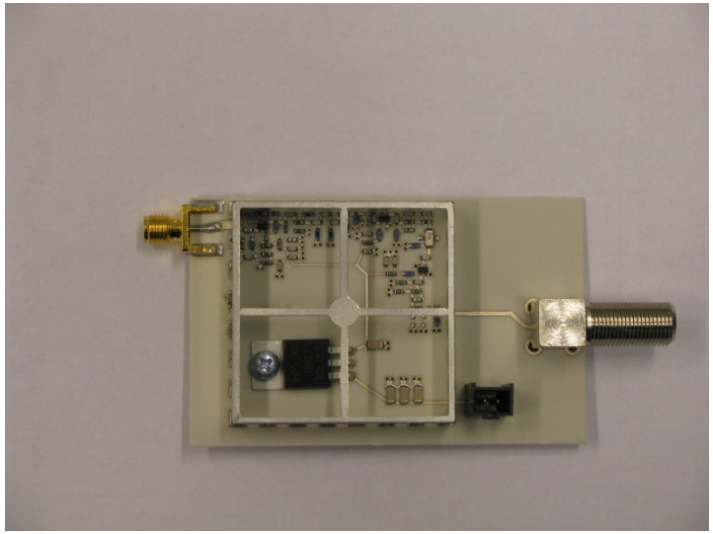
FPA for the WSRT
One dish fully dedicated to FPA
8 x 7 x 2 elements Vivaldi array
Dual polarisation
60 Receiving chains
Frequency range 1.0 – 1.7 GHz
30 MHz bandwidth
Element separation: 10 cm
($\lambda/2$ @ 1.5 GHz)
Data recording backend
**Tsys ~120K ($T_{LNA}$ ~70K)**





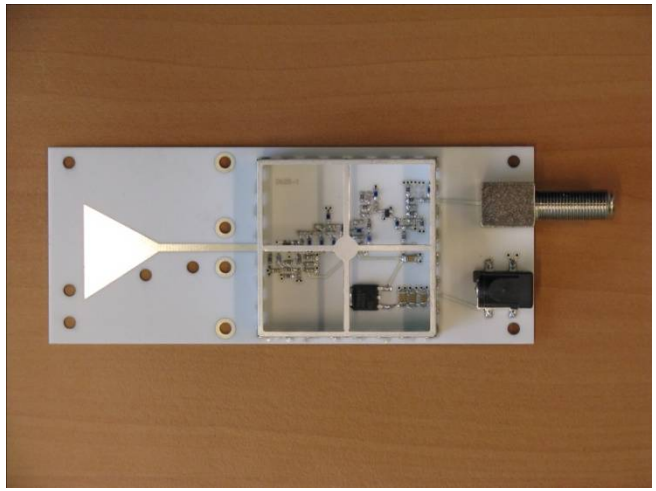
# First generation LNA

- Design for 50ohm input impedance
- >40 dB gain (flat)
- HPF with 25dB attenuation at 800MHz
- 3 stages, with high pass filtering after first stage and second stage
- Reasonable S11
- OIP2 first stage ~45dBm
- Sma input connector (50ohm)
- F-connector output (75 ohm)
- 120 devices installed in prototype
- LNA based on ATF-54143 ->low Rn

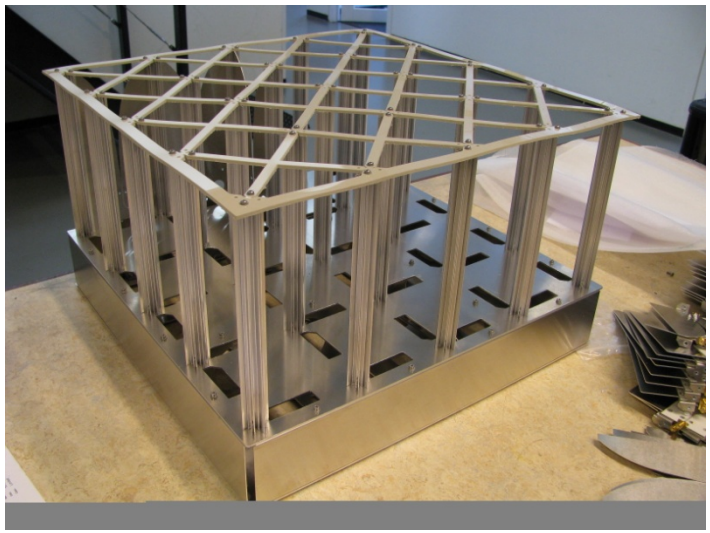


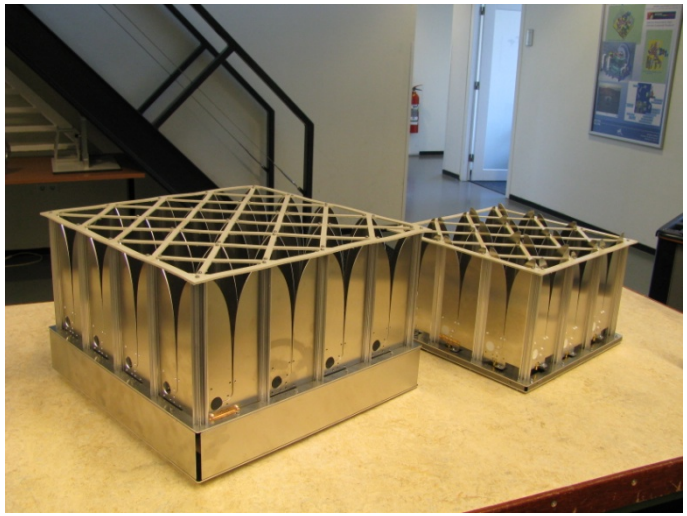
# Second generation LNA

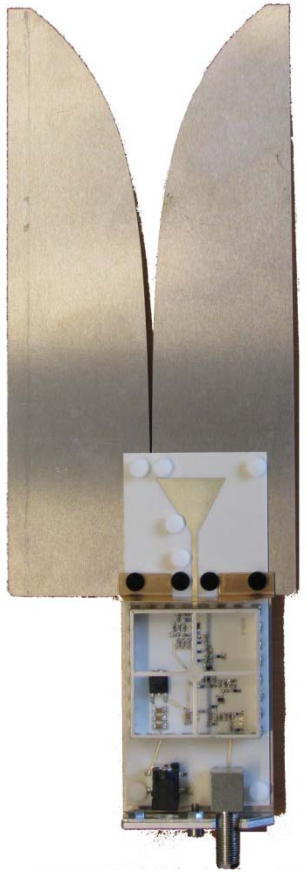
- Feed integrated with LNA
- Design for 50ohm input impedance
- >42 dB gain (flat)
- HPF with 25dB attenuation at 800MHz
- 3 stages, with high pass filtering after first stage
- Reasonable S11
- OIP2 first stage ~45dBm
- F-connector output (75 ohm)
- 160 LNAs are currently being manufactured (available July 2009)
- LNA based on ATF-54143



# New array

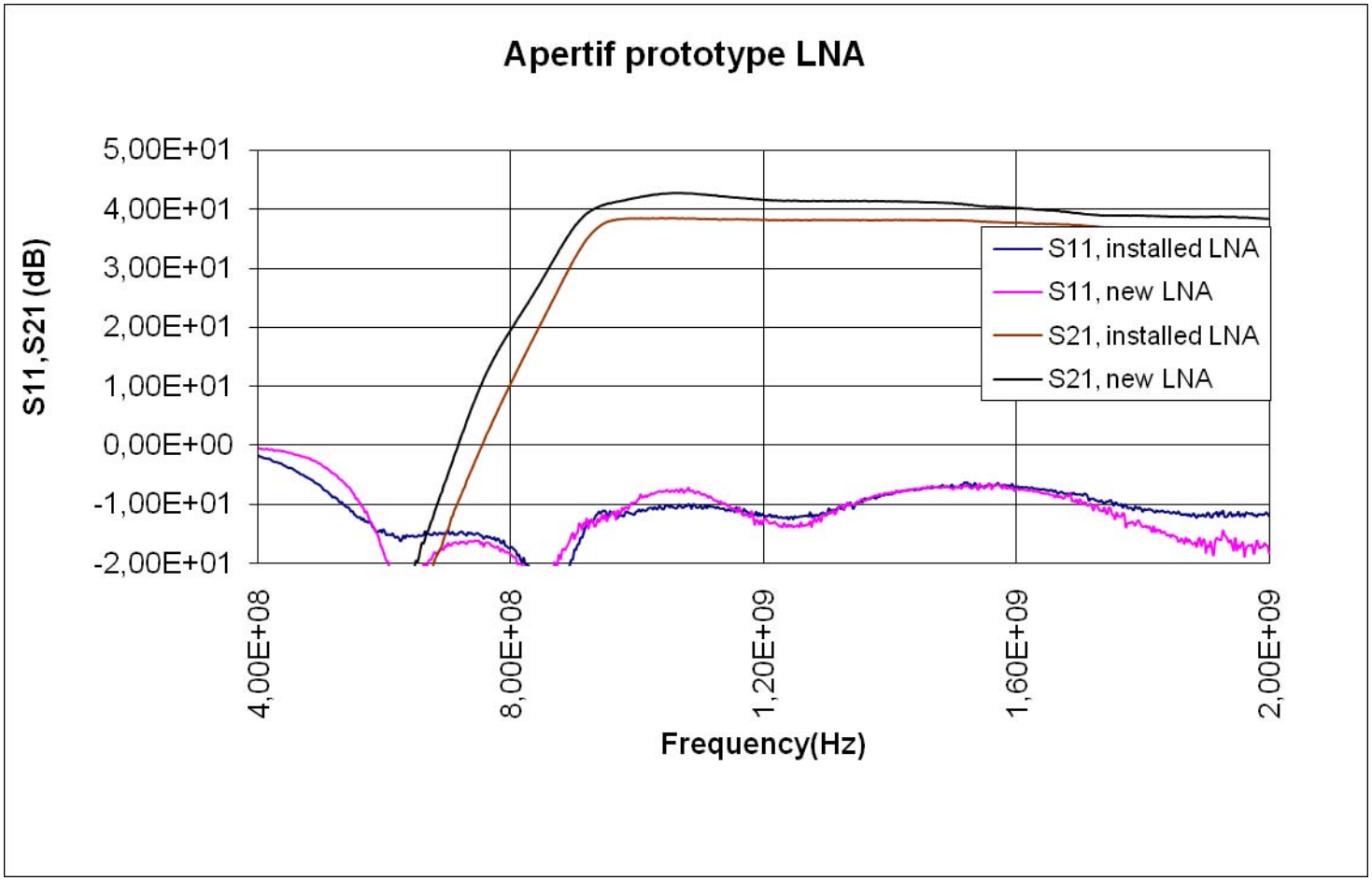




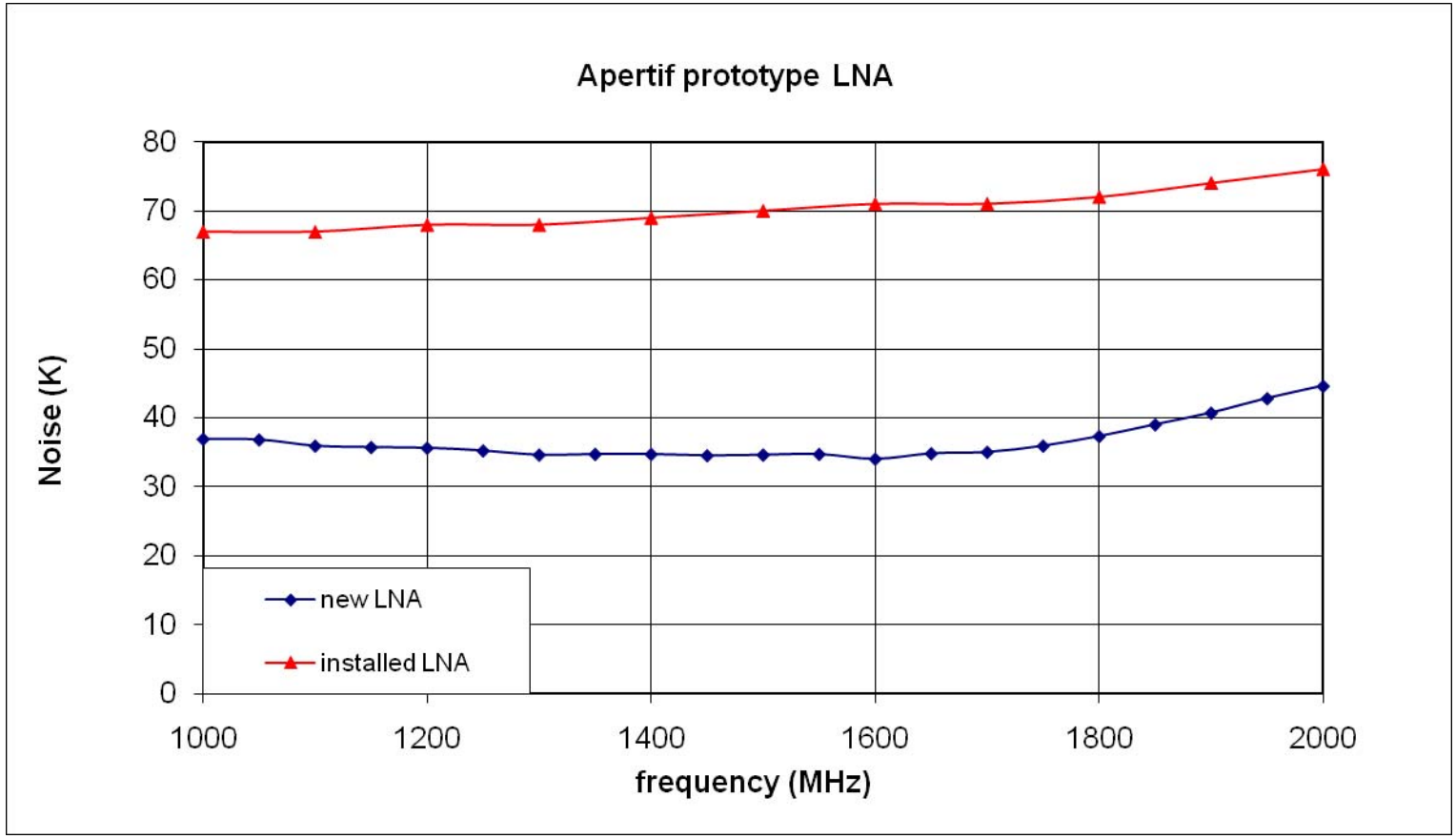


Measured $T_{LNA}$
< 37 K  1.0 – 1.8 GHz
  35 K  1.4 GHz

# LNA measurement results



# Noise measurements




- In 50 ohm using 5.2dB noise source and NFA
  - Liquid nitrogen gives a up to 5K better results
    - But also some points up to 10K worse
- New LNA measured with connector soldered at input

# System temperature

- LNA noise temperature vs. Tsys
- Current installed APERTIF LNA(first stage) is ~55K
- Current installed APERTIF three stage LNA ~70K
- Current measured Tsys ~120K
- So Tsys about 65 K higher than LNA
  - 15K second consecutive stages LNA
  - Feed loss and loss connectors ~15K ('expensive' RF material used)
  - Active impedance / Rn effects about 15K
  - Sky noise 3K
  - spillover about 15K
- Quite some challenges ahead achieving Tsys numbers < 55K as specified (at low cost)

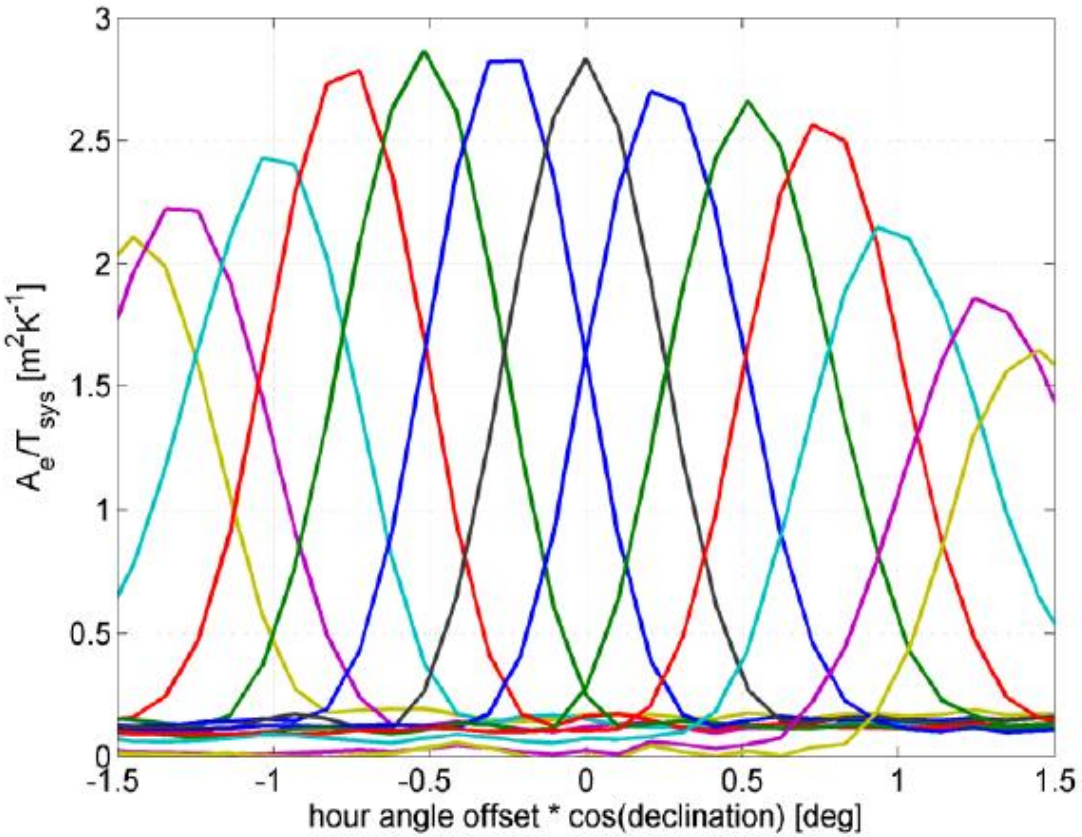
## Noise budget

| APERTIF prototype | | July '09 | Final APERTIF 2012 |
|---|---|---|---|
| Spill-over | 15 K | 10 K | 10 K |
| Vivaldi feed losses | 15 K | 7 K | 7 K |
| Receiver noise (single) | 75 K | 43 K | 28 K |
| Active Impedance/Rn effects | 15 K | 10 K | 7 K |
| Sky | 3 K | 3 K | 3 K |
| Total | 123 K | 73 K | 55 K |

# Measured compound beams

- 56 elements per **beam**
- Single polarisation
- Beams overlap at
  -0.7 dB points
  (will be -3 dB in final system)
- Max SNR weights
- Source: Cas A

- Sensitivity almost flat up to ±0.8 deg
- 25-30% sensitivity loss at edge of FoV



## Sensitivity

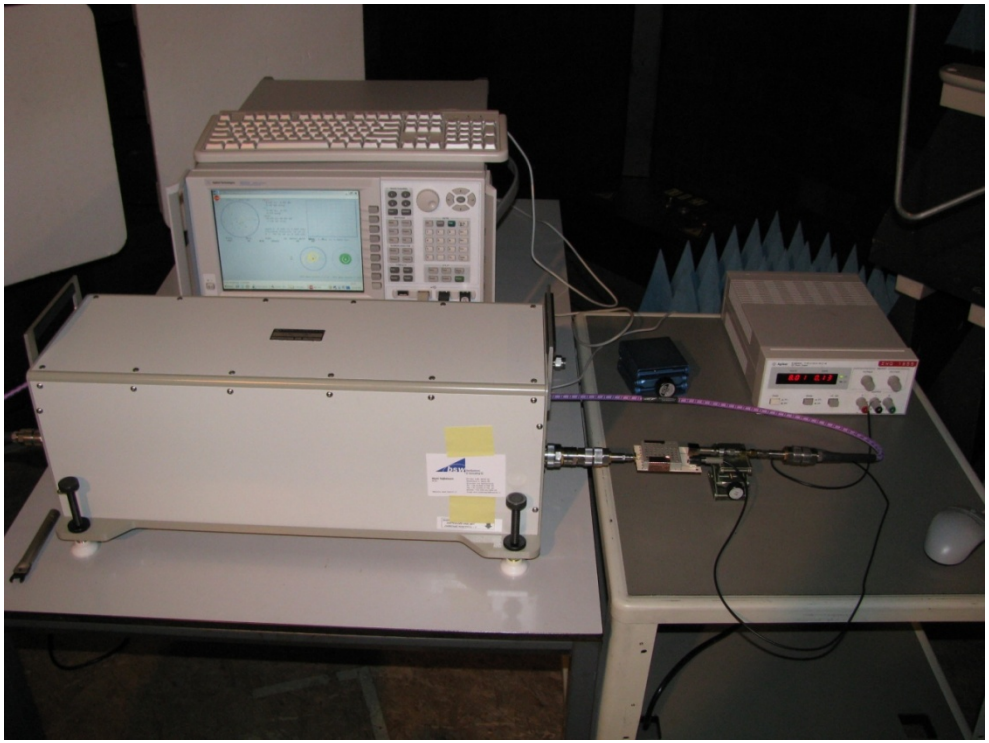
- Measured with APERTIF prototype: $A_e/T_{sys} = 2.9$ (central beam)

  with weights optimized for maximum SNR. Other weights (e.g. to shape the beam and sidelobes) will have lower sensitivity.

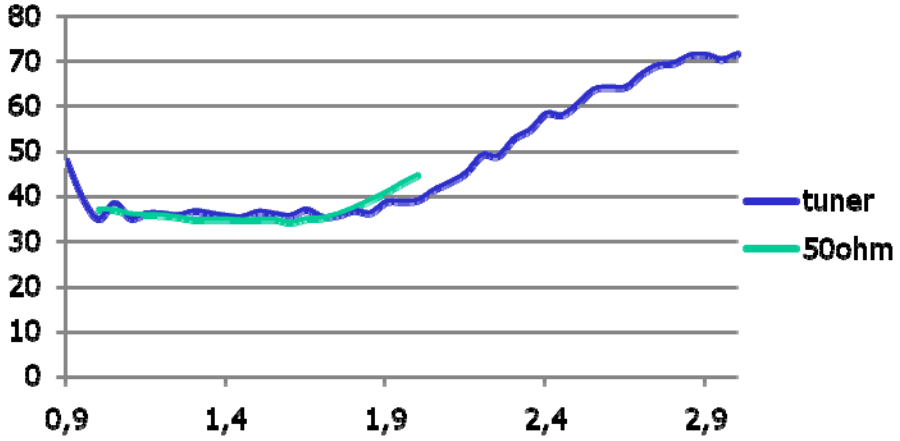
- Corresponding $A_e = 70\%$ (with $T_{sys} = 123$ K)

# Noise parameter measurements

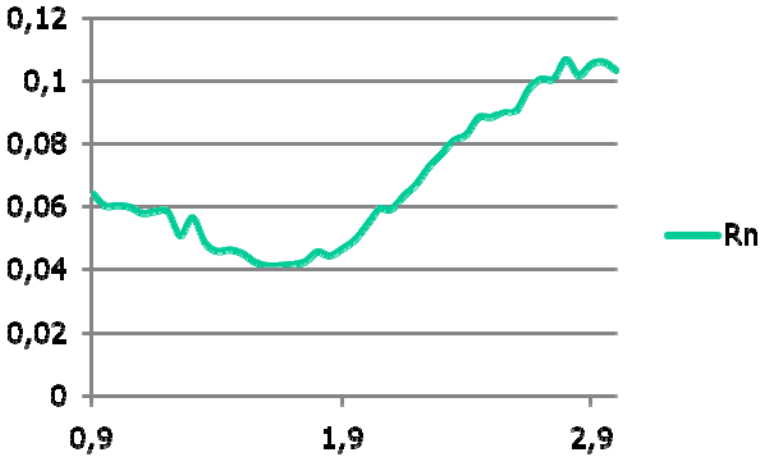
- Maury tuner
- Agilent 5.2dB noise source
- PNA-X
- Commercial Maury software
  - Both hot/cold and cold method possible
  - Different algorithms to determine noise parameters
- Very repeatable results



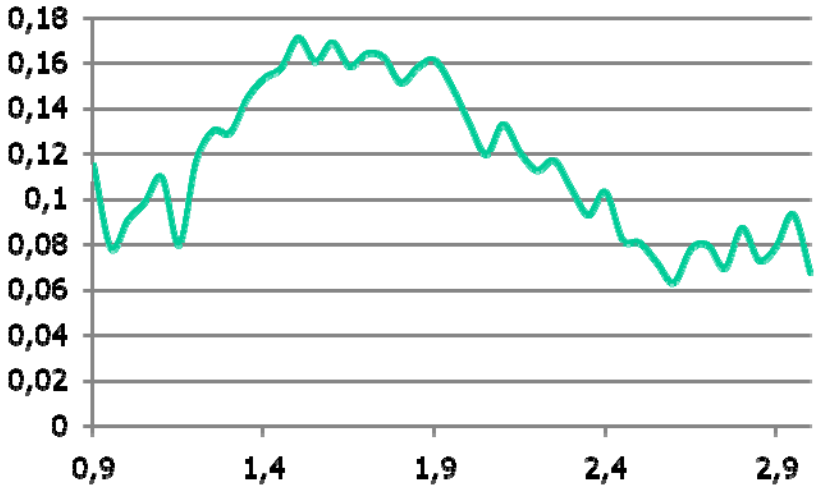
# Noise measurements



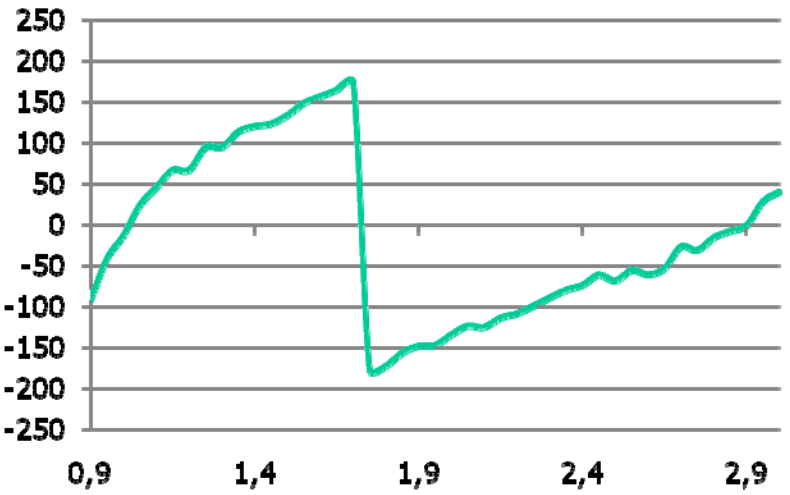

Noise temperature (K)




rn



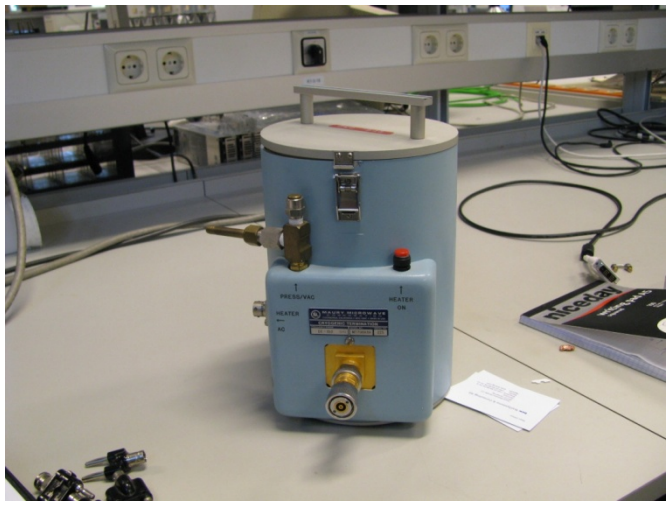

gamma_opt, magnitude




gamma_opt, angle

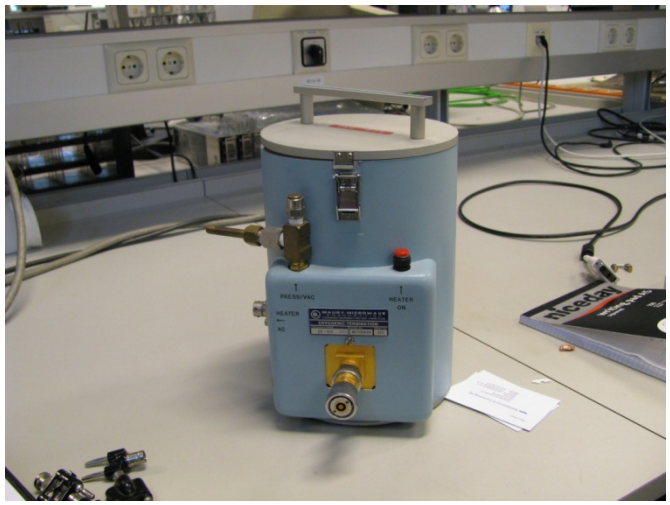
# Noise parameter measurements improvements considered

- Use LN2 load to have a well defined hot and cold load
  - Don't cool down the LNA
- Writing own tuner software
  - Cross checking of different methods (ENR, cold load, cold method, …)
  - Cross checking different algorithms
  - to understand better what is happening
  - To include LN2 load
- Error analysis
- Shielding tuner for RFI



# Noise parameter measurements improvements

- Use LN2 load to have a well defined hot and cold load
  - Don't cool down the LNA
- Writing own tuner software
  - Cross checking of different methods (ENR, cold load, cold method, …)
  - Cross checking different algorithms
  - to understand better what is happening
  - To include LN2 load
- Error analysis
- Shielding tuner for RFI



**In general: built confidence in the measurement results**

## Conclusion and future work

- Tsys <75K expected for the new FPA prototype
  - Low Rn transistors essential for phased array feeds
  - Still quite some challenges ahead reaching the required Tsys of 55K(uncooled)
- Integrate design LNA/antenna more closely

- Evaluate more transistors (bare transistor stability issues?)
- Testing antenna and LNA together in outside Hot/cold facility (talk Jan Geralt) and in telescope
- Cross verification of reference DUT amongst different institutes would help improve confidence