BRAND EVN —

A wideband receiver for astronomy and geodesy

W. Alef on behalf of the BRAND team

Yebes Observatory

Netherlands Institute for Radio Astronomy

BRAND JRA in Radionet

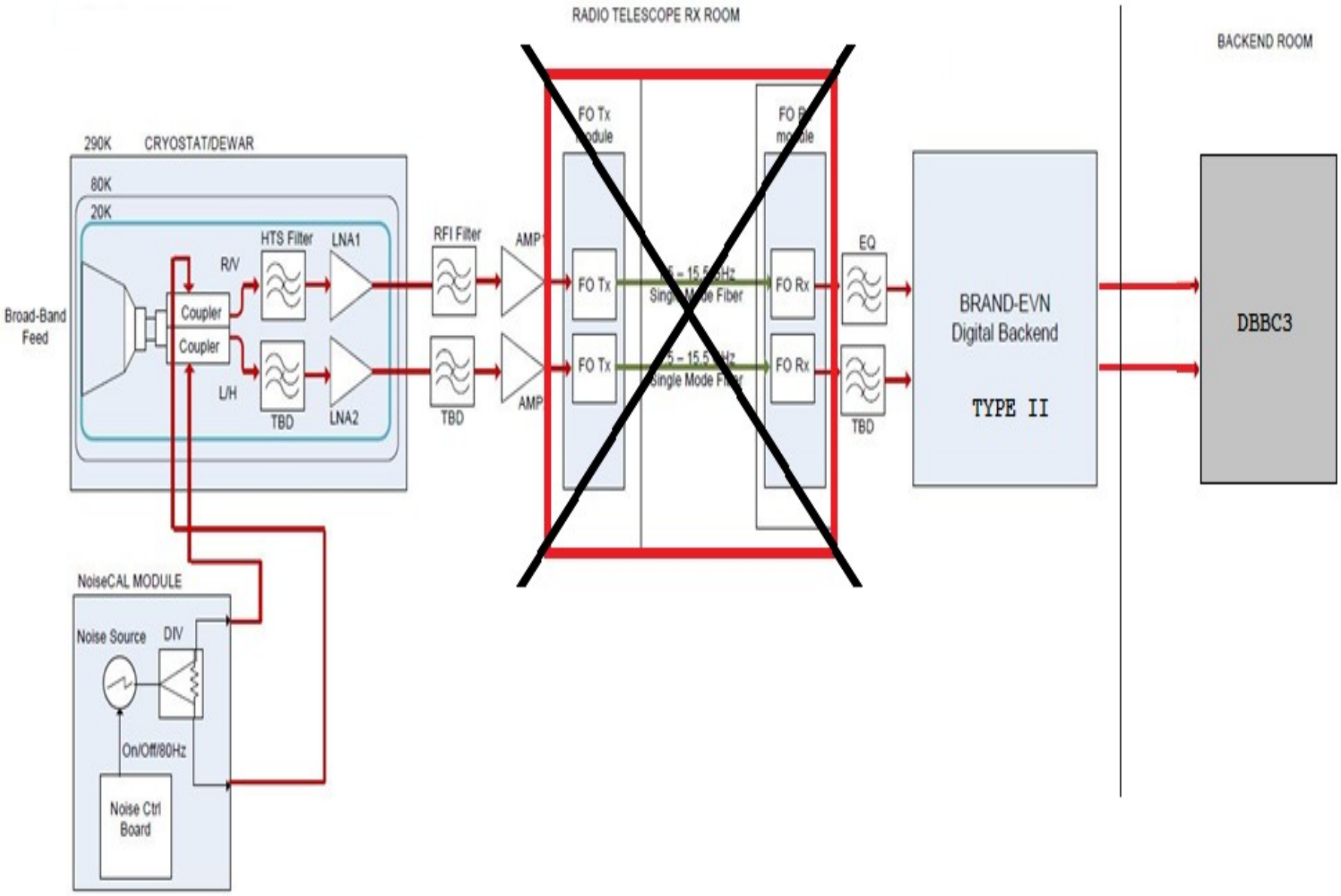
- BRAND EVN is a Joint Research Activity (JRA) in Radionet
  - Contract with the EU No: 730562
- Budget sponsored by the EU: ~1.5 M€
- plus contributions by partners:
  - MPIfR, INAF/Noto, OSO, UAH/IGN, ASTRON, VUC
- Project started: January 2017
- Project ends: June 2020 (hard deadline: December 2020)

What is a BRAND receiver?

- “digital” VLBI-receiver for the EVN (and other) telescopes:
  ~1.5 - 15.5 GHz (all useful pieces)
  - Prototype for prime focus (Effelsberg)
    - + research for secondary focus feed
  - Whole band will be digitized without down-conversion - 1 chip

- Will allow multi-wavelenght VLBI for astronomy
  - Fringe-fitting over whole band necessary (RadioNet JRA RINGS)
- Will extend VGOS band
- Digitization in receiver box – no down-conversion
- Data transport from receiver to backend via optical fibres!
  - Will bypass band-limited IF of legacy antennas

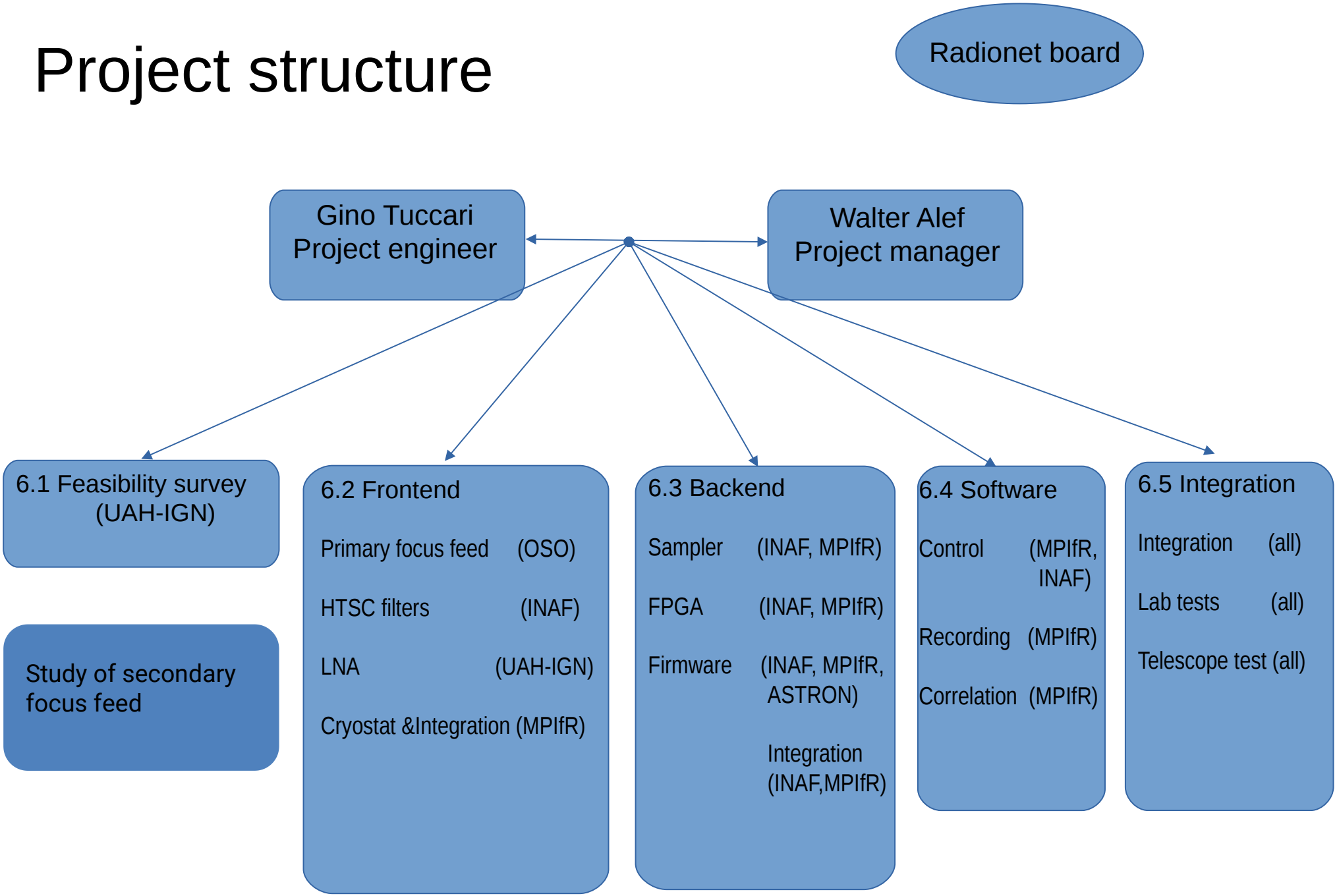
BRAND block diagram



BRAND — The Team

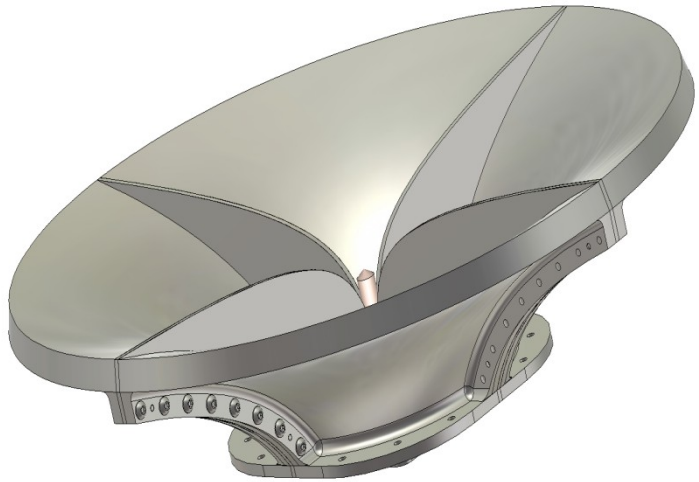
W. Alef	MPIfR Bonn, Germany	Project Manager, VLBI test observations
G. Tuccari	INAF Noto & MPIfR Bonn	Project Engineer, BRAND architecture, HTSC filters, backend design, firmware, secondary focus study
J. Flygare, M. Pantaleev	OSO, Sweden	Feed Horn, measurements of filter plus LNA
J.A. López-Pérez, F. Tercero, I. Malo, I. López-Fernández, C. Diez	IGN/UAH, Spain	LNAs, RFI, measurements of filter plus LNA, analogue polarisation conversion
C. Kasemann, M. Nalbach	MPIfR Bonn, Germany	Dewar, frontend integration, integration in Effelsberg tel.
M. Wunderlich, S. Dornbusch, A. Felke	MPIfR Bonn, Germany	Sampler & processing board layout, firmware, software
J. Hargreaves, G. Schonderbeek, R. de Wilde	ASTRON, Netherlands	Digital polarisation conversion, software

Project structure

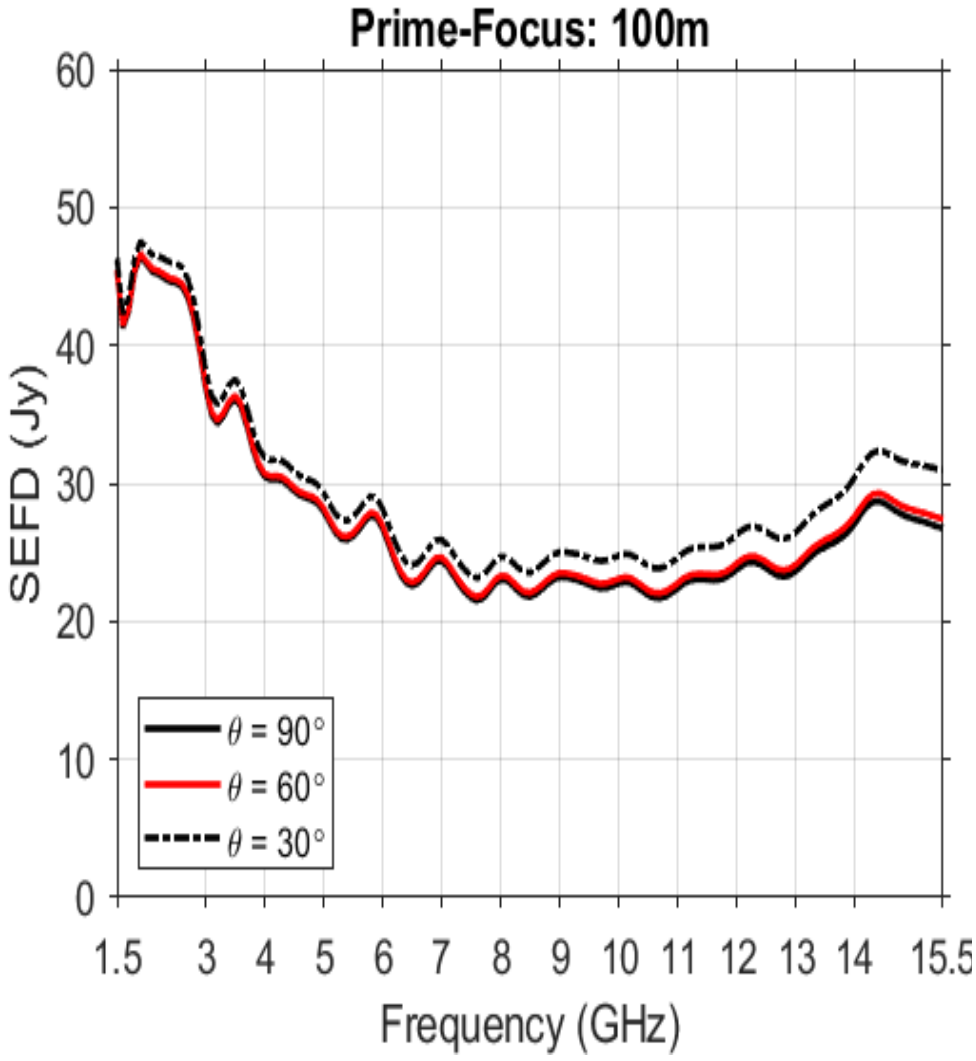


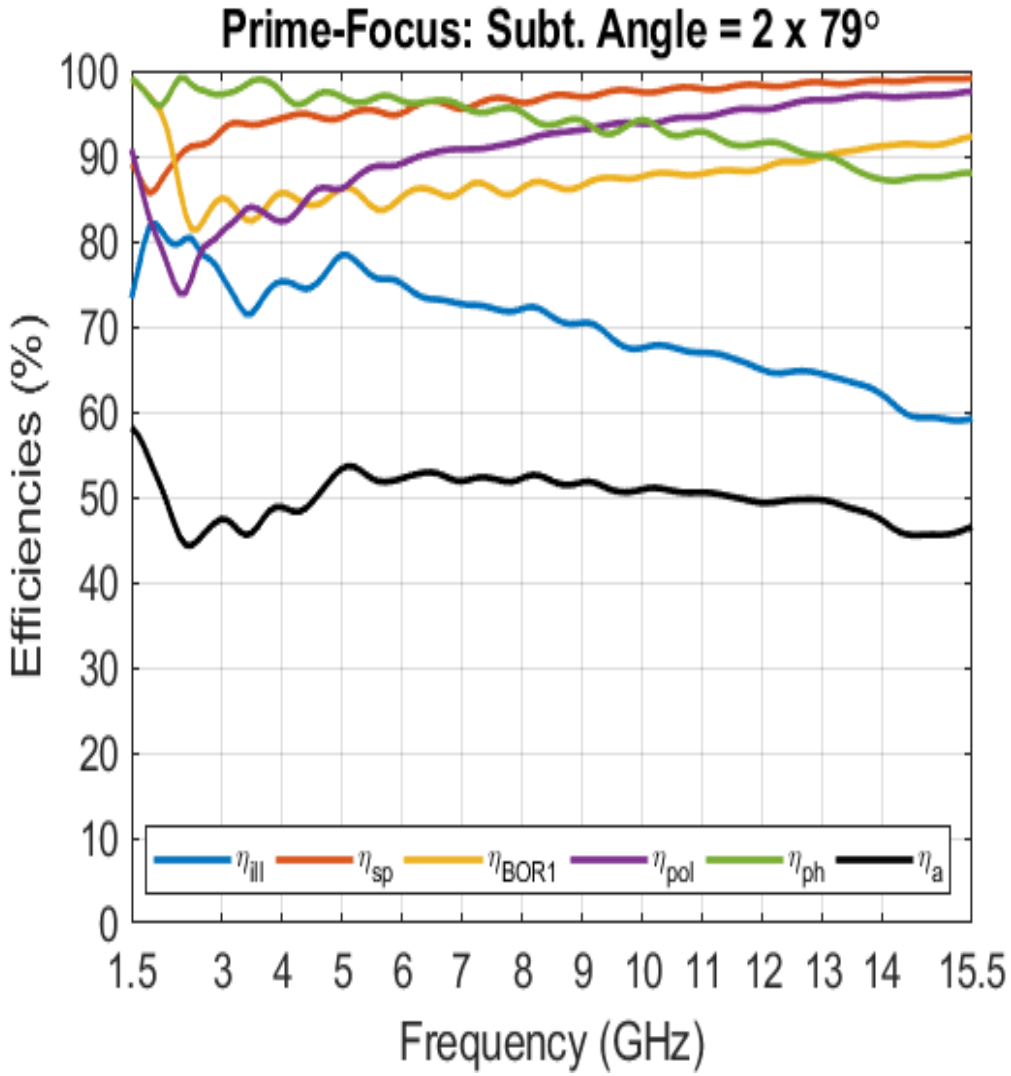
Status: Feed horn

- Feed horn designed by J. Flygare, M. Pantaleev, OSO
- Solution found for Effelsberg: QRFH feed with dielectric inset
- Antenna parameters:
  - Opening angle 2 × 79°
  - f/D = 0.3
- Feed characteristics (over whole band):
  - average aperture efficiency of 50%
  - input reflection better than -10 dB
- Feed manufactured
- Ongoing: Lab measurements



Feed horn: SEFD & efficiency





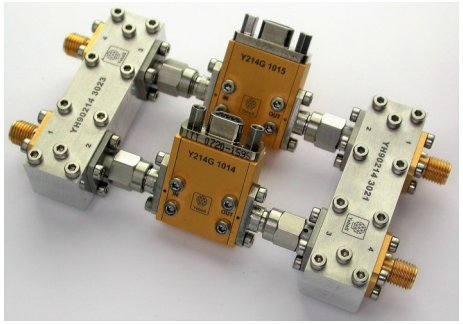
Manufactured feed horn

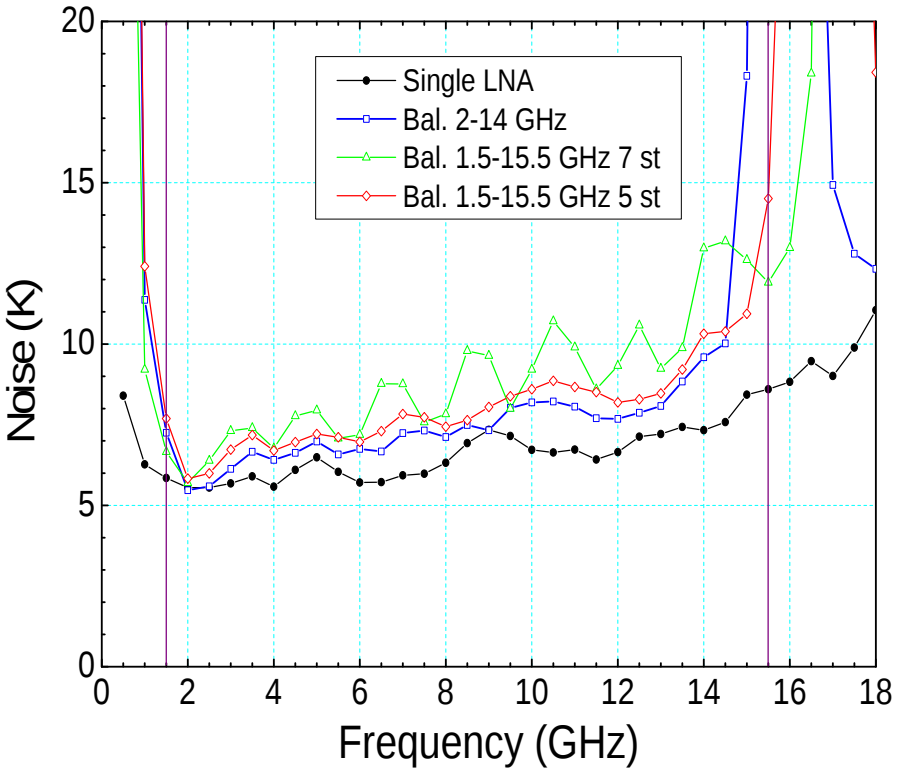
Status: HTSC filters

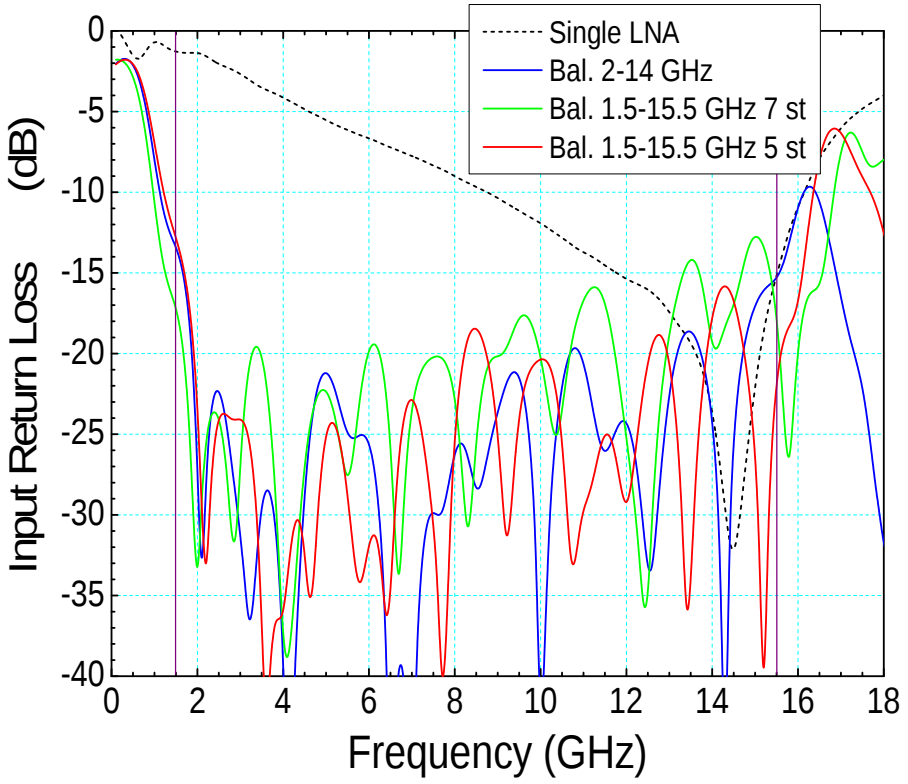
- High Temperature Superconductor Filters, desired:
  - a high pass to cut below 1.5 GHz
  - 2 notches for strongest RFI → (1.8 GHz, 2.2 GHz)
  - A direction coupler for phase-cal & calibration
- Realised in 3 separate devices
  - Delivery of last part in April 2019

Status: LNA

- Best solution for extreme bandwidth found:
  - Balanced amplifier with 2 hybrids and 2 LNAs

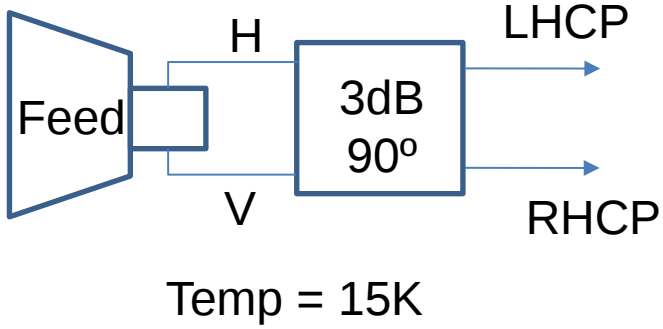






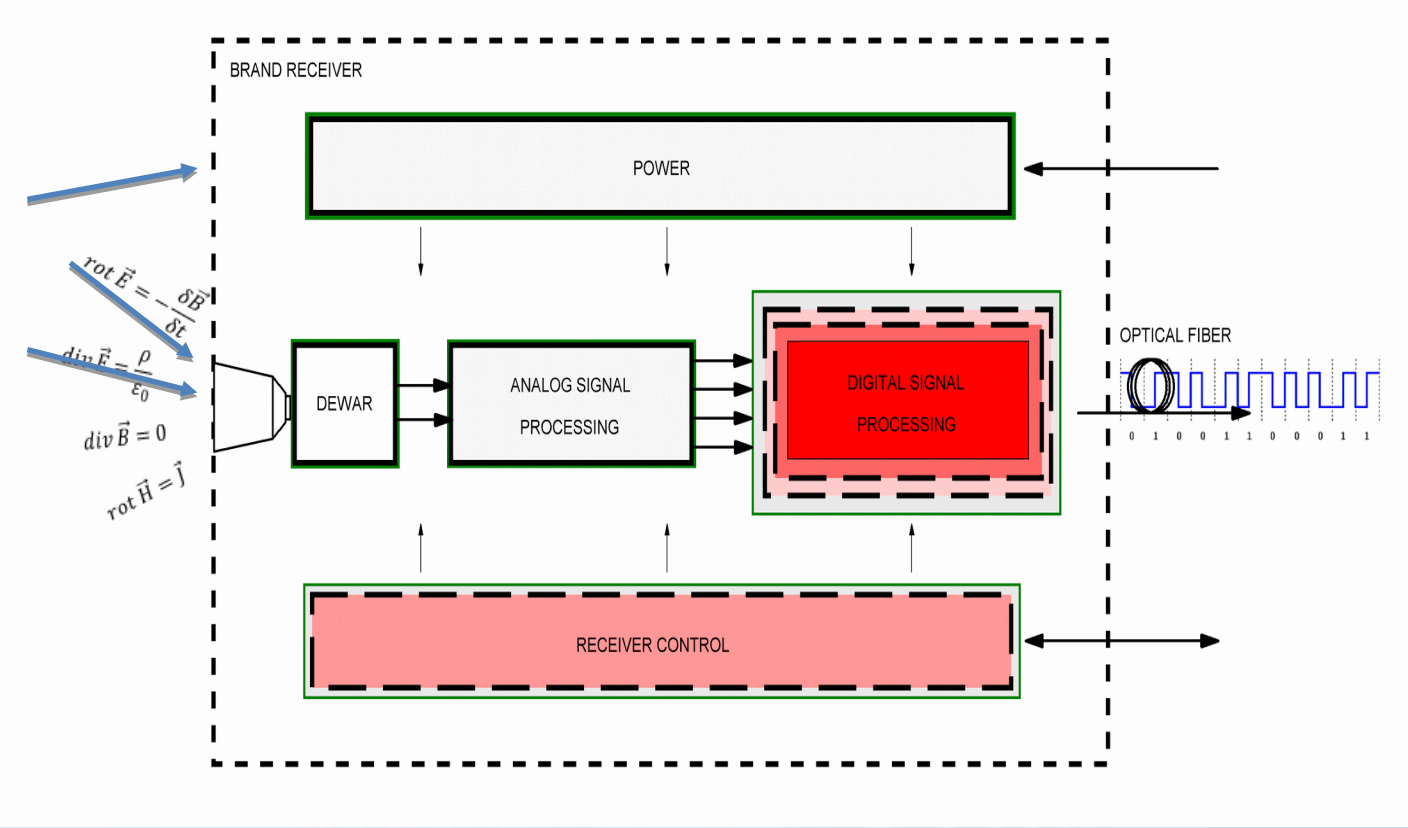
Status: Polarization

- Linear to circular polarization conversion can be achieved using 3dB/90º hybrid (same hybrid as for balanced LNA)
- Average noise penalty across the band < 2.5 Kelvin
- Yebes development for BRAND and VGOS



Temp = 15K

Signal processing in receiver



- Receiver output: digital signal via optical fiber
- Strong shielding is required to avoid ‚self-inflicted' RFI (> 120 dB)
- Good temperature management is needed to get rid of the resulting heat

Status sampler and FPGAs

- We were able to procure 16 GHz samplers and an evaluation board
- The samplers were tested successfully
- In a first design the evaluation board will be used together with the FPGA processing board
  - Is needed for firmware development: feeding the enormous data-rate from sampler to FPGA
- The final design of our own sampling/processing board has started
  - Will handle 2 polarisations and full bandwidth.
  - 1 sampler w. 4 inputs @14GHz, 4 Xilinx Kintec Ultrascale FPGAs
    - 2x 0GHz – 14GHz, 2x 14GHz – 15.5GHz in 2nd Nyquist zone
  - PCB will work in the microwave regime
  - Will have an enormous number of connections

Status firmware

1) Interface sampler with FPGA and data reconstruction
   – tests in next few weeks

2) Band selection and first data processing:

   - OCT (arbitray band selection) and DDC (digital downconverter)
     – DDC and OCT to be tested

3) Ethernet data from frontend to DBBC3 – to be tested

4) Further channelisation in DBBC3: exists – tests

   - Modifications needed for 8 outputs per board

5) Polarization conversion
   – block design ready (digital; ASTRON)

Cryostat, integration, testing

- Design of the cryostat and receiver layout in prime focus cabin is progressing – window Ø 80 cm!
  - Simulation of the feed with dewar/window indicate no problems
- Integration will be done at MPIfR together with all partners
- Testing will be in the lab, on the telescope and with VLBI observation – preferably with VGOS antennas

- BRAND prototype ready before end of 2020!