BRAND EVN — the next generation receiver for VLBI

W. Alef on behalf of the BRAND team

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? Why?

- “digital” VLBI-receiver for the EVN (and other) telescopes:
  ~1.5 - 15.5 GHz (all useful pieces; include VLBA 2 cm)
  - Prototype for prime focus (Effelsberg)
  - + research for secondary focus feed

EVN has separate receivers to cover:
18 cm (all) / 13 cm (many) / 6 cm (all) / 5 cm (many) / 4 cm (many)

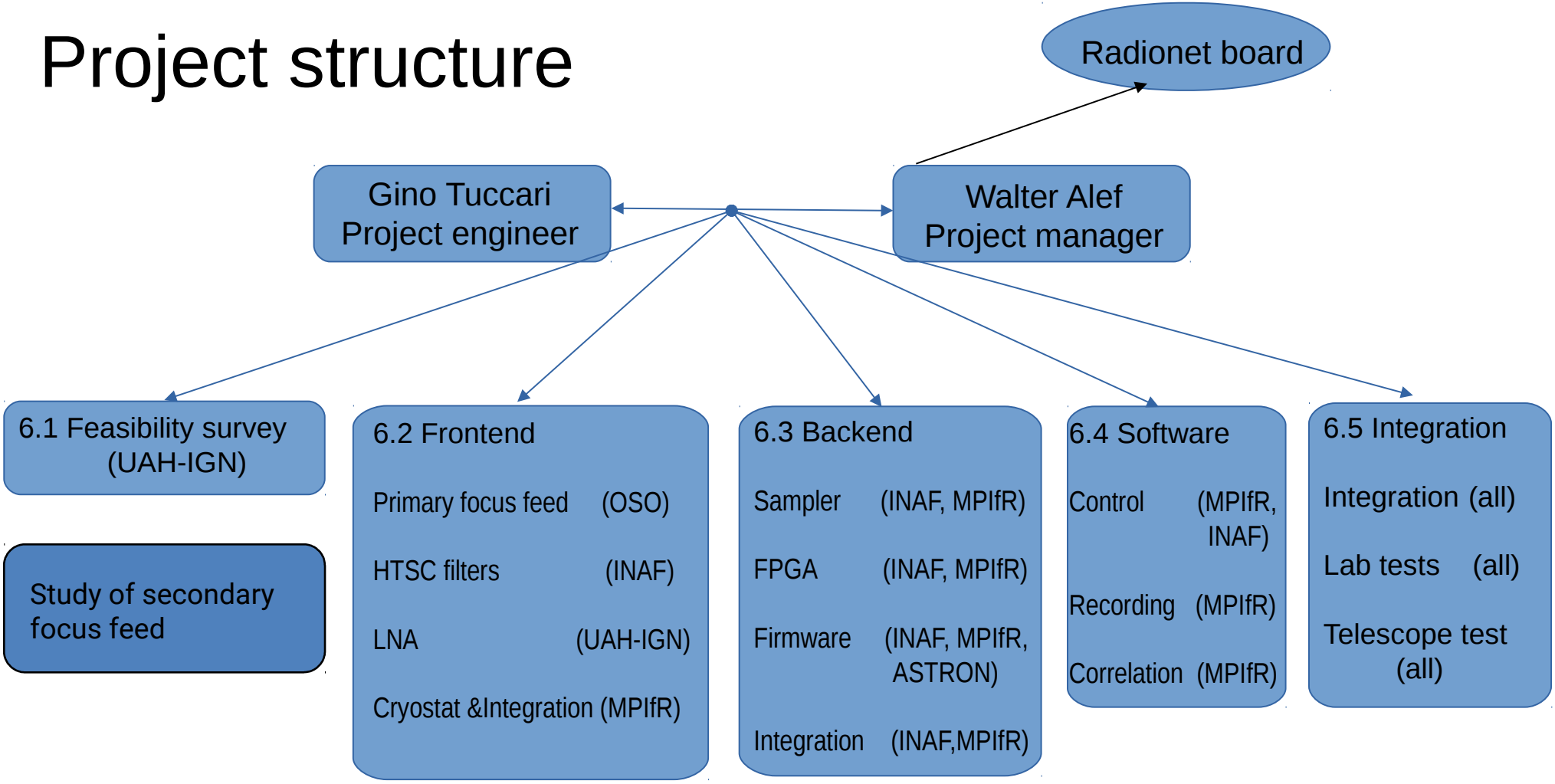
- in addition: 21 cm; 1.3 cm; 7mm only globals; 50 cm
- In each EVN session ~3 freqs. observed in succession
- No multi-band (quasi-) simultaneous observations !!

Scientific motivation

- VLBA: fast frequency switching
- BRAND EVN: real multi-wavelength VLBI
  - Single receiver, single LNA, single sampler chip, single backend
    - → no instrumental offsets over whole band!
  - with coherent fringe-fitting over whole frequency range + Ionosphere (cf. VGOS)
  - precise registration of simultaneous images at different frequencies
  - over-compensate reduced sensitivity due to wide-bandwidth

- superior to fast switching! → can connect phase over whole freq. range
- UV-coverage vastly improved due to wide frequency band
- VGOS compatibility, Spectroscopy, single dish, pulsar....

Project structure

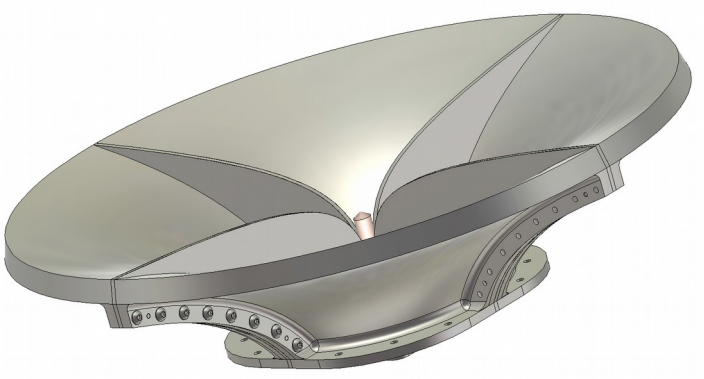


Status: Feasibility study for BRAND in EVN

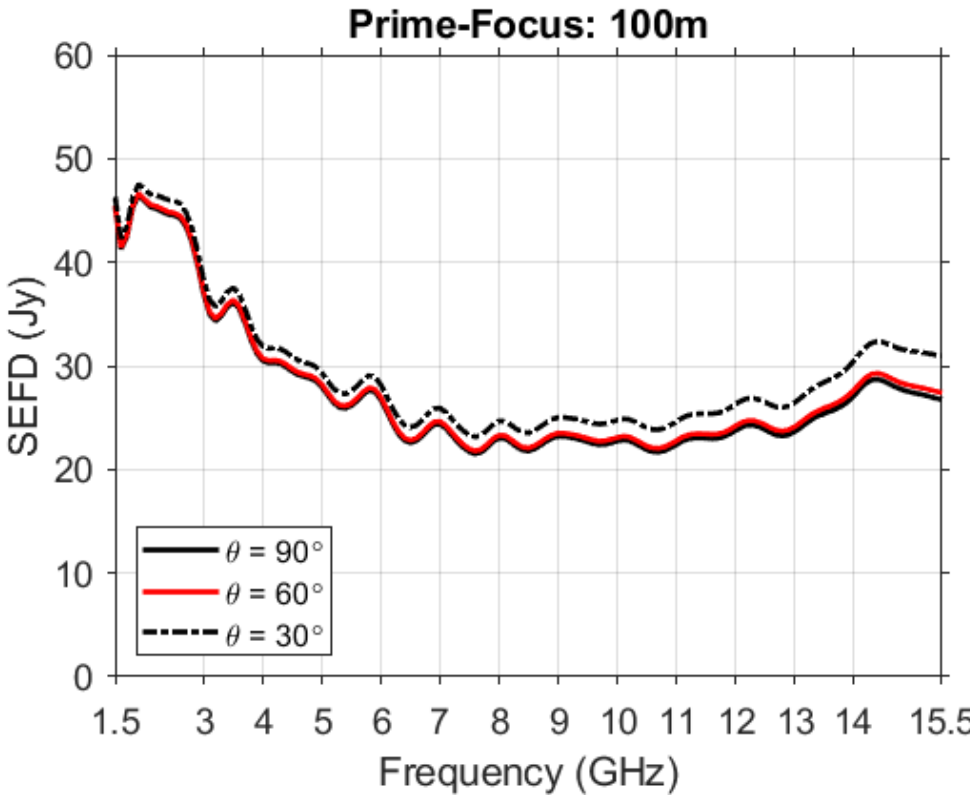
- Survey of EVN telescopes done
  - Aim is to equip hopefully all EVN antennas with a BRAND receiver in next decade
  - Not all telescopes answered questionnaire
  - Document will be upgraded till end of project

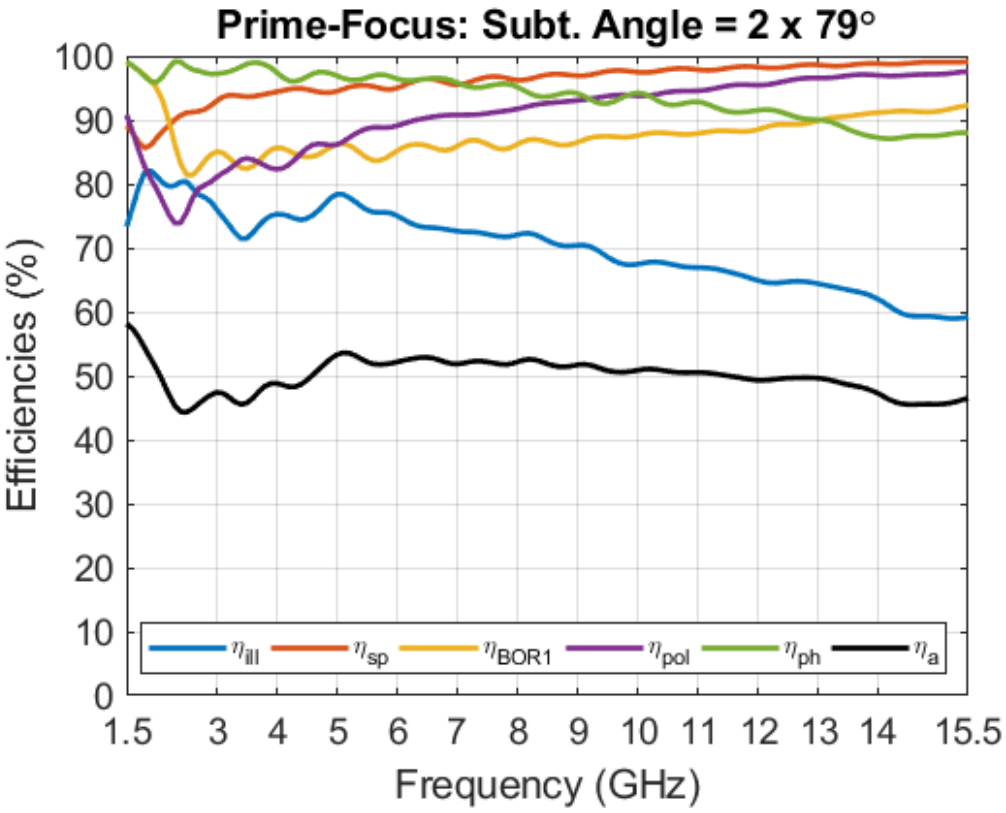
Status: Feed horn

- 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





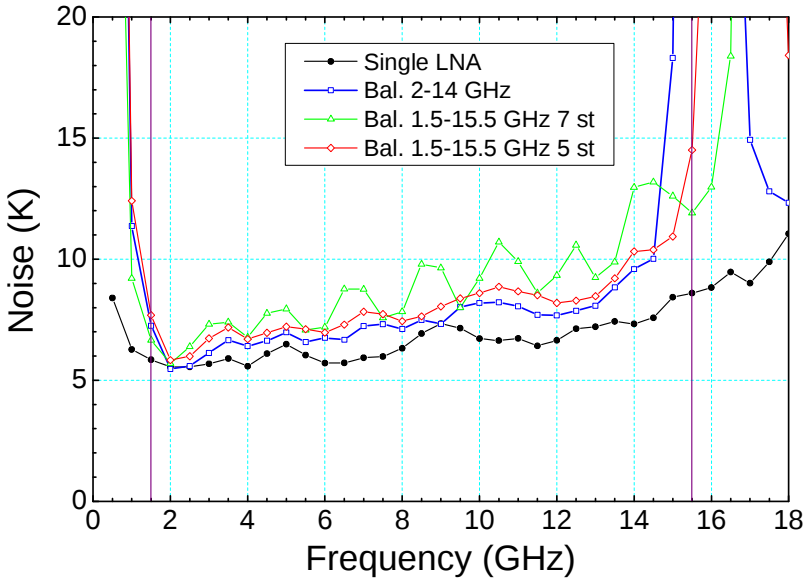
Manufactured feed horn

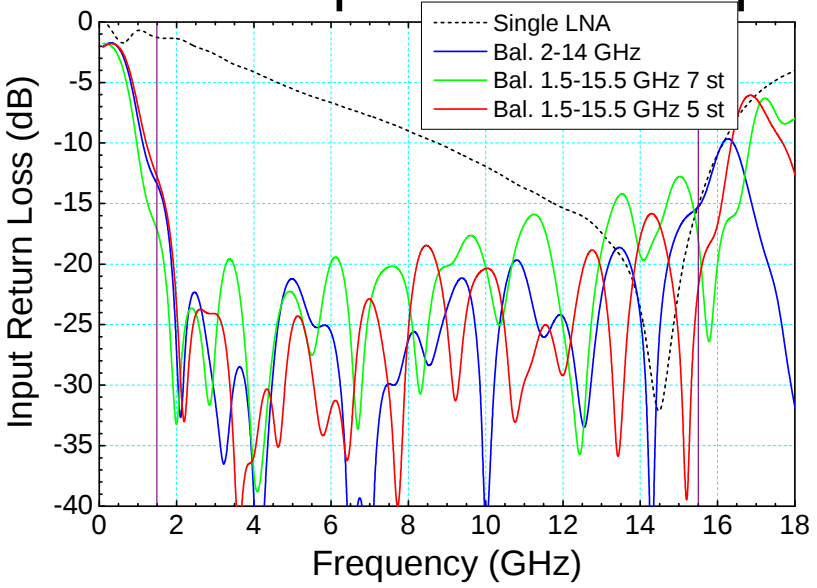
Status:HTSC filters

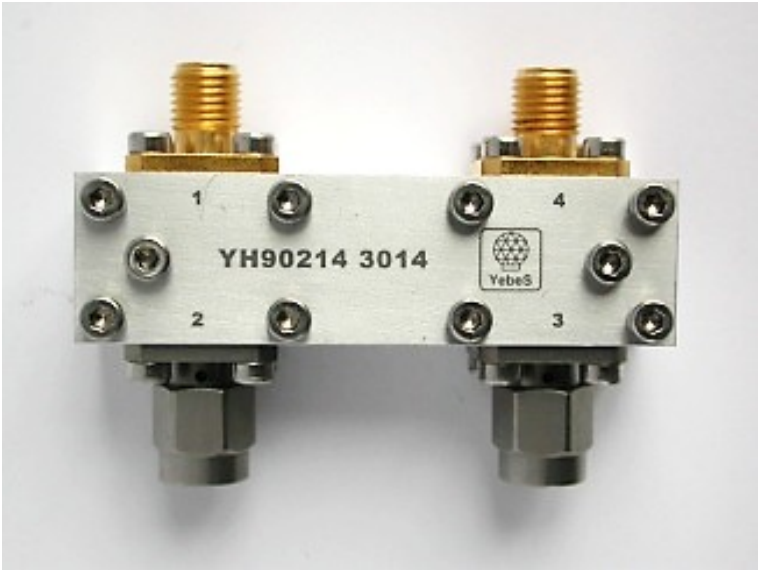
- High Temperature Superconductor Filters, desired:
  - a high pass to cut below 1.5 GHz
  - 2 notches for strongest RFI → (1.8 GHz, 2.2 GHz)
  - A direction coupler for phase-cal & calibration
- Problems encountered! Solutions are investigated
  - Might have 2 filters attached
  - Will be decided soon

Status:LNA

- Best solution for extreme bandwidth found:
  - Balanced amplifier with 2 hybrids and 2 LNAs
  - Can even be used to convert linear input to circular pol!





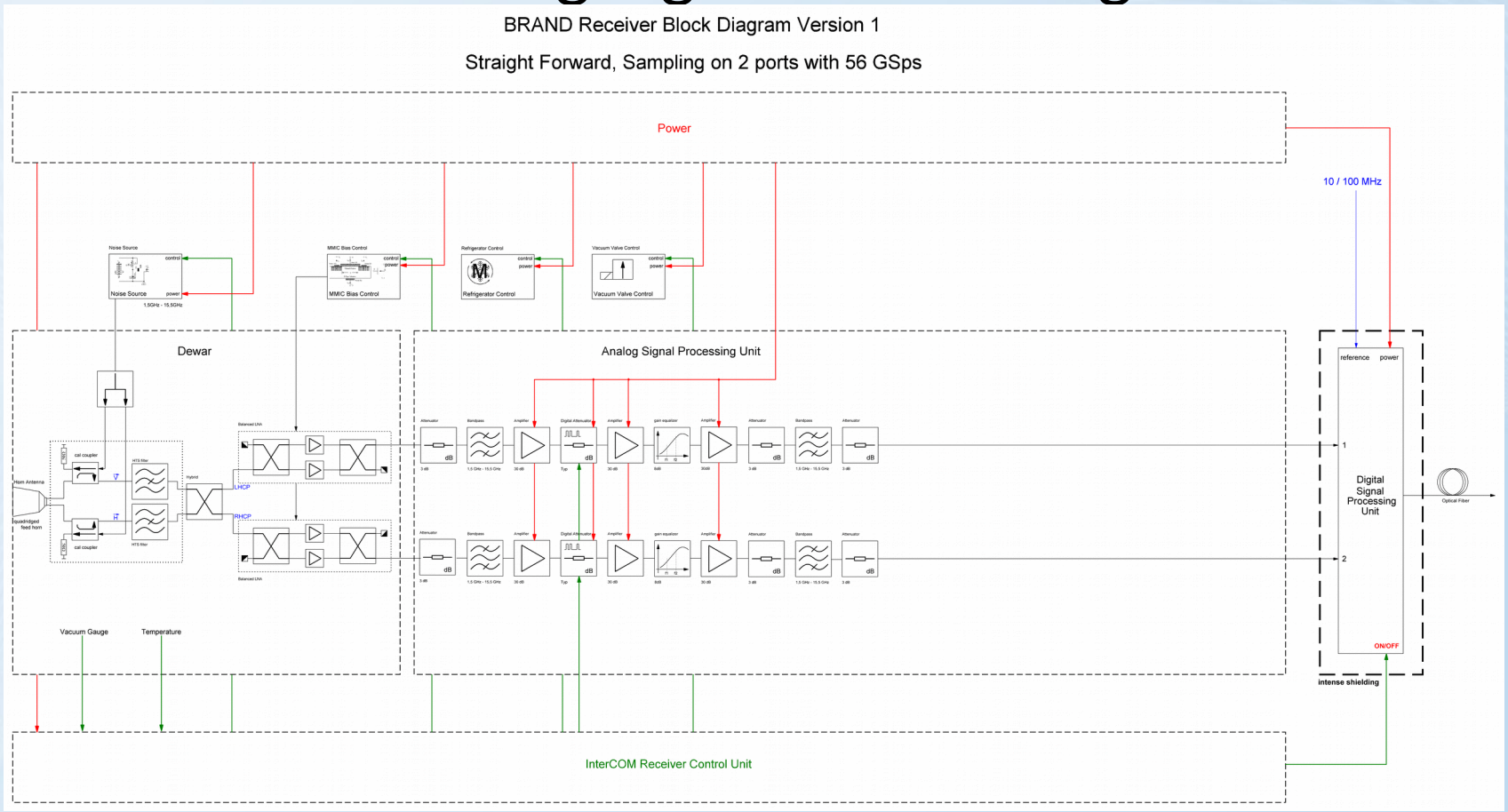


External view of the ultra-wide band cryogenic LNA developed.	External view of one of the cryogenic 3 dB 90° hybrid couplers used in the balanced amplifiers together with the LNA on the left.

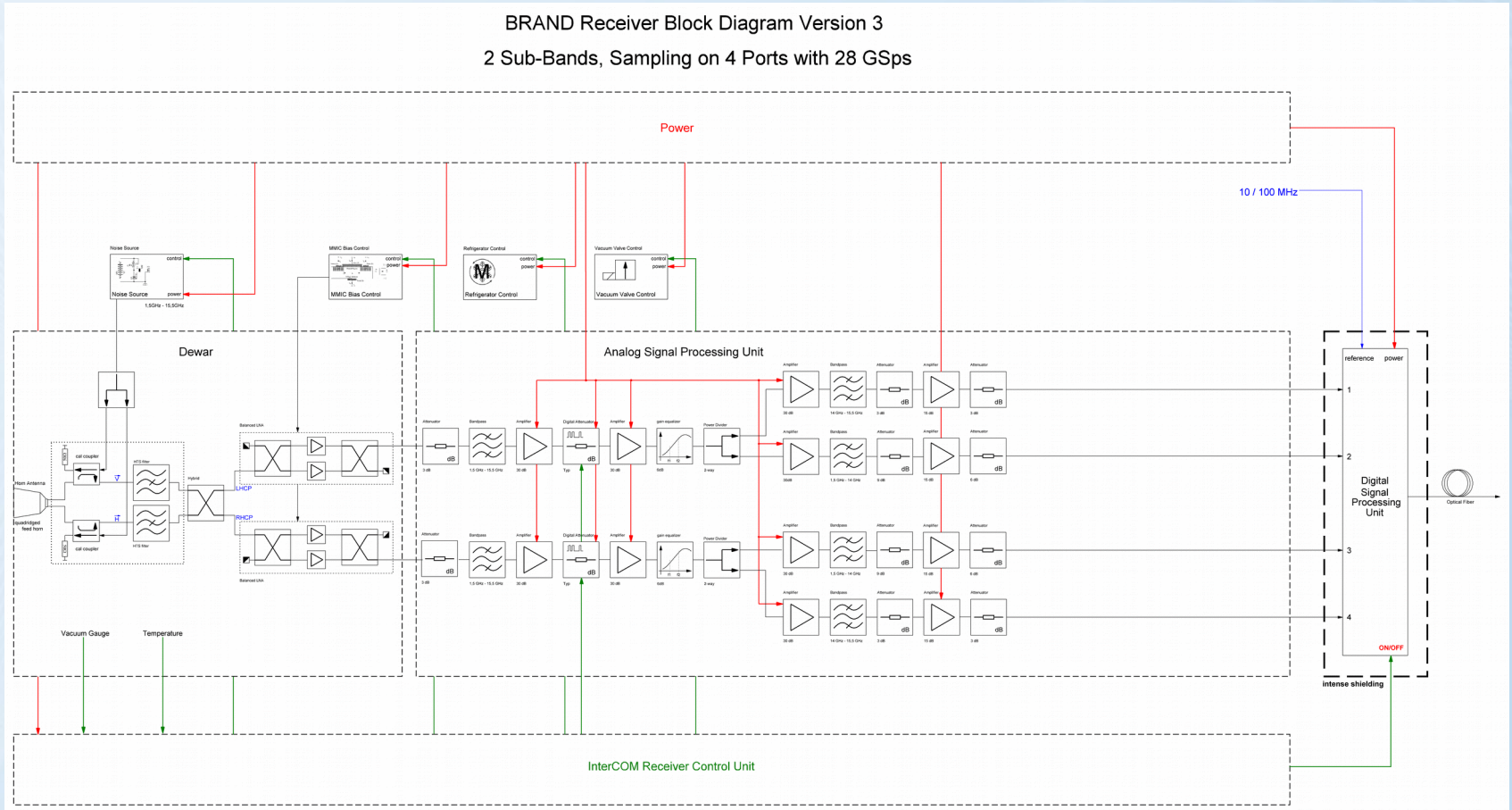
Analogue signal path

- Signal path will be without mixer
- Boundary condition from sampler:
  - 4 input ports
  - 14 GHz bandwidth @ 28 Gsps
  - 16 GHz bandwidth @ 56 Gsps
  - 96 output ports @ 11.2 Gbps

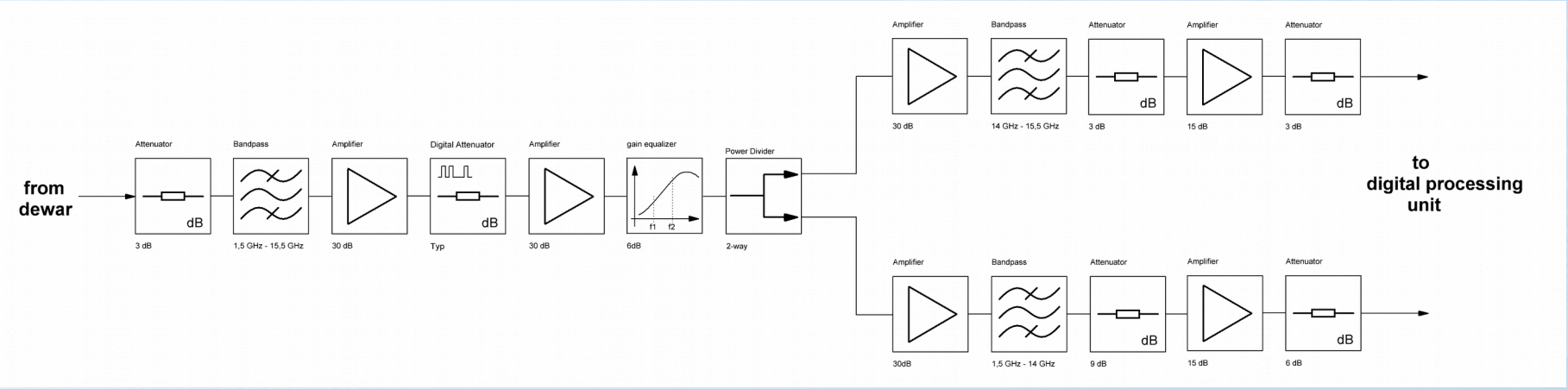
BRAND Receiver
Analog Signal Processing



BRAND Receiver
Analog Signal Processing



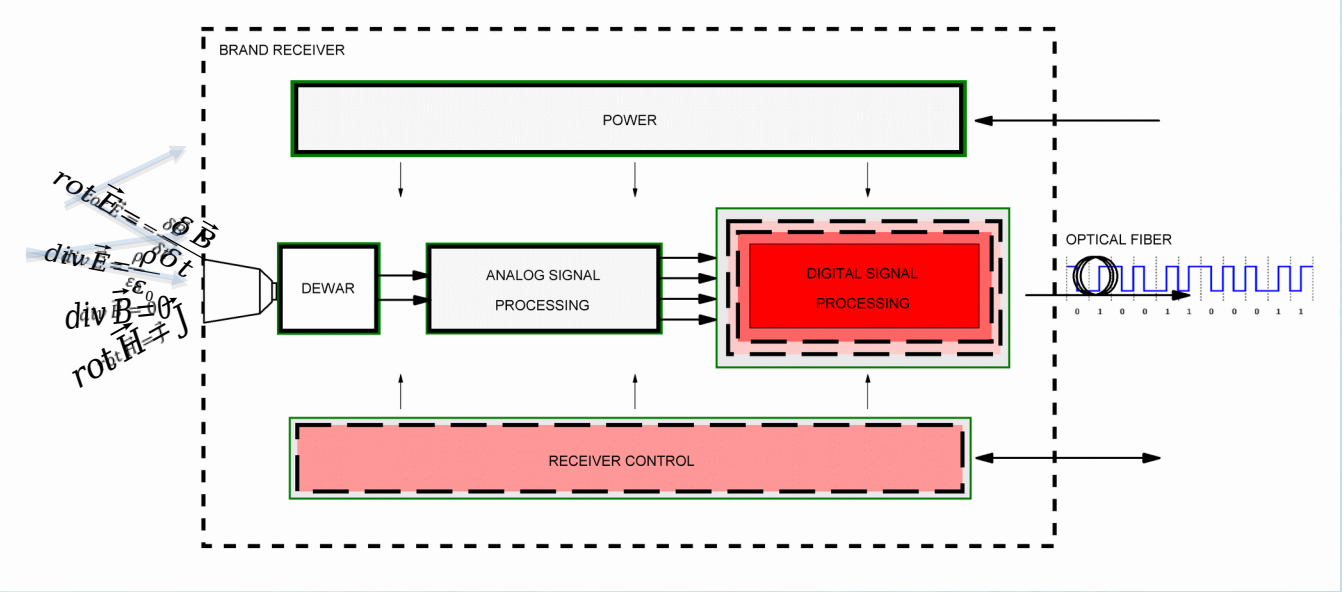
BRAND Receiver
Analog Signal Processing



- Sampling in 2 sub-bands avoids the use of the high sampling clock (but needs 4 instead of 2 ports)
- Very good filters are required to minimize aliasing effects at 14 GHz
- Hardware can be changed to Version 1 with moderate effort (for testing data capturing with 56 GSps data rate)

Sampling on 4 ports with 28 GSps

BRAND Receiver
Analog Signal Processing



- 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

- 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
- The final design will be with our own sampling board
- Firmware for feeding the enormous data-rate to the FPGA board is under development.

Status: high data-rate processing board

- FPGAs selected belong to latest Xilinx programmable series
- PCB will have very large number of connections
- Will work in Microwave regime
- Found company which can manufacture such a board
- Design of board ongoing

Status: Firmware

1) Interface with the samplers and data reconstruction
   – well underway
2) Data processing in the different modes: DDC (digital downconverter), OCT (arbitray band selection), PFB (polyphase filterbank)
   – DDC and OCT progressing
3) Ethernet data format for output
   – not started
4) Polarization conversion
   – block design ready (digital; ASTRON)

Cryostat, Integration, Testing

- Design of the cryostat and receiver layout in prime focus cabin is progressing
- 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!

Thank you !

Walter Alef

RadioNet has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730562