SKACH

Square Kilometer Array Swiss project (SKACH)
2024 spring meeting
MID band 6 instrument EBB Status and progress

Hes·so
Haute Ecole Spécialisée de Suisse occidentale
Fachhochschule Westschweiz
University of Applied Sciences Western Switzerland

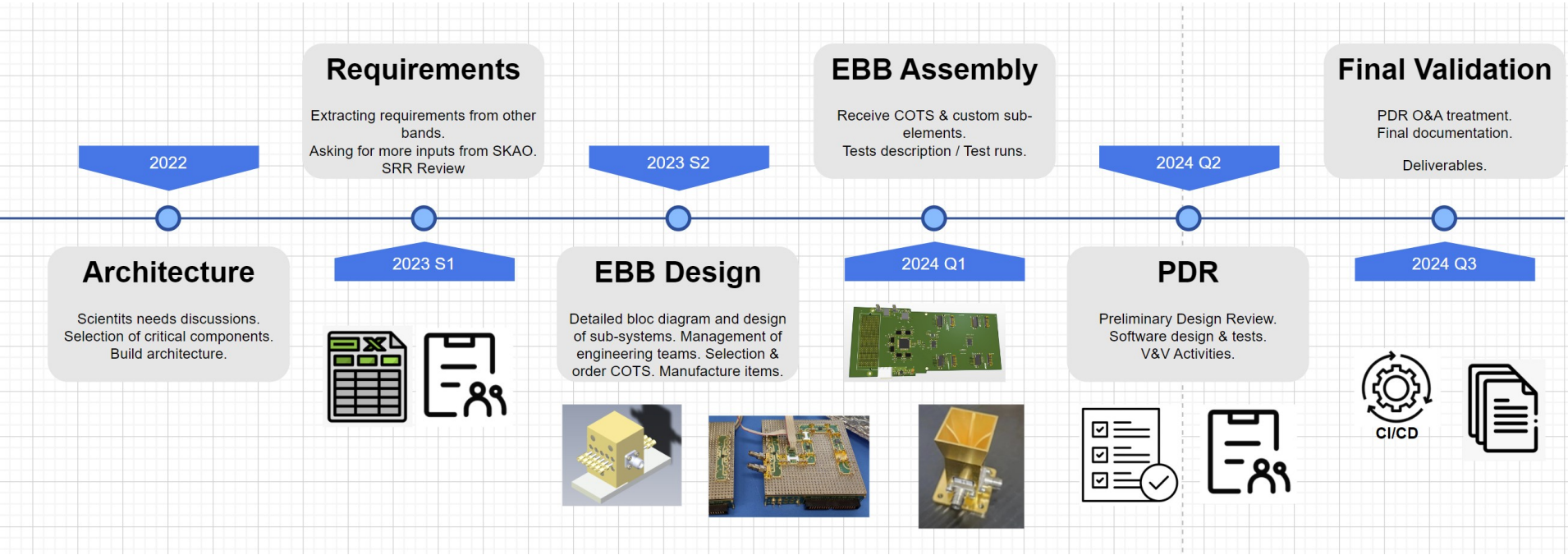
Winterthur, ZHAW
11.6.2024

HEIG VD
SCHOOL OF ENGINEERING AND MANAGEMENT

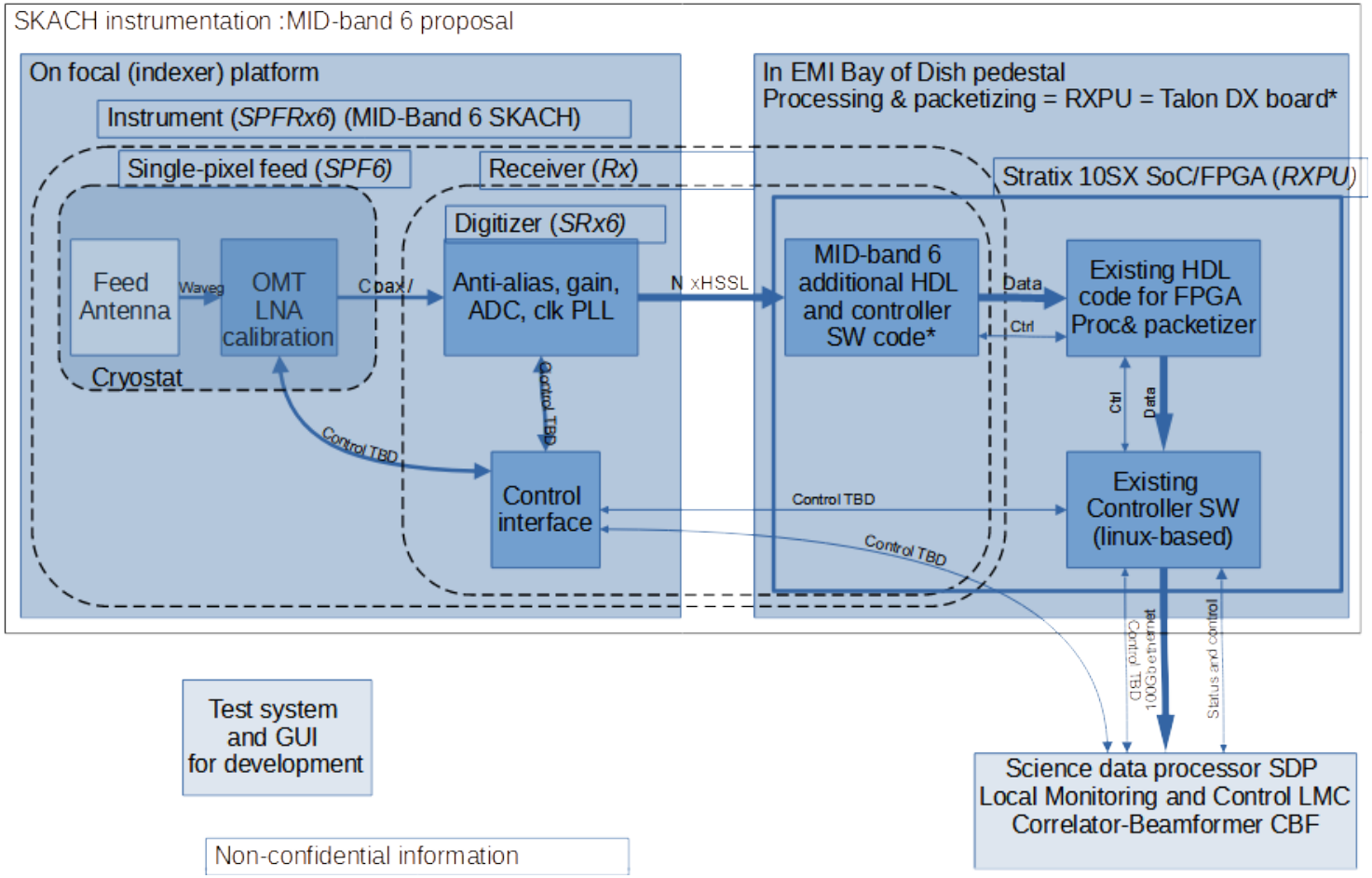
Mid-band 6: presentation outline

- Brief reminder of overall project
- Requirements evolution
- Planning of activities
- Status of EBB work packages
  - Project management and documentation (WP2404)
  - System design and requirements (WP2410)
  - Front-end (WP2400)
  - Digitizer (WP2300)
- EBB system setups
- Next actions
- Activities in other projects

Mid-band 6: Roadmap

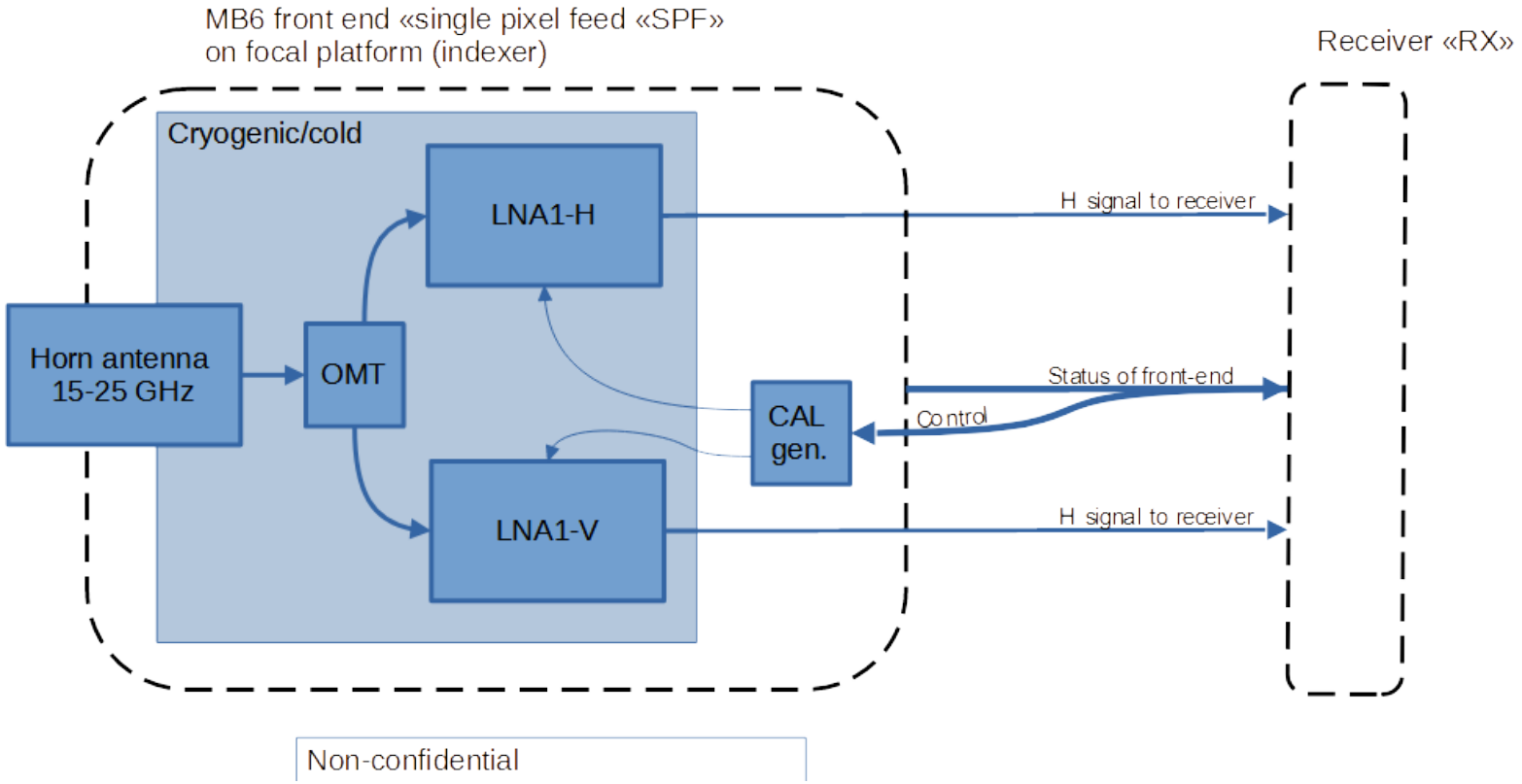


Block diagram of MID-band 6 receiver



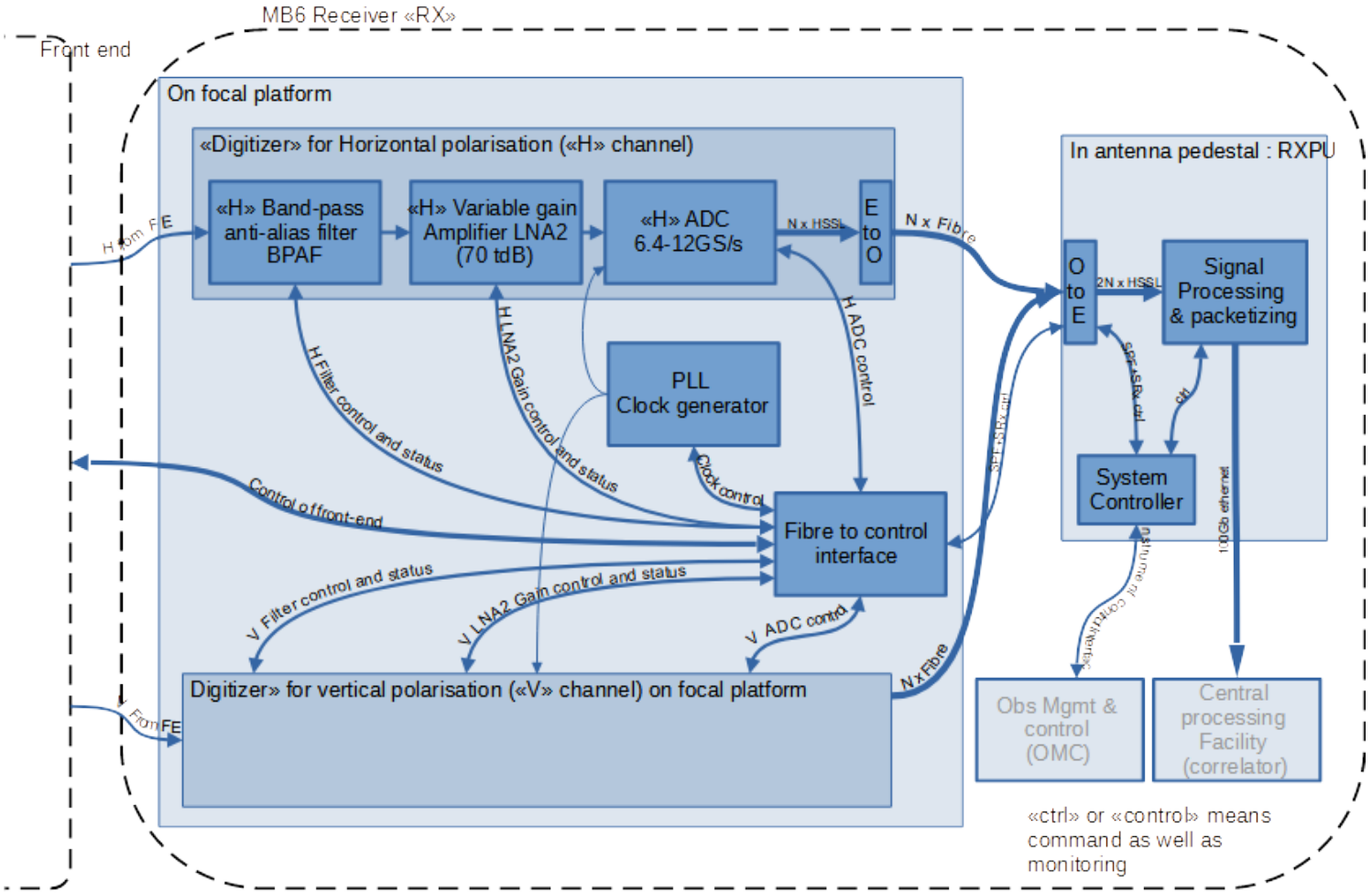
15-25GHz in 4 x 2.5GHz sub-bands

Front end block diagram



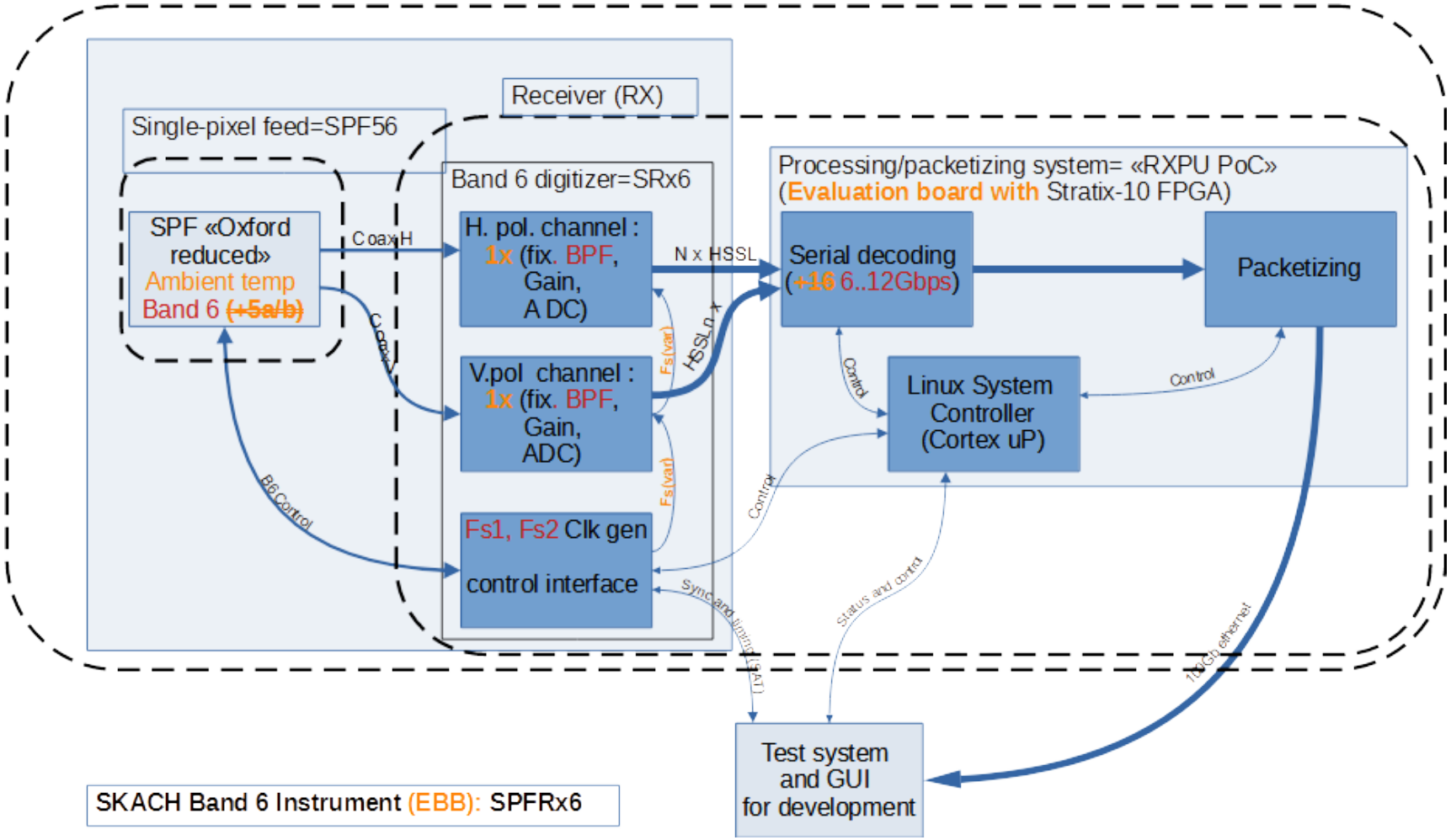
EBB is ambient/connectorised, EM will be cryo (20K) and wave-guide based

Block diagram: receiver

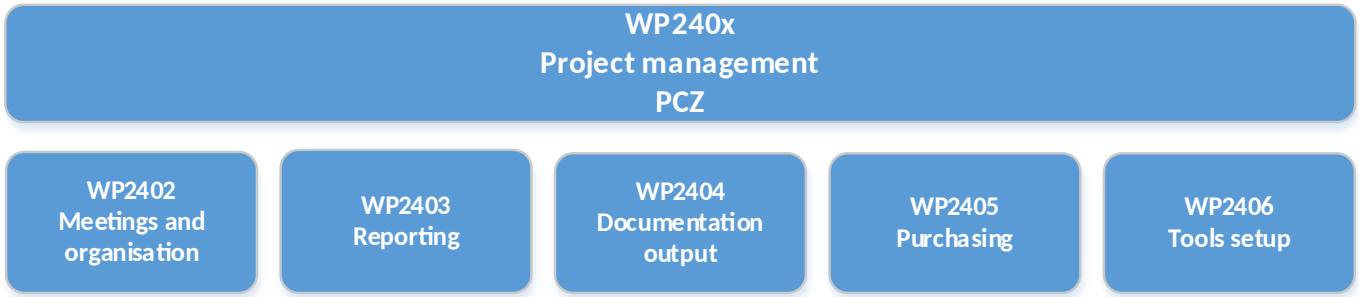


Non-Confidential

Block diagram: Mid-band 6 receiver EBB



EBB Work breakdown: WP240x PM



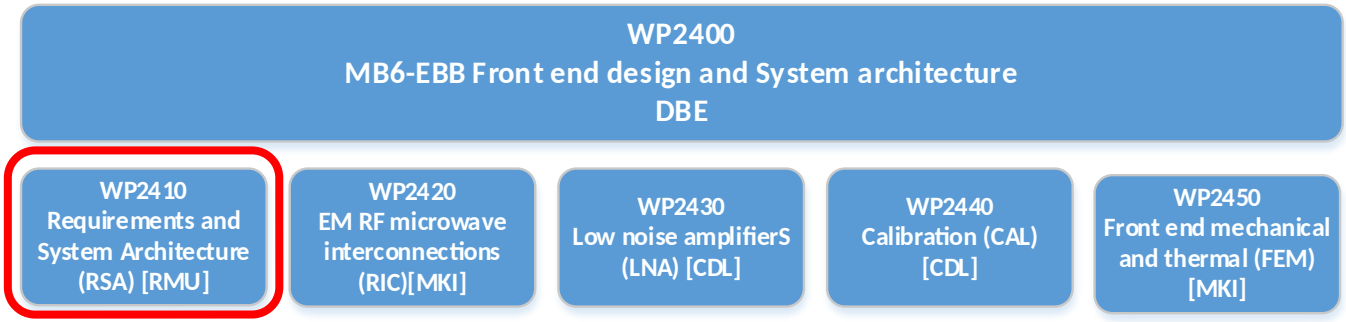
- **WP2404:** Documentation: SRR in dedicated slide
  - ☑ **Project Management Plan (PMP) update**
  - ☑ **Design & Development Plan (DDP) update**
  - ☑ **Specifications list updated after SRR**
  - ☑ **Template for the "Stories" for the "agile" Sprints**
  - ☑ EMC control plan for EM
  - Master test plan (MTP) to be update for subsystems unit and full tests of EBB

- **WP2405**: purchasing is a critical activity in the current times of shortage of electronic components, establishing a Long Lead Item list
- **WP2406**: Cameo and git
  - ☑ setting up
  - Maintenance
  - next milestone: Preliminary Design Review, june 2024

Requirements evolution

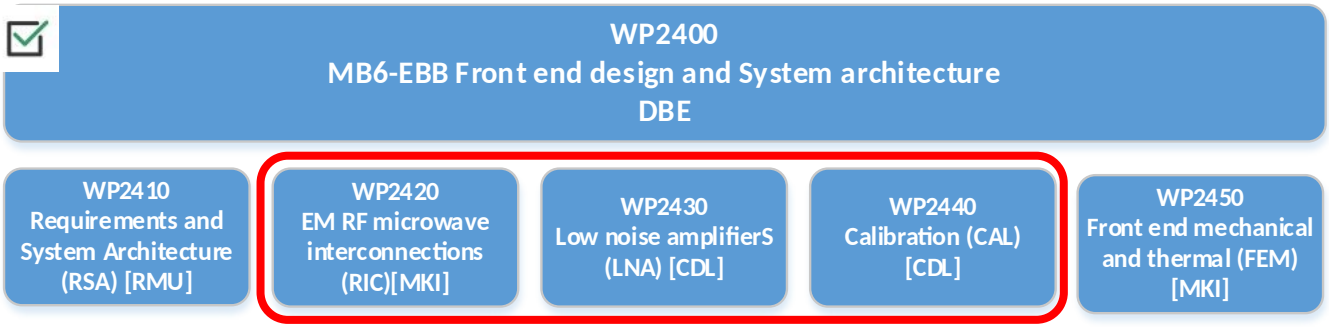
- **Requirements**
  - Astronomical science needs have been taken into account for EM (e.g. 40/50GHz)
  - Astronomy not really relevant for band 6 (15-25GHz), except as water vapour radiometer (IRAM collaboration in HE Radioblocks)
  - No requirement was written by SKAO for HES-SO
  - HEIG-VD gets inspiration for requirements from those written for band 5
    - Tailored for EBB
- **Action plan**
  - Design EBB to state of the art and using cutting edge technologies
  - EBB results will confirm requirements or define them more precisely
  - After PDR, final requirements for the EM in frame of future development projects
- **Roadmap to 50GHz MB6?**
  - 40GHz should be possible for digitizer (ADC specified, 5-6 bits)
  - 50GHz may be possible
    - requires measurement of state of the art ADC on state of the art PCB
  - Will require a complex “dual-path” front-end
    - no LNA and waveguides can cover 15-50GHz which is Ultrawideband (UWB)
    - e.g. 2 bands: 15-28GHz, 28-50GHz (WB)
      - either separate positions on indexer (bands 6+7), 2 horns
      - OR 2 bands combined into same output (band 6+)
  - band 6+ 015-50GHz feed horn
    - must have sufficient performance (constant aperture ratio)
    - tough project in itself (not SKACH)
  - some aspects covered in radioblocks project

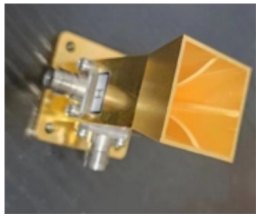
EBB Work breakdown: WP2410 Req+Sysarch



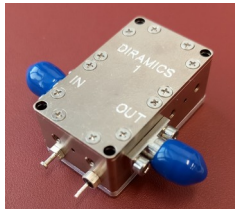
- **WP2410:**
  - ☑ **System requirements review SRR**
  - **Noise model and analysis**
    - **Electronics (Horn output to ADC)**
      - ☑ **Rough model (excel file) for ambient temp EBB**
      - **Fine model with frequency caracteristics of subsystems**
    - **Antenna noise**
      - **Sky and earth noise**
      - **Need geometrical model of full dish + imperfections**
      - **Collaboration needed**
  - **Science requirements**
    - ☑ **For EBB**
    - **For EM**

EBB Work breakdown: WP2400 front-end

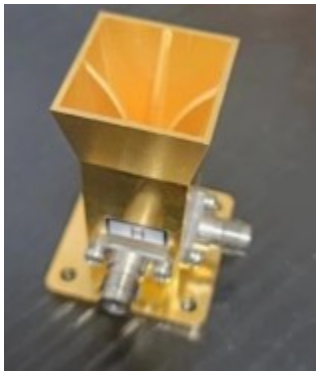




- **WP2420**: microwave **front end components**
  - ☑ COTS Horn with Built-in OMT **in delivery** (1x)
  - ☑ Microwave cables listed
- **WP2430**: LNA1 v2 in delivery and validated at ambient
  - ☑ Gain 27-28dB, Noise figure 1.8dB, X-microwave format, encased
  - ☑ Miniature polarisation (“power supply”) circuit **validated**
- **WP2440**: A **calibration** white noise source
  - ☑ is **ordered** (calibrated, custom-made)
  - ☑ Coupling mechanism **via relay switching: relays ordered**
- 🕒 **WP2450**: For the EBB, **mechanical design** of the front end (fitting of the various connectorized elements on a chassis) once we have all the elements



Front end components

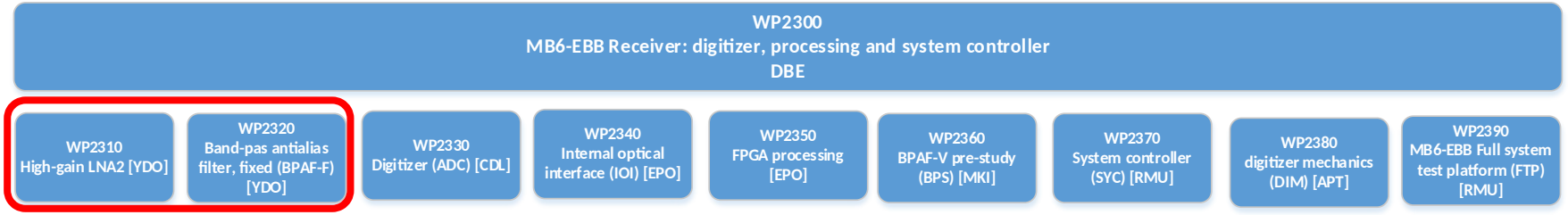


- ☑ 10-**50**GHz QRFH Feed antenna (Acura Microwave)
- ☑ 2-40GHz splitter (Mini-Circuits or HEIG-VD design)
- ☑ 10-40GHz high ENR noise source (Noisewave) **received**

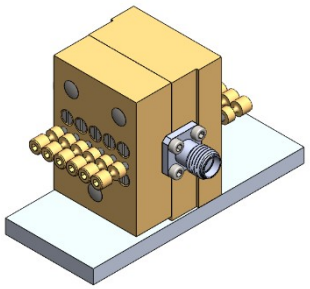
- ⚠ coaxial relays: **ordered**
- ⚠ Circulators: **Custom** 15-25GHz **received** (Acura)

- ⚠ Coaxial cables, adapters **in order** etc (Mini-Circuits et al.)

EBB Work breakdown: digitizer 1/3

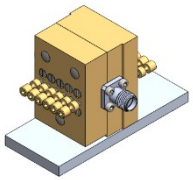


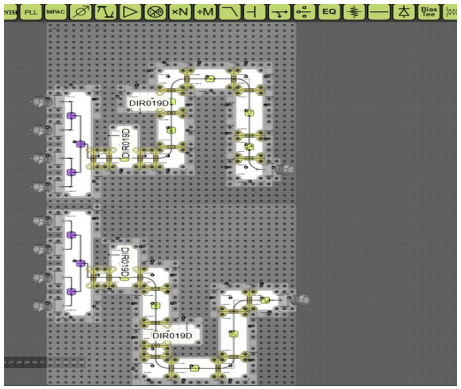
- **WP2310:** Second LNA needs a lot of gain (60dB)
  - ☑ Diramics MMIC selected (2x2)
  - ☑ Circuit architecture defined, although searching some means of decreasing the cost
  - ⚠ X-MW based build
- **WP2320**: fixed band-pass **anti-alias** filter for selecting the 2.5GHz sub-bands (1 in 4)
  - ☑ HEIG-VD design for adjustable filters for sub-bands (“almost” single design for 4 bands, same principle of operation as for variable filter WP2360 but screw-adjusted
  - ☑ Mechanical drawings **completed, in discussion with manufacturer**
  - 🕒 To be manufactured
  - ☑ 4:1 sub-band switches
    - 2x solid-state X-MW **mounted**
    - 2x radiall coaxial relays **ordered**



Digitizer 2/3 analog design (WP2310+20)

8x BPAF-F filter
(WP2320)





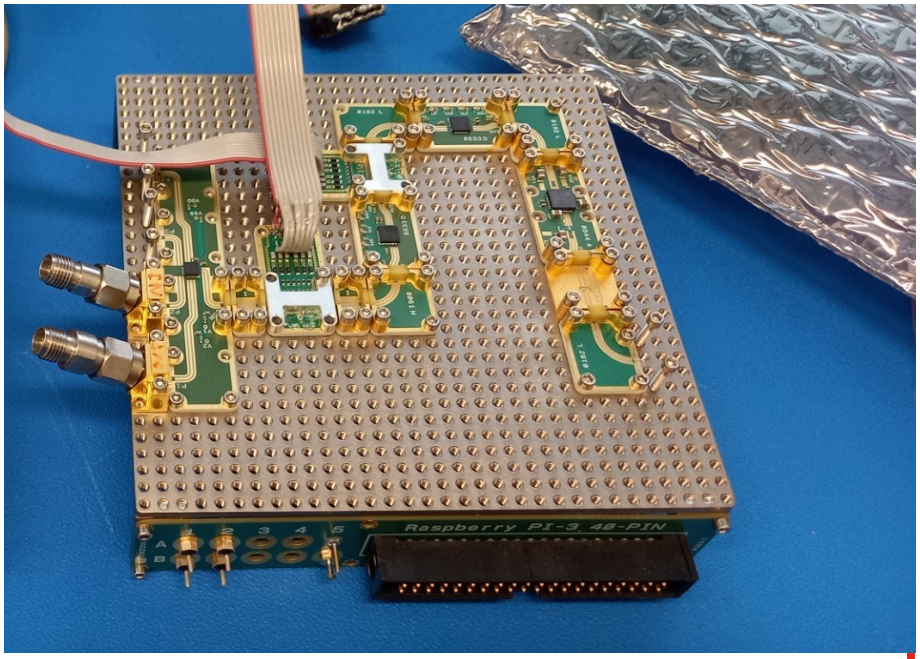
X-Microwave prototyping

Switching of BP filters

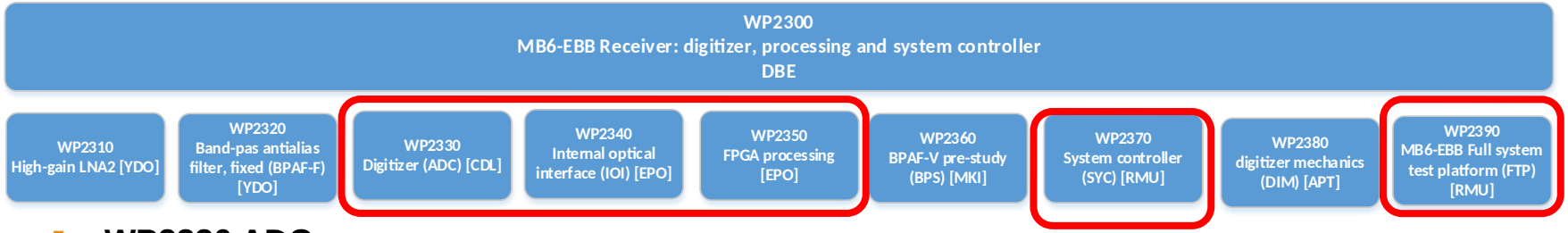
large variable gain

Diramics amplifiers

2x 4:1 relay
(WP2310)



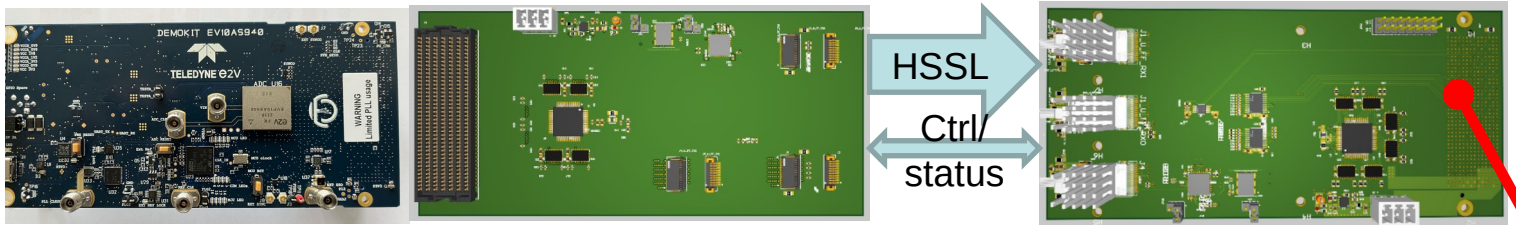
EBB Work breakdown: digitizer 3/3



- **WP2330 ADC**:
  - Approach changed
    - ☑ Instead of 1x dual ADC board developed for mfr, use 2x single ADC boards designed by ADC mfr
      - Decouples one project from the other (de-risking)
  - HEIG-VD gets 2x single-ADC board from mfr, **1 received end march 24**
- **WP2340**: **optical Links:**
  - ☑ tech pre-study: some resources identified → DDP*
  - ☑ Block diagram re-defined → DDP
  - Electronic design ongoing: schematic ☑ PCB
- **WP2350 FPGA packetizer**:
  - ☑ FPGA eval board (Stratix 10 SX) operational
  - ☑ HDL code validated - data from ADC out to 100GB ethernet at up to 11.5GSamples/s (margin, 92gb/s out)
  - ☑ Design of control system through the fiber
- **WP2370 SYC system controller:**
  - ☑ architectural decision → NOT USING processor core on FPGA
  - PC GUI will control FPGA
- **WP2390 testing:**
  - Test architecture design

Digitizer conv+digital part (WP2330,40,50)

H

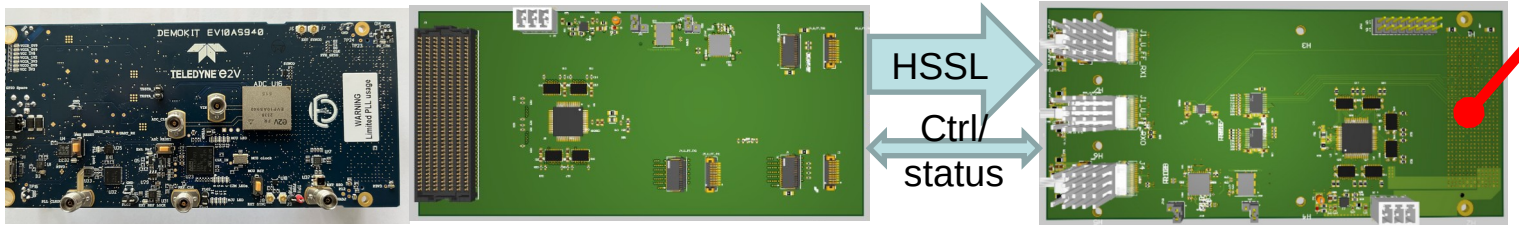


MonoCAN ADC board (WP2330):
Integrating 2x single ADC eval board in system, distributing 1 CLK 2 channels, phase compensation, uC FW adaptation

Electrical-optical-electrical boards (WP2340): enabling HS data transfer and control of digitizer and front end **through optical fibre**

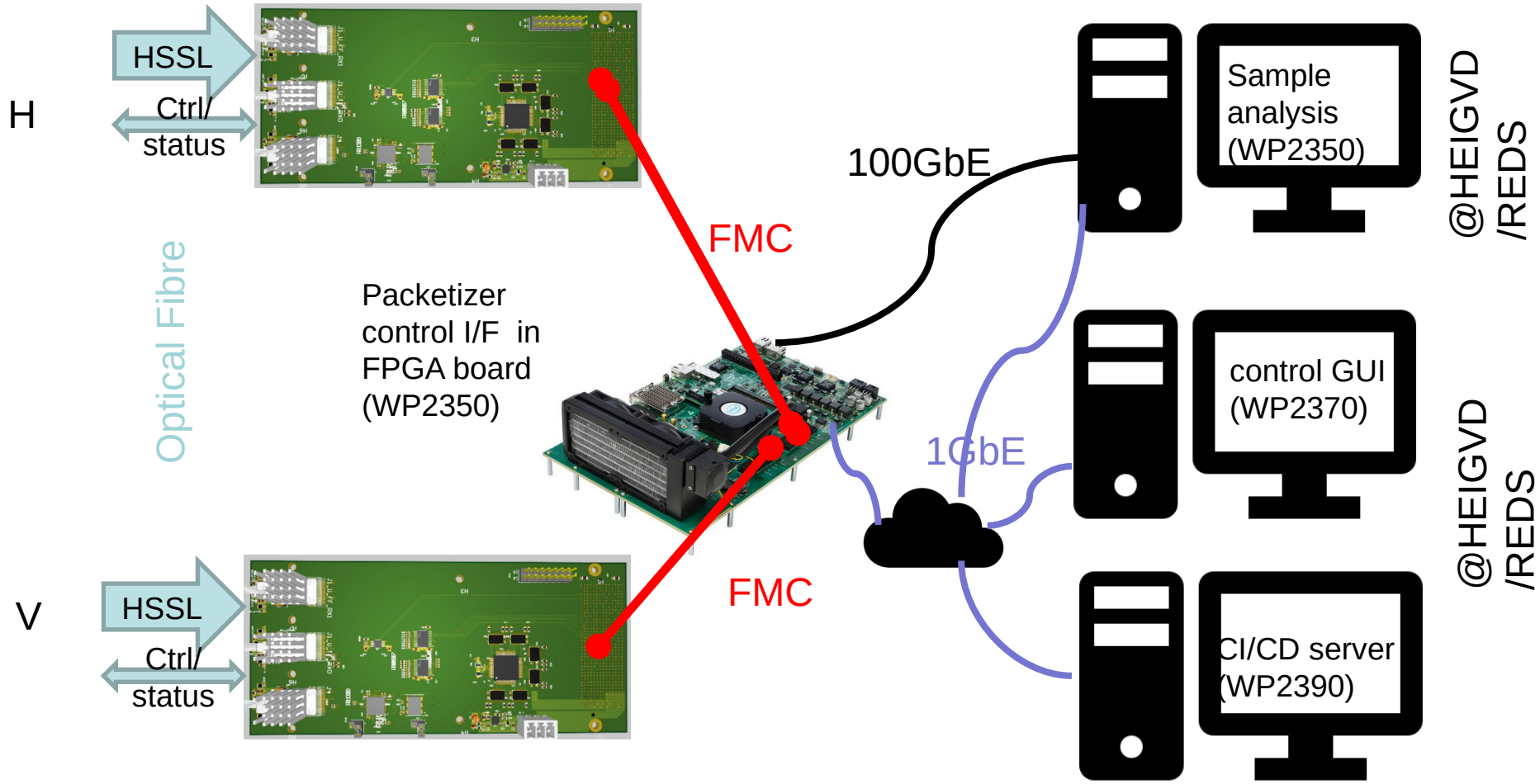
Packetizer control I/F in FPGA board (WP2350)

V



Optical Fibre

Digitizer digital + test part (W2340,50,70,90)



ADC-FPGA integration test @REDS (WP2350)

MonoCAN ADC board

Packetizer and control I/F in FPGA board (WP2350)

FMC

100GbE

1GbE

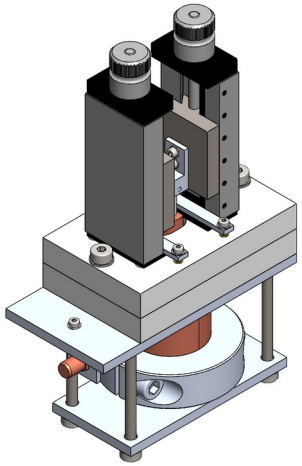
Sample analysis (WP2350)

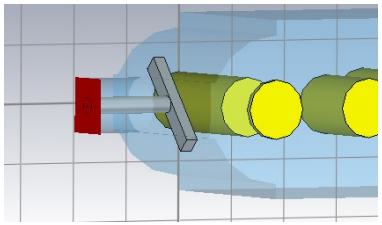
control GUI (TBD)

WP2360 EBB variable filter pre-study 1/2

WP2300
MB6-EBB Receiver: digitizer, processing and system controller
DBE

WP2310 High-gain LNA2 [YDO]	WP2320 Band-pas antialias filter, fixed (BPAF-F) [YDO]	WP2330 Digitizer (ADC) [CDL]	WP2340 Internal optical interface (IOI) [EPO]	WP2350 FPGA processing [EPO]	**WP2360 BPAF-V pre-study (BPS) [MKI]**	WP2370 System controller (SYC) [RMU]	WP2380 digitizer mechanics (DIM) [APT]	WP2390 MB6-EBB Full system test platform (FTP) [RMU]



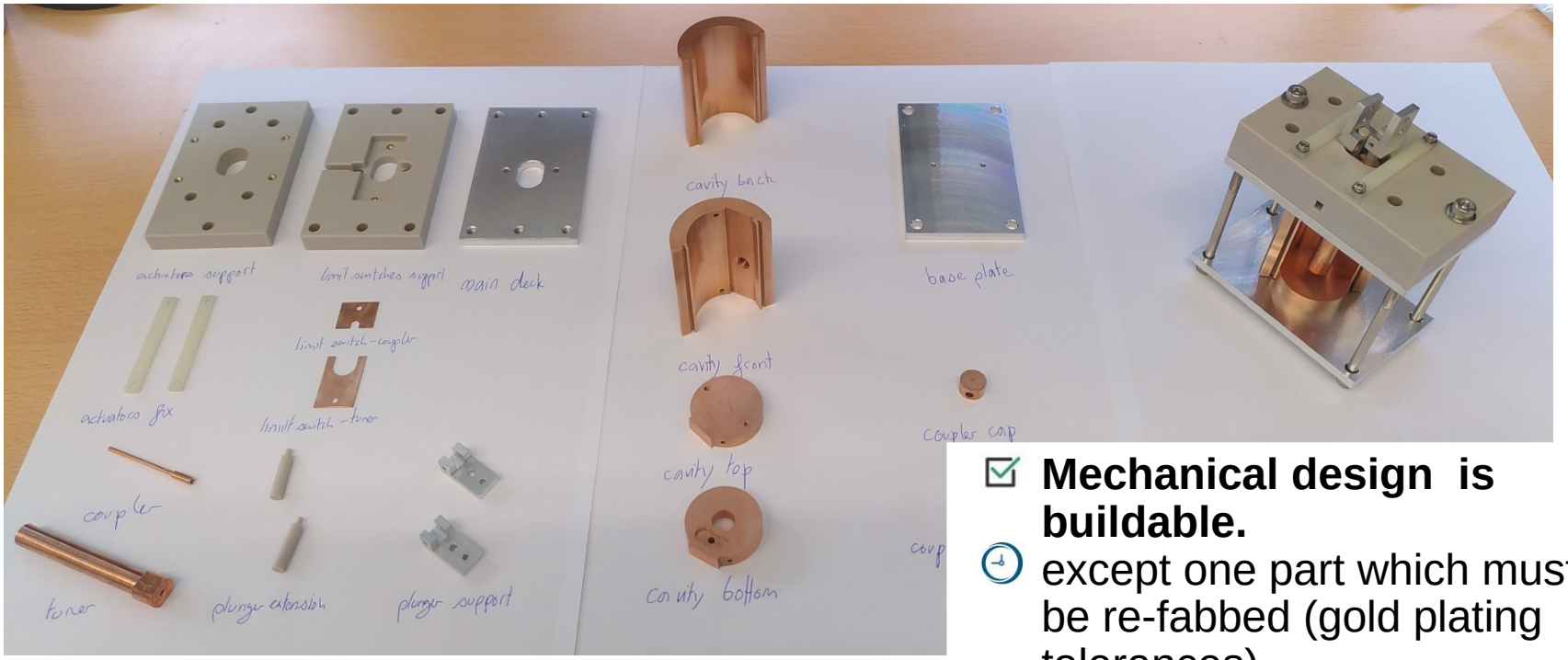


- **Single cavity PoC as preparatory work for future full filter (Proof of Concept)**
- **PoC scaled down 8:1 in frequency**
  - 1.9-3.1GHz
  - Single cell resonator
  - Single coaxial interface (SMA)
  - Actuators for frequency and coupling factor are commercial micrometric screws
  - Will enable studying effect of temperature variations etc.
  - Will be used in radioblocks
    - to continue development of a multi-cavity filter
    - Study upper modes in an easier way (**same filter size used 3-4x higher in frequency**)

EBB Filter prestudy 2/2 (WP2360)

WP2300
MB6-EBB Receiver: digitizer, processing and system controller
DBE

WP2310 High-gain LNA2 [YDO]	WP2320 Band-pas antialias filter, fixed (BPAF-F) [YDO]	WP2330 Digitizer (ADC) [CDL]	WP2340 Internal optical interface (IOI) [EPO]	WP2350 FPGA processing [EPO]	**WP2360 BPAF-V pre-study (BPS) [MKI]**	WP2370 System controller (SYC) [RMU]	WP2380 digitizer mechanics (DIM) [APT]	WP2390 MB6-EBB Full system test platform (FTP) [RMU]



- **Mechanical design is buildable.**
- except one part which must be re-fabbed (gold plating tolerances)
- needs gold plating
- to be RF tested

Mid-band 6: Next actions in SKACH

- Finalize development of EBB
- PDR june 2024
  - Designs of all subsystems
  - Documentation notably:
  - Design, Test, Risk, Quality (“SKAO-compatible”)

- Milestone 2024-06:
  - Is HW ready for Swiss SKA days demo?
- Goal: EBB operational 2024-09
- Next EBB milestone: PDR 2024-04
- End of project: 2024 anyway!!!

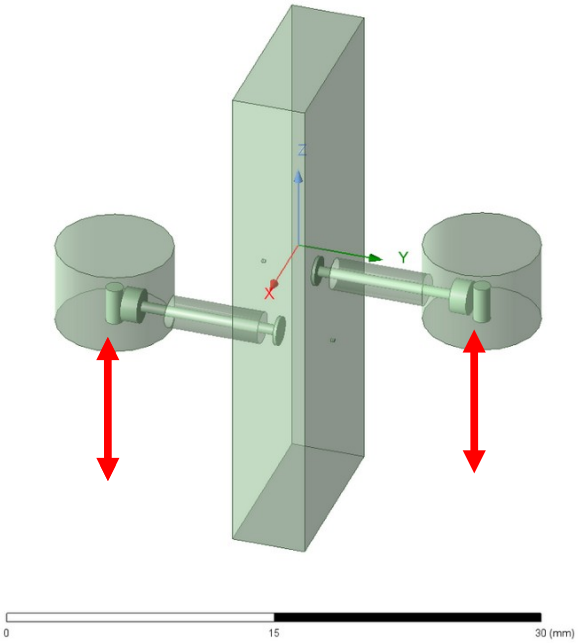
RadioBlocks (Horizon Europe)

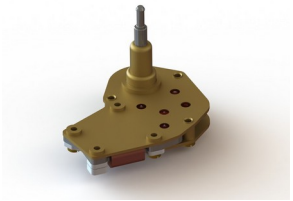
- Scientific collaboration
  - 30+ partners (MPIfR, IRAM, EVN, JIVE, ASTRON, EPFL...)
  - Project meeting in Madrid June 4-6
  - “Blocks” for radio-astronomy
    - Technological goals
    - (industry collaboration)
    - Opensource the results (as much as possible)
  - WP2 (front-end): HES-SO: Bandstop/notch filters
    - For radio-frequency interference (RFI) rejection/attenuation
    - Important when infrastructure in inhabited areas (phones, car radar...)
    - Satellite interference
    - Specs and interest confirmed (IRAM, radiometer)
    - **NEW** Collaboration with Yebes Observatory (SP) on RFI filters
      - Tune high-temp superconductor (YbaCuO) filter (70K)
      - Cavity filter operating in cryo (20K)
      - Evaluate feasibility of superconductive (8K) RFI filters (bandpass, bandblock)
  - WP3 (innovative digitizers)**:** HES-SO: passband digitizer
    - 5 to 7-cavity mechanically tuned bandpass filter
    - Digitizer
    - **NEW**
      - Integrate digitizer in instrument for MPIfR (Bonn) (optical front-end control)
      - 100GbE on FPGA and data sync (INAF, Cagliari)
      - EBB Digitizer as (lab) measurement instrument for Chalmers (SE)
- **Trying to leverage this for future SKAO MidBand 6 Engineering Model!**

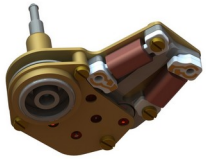
Single cavity notch 1:1 size

Single/multiple notch filter for ambient temperature (WVR)

- First «proof of principle» simulations : 18-22GHz range for notch frequency, WR51 waveguide with SMA transitions
- Coupling using coaxial and pigtail
- Single cell, scalable for multiple
- Retrofittable on existing WG
- Goal : setting for frequency through micro-stepper motor with ~1um resolution
- Coupling factor



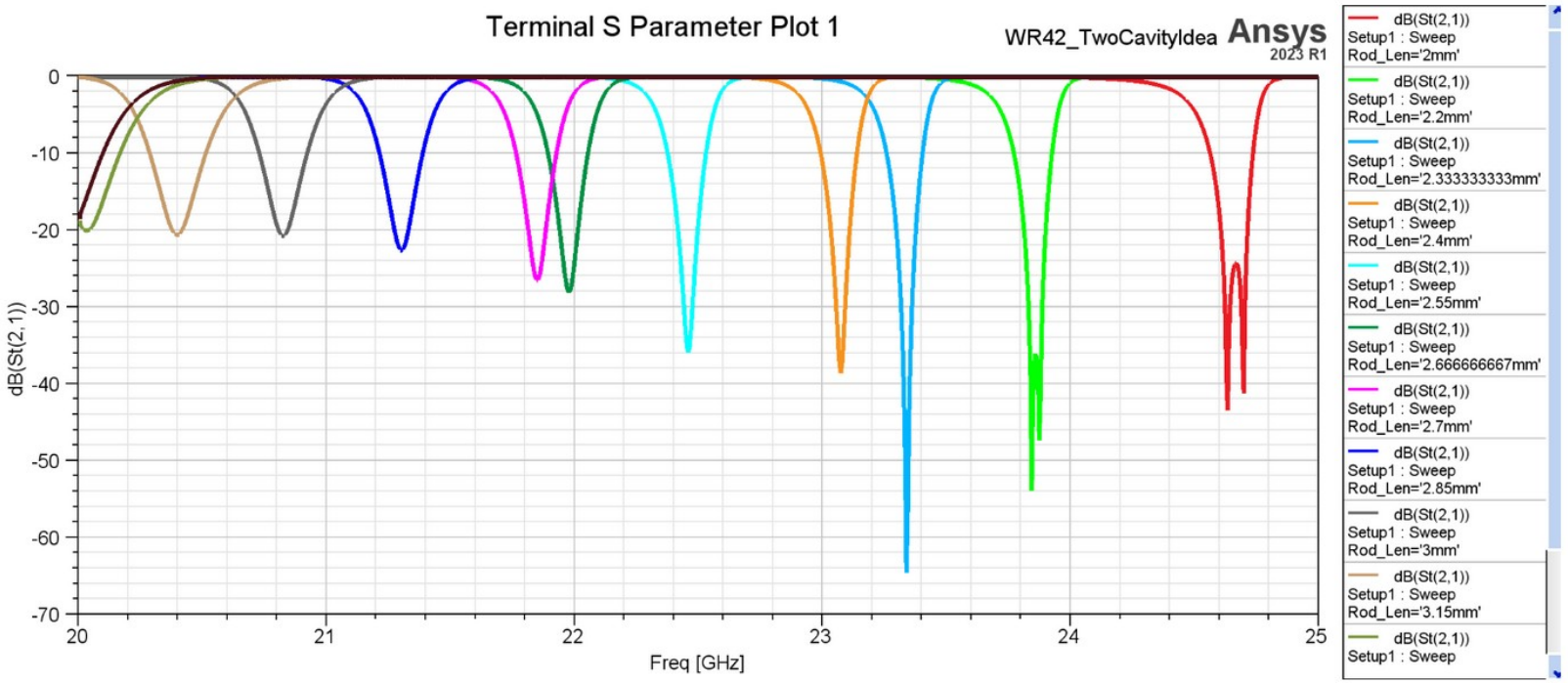




Single cavity notch 1:1 size

First simulations 20-25GHz

Frequency responses : 20um “plunger” difference allow 100MHz bandblock



PAF2024

- Phase Array Feeds 2024, @ BYU, Provo, UT, USA (near Salt Lake City)
- Interesting presentations about ongoing projects
- (http://csas.ee.byu.edu/PAF2024/)
    - L/S band PAFs
        - L-band ALPACA for Greenbank RT (BYU, Cornell)
        - L/S band 100-channel PAF for Effelsberg (MPIfR)
    - Back-ends
    - CASPER instrumentation
    - Dielectric antenna beamformers??
- Visit of ALPACA lab at BYU
- No coffee, no tea...
- Presented our work on filters and digitizers
    - Showed the interest for of direct conversion for higher bands
    - Direct conversion receiver more scalable than heterodyne receivers
    - Digital optical transmission instead of RfoF enables different architectures
    - Issues with antenna arrays
        - Compact beamformers leave little space $d_{opt} = \lambda / 2$
        - Sparse arrays are less efficient and present high fringes
        - Multiband is even more challenging
        - However ALMA has PAFs with much higher spacing
        - To be researched
    - Future applications

Mid-band 6: industrial colaboration

- Innosuisse project:
  - Tried with 3 companies, not interested
    - No “bandwidth” available
    - Too long term
    - Too risky
    - Despite (potential) high return
  - **Still trying to find swiss partners**
    - Refactor for quantum?
- **NEW** Collaboration with ADC manufacturer
  - Interested in a demonstrator with optical interface
    - showcasing radio-astronomy applications
    - Other science applications
    - Write common paper
  -