SKACH

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

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

Biotech Campus (UniGE)
Geneva 03.09.2024

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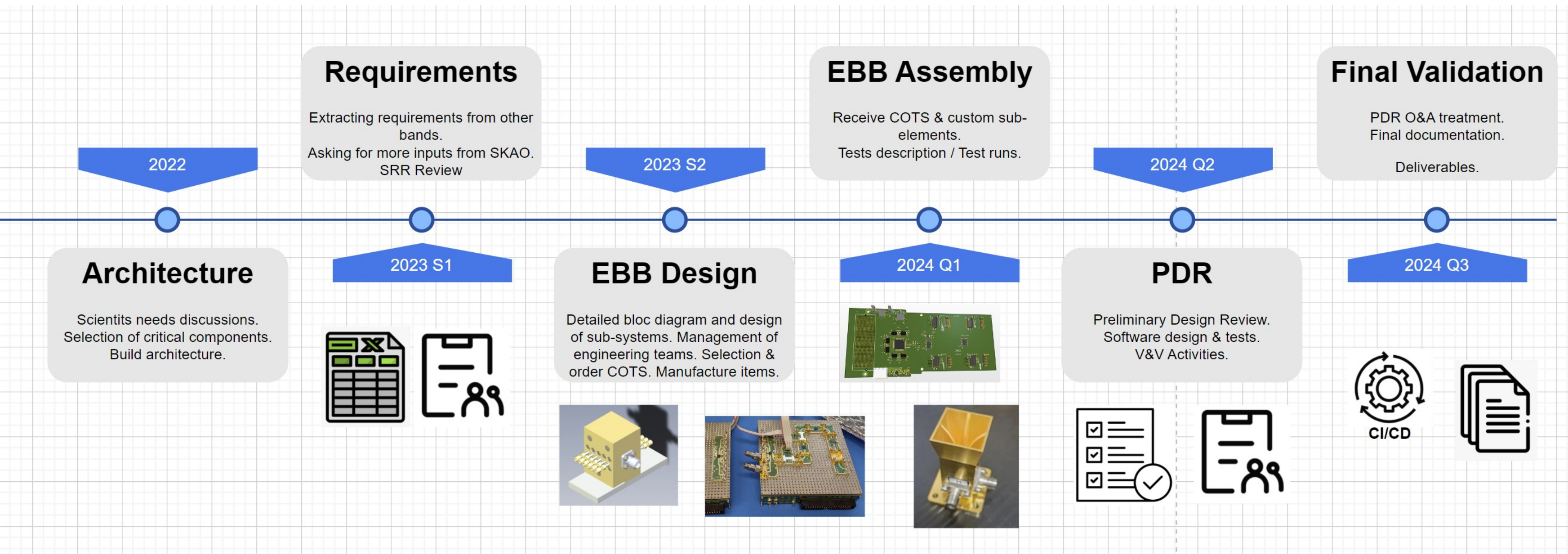
Mid-band 6: presentation outline

- Brief reminder of overall project
- Status of EBB
- EBB demo
- Next actions
- Activities in other projects

Mid-band 6: Roadmap



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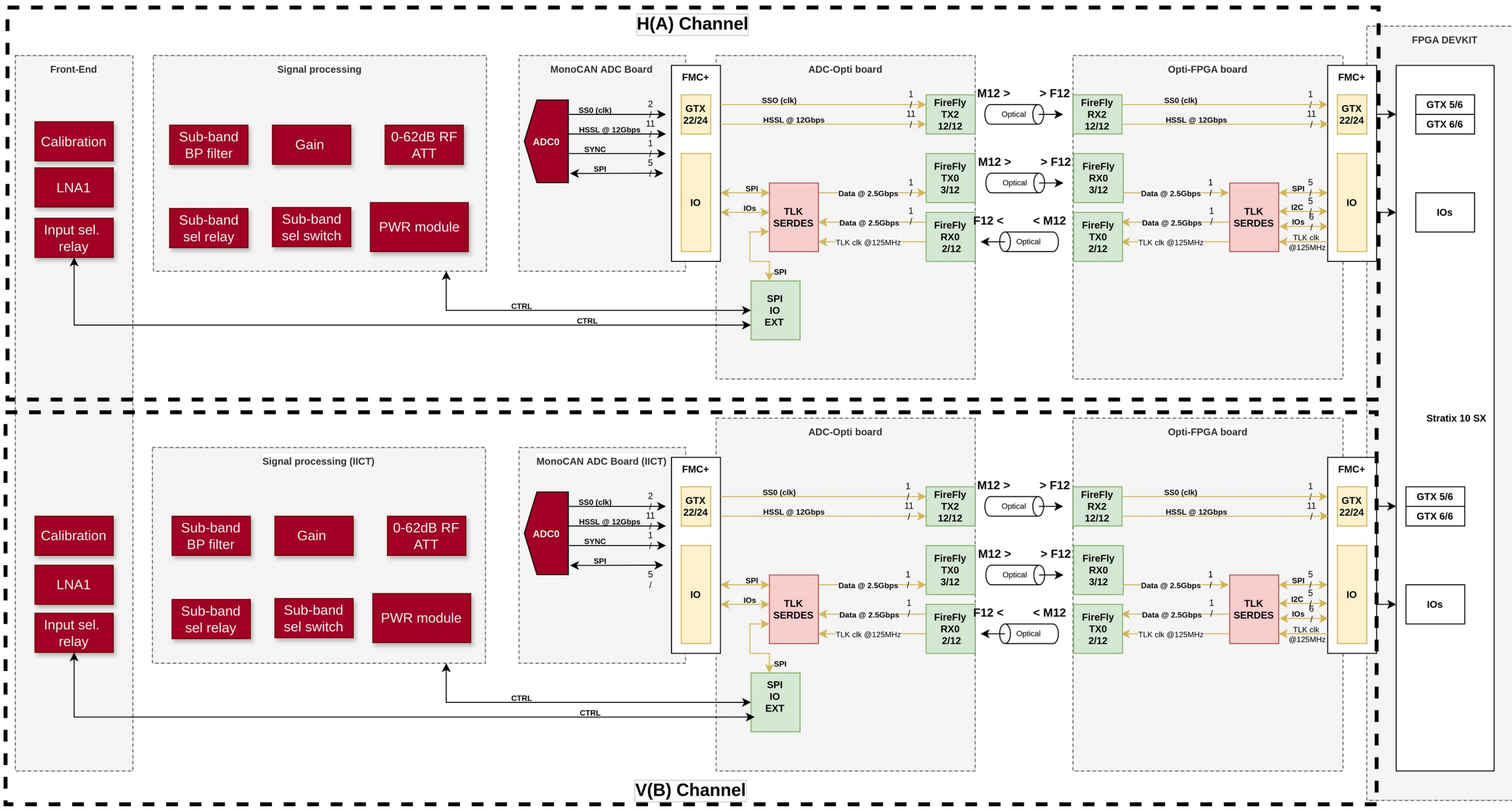
Block diagram of MID-band 6 receiver



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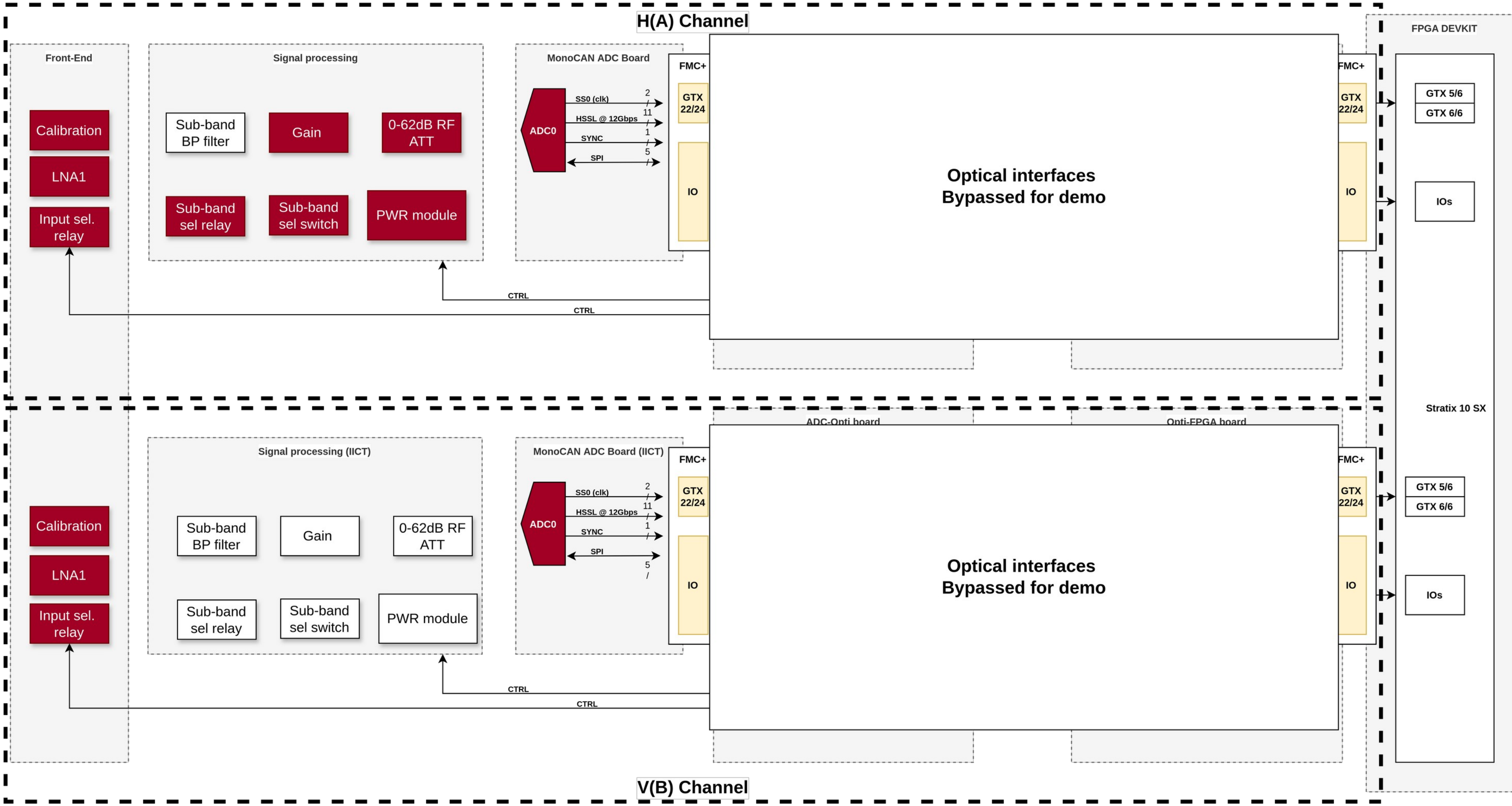
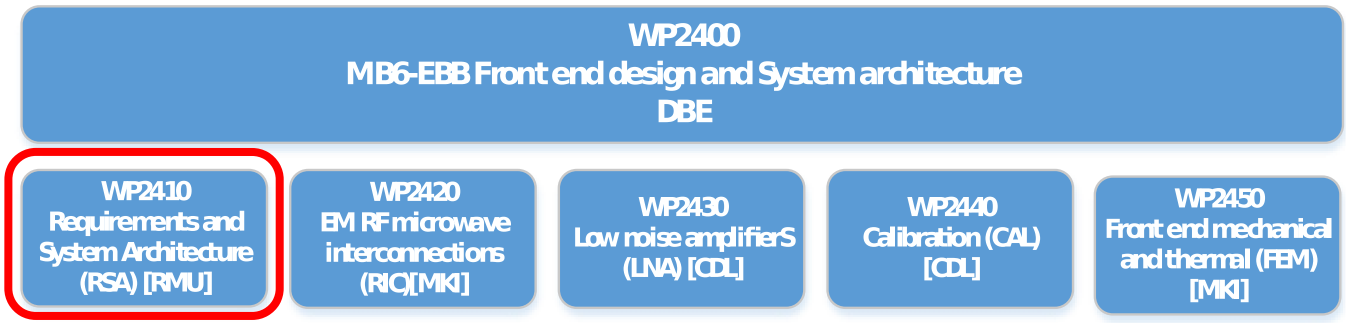
Block diagram: Mid-band 6 receiver demo vs EBB



EBB Work breakdown: WP2410 Req+Sysarch

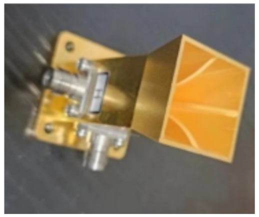


- **WP2410:**
  - ☑ **System requirements review SRR**
  - **Noise model and analysis**
    - **Electronics (Horn output to ADC)**
      - ☑ **Rough model (excel file) for ambient temp EBB**
      - 🕓 **Fine model with frequency caracteristics of subsystems**
    - **Antenna noise**
      - 🕓 **Sky and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

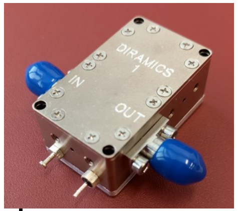
EBB Work breakdown: WP2400 front-end

WP2400
MB6-EBB Front end design and System architecture
DBE

WP2410	WP2420	WP2430	WP2440	WP2450
Requirements and System Architecture (RSA) [RMU]	EM RF microwave interconnections (RIC)[MKI]	Low noise amplifierS (LNA) [CDL]	Calibration (CAL) [CDL]	Front end mechanical and thermal (FEM) [MKI]



- **WP2420**: **front end** assembled
  - ☑ Assembled and tested to be functional
- **WP2430**: **LNA1** validated in front end
  - ☑ Gain 27-28dB, functionally tested
- **WP2440**: **calibration** white noise source
  - ☑ Functional
  - ☑ **Connection via coaxial relay :** functional
- **WP2450**: For the EBB, **mechanical design** implementd for demo



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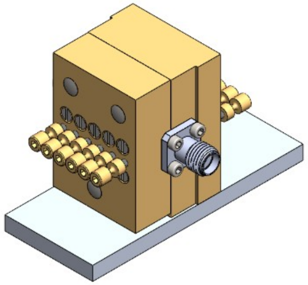
EBB Work breakdown: digitizer 1/3

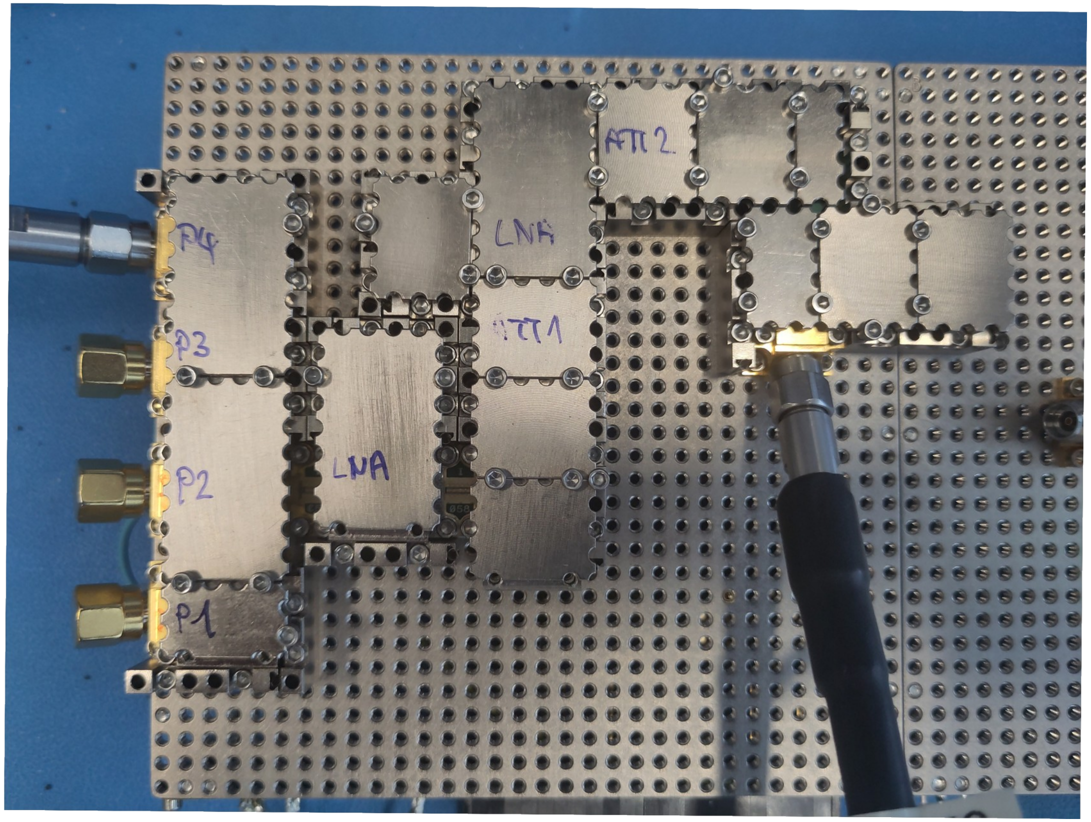
WP2300
MB6-EBB Receiver: digitizer, processing and system controller
DBE

- 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]

- **WP2310:** Second LNA needs a lot of gain (56dB)
  - ☑ Diramics MMIC in initially two amplifiers, achieved gain 51dB
  - ☑ Added 3rd stage of MMIC
  - X-MW based build **updated and functional**
- **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” design for 4 bands, same principle of operation as for variable WP2360 but screw-adjusted
  - ⚠ Mechanical parts being manufactured (due 9.9.2024)
  - ☑ 4:1 sub-band switches functional
    - solid-state X-MW (filter output)
    - Coaxial relays (filter input) with high-side switches
    - Parallel or SPI drive



Digitizer 2/3 analog design (WP2310+20)



- **“LNA2”**
- X-Microwave prototyping
  - agile HW !
- Switching of BP filters
- large variable gain (..51dB)
- Uses same Diramics amplifiers as LNA1 (low power)

EBB Work breakdown: digitizer 3/3

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

- WP2310 High-gain LNA2 [YDO]
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- WP2380 digitizer mechanics (DIM) [APT]
- WP2390 MB6-EBB Full system test platform (FTP) [RMU]

- **WP2330 ADC**:
  - ☑ 2 MonoCAN single ADC board **functional in demo**
  - ⚠ Synchronisation work to be done, but no additional HW is required to sync
- **WP2340**: **optical Links**
  - ☑ Schematic and PCB design
  - ⚠ In fabrication
- **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
- **WP 2370 SYC system controller:**
  - ☑ architectural decision □ NOT USING processor core on FPGA
  - ☑ State machine on FPGA
  - ⚠ PC GUI will control FPGA

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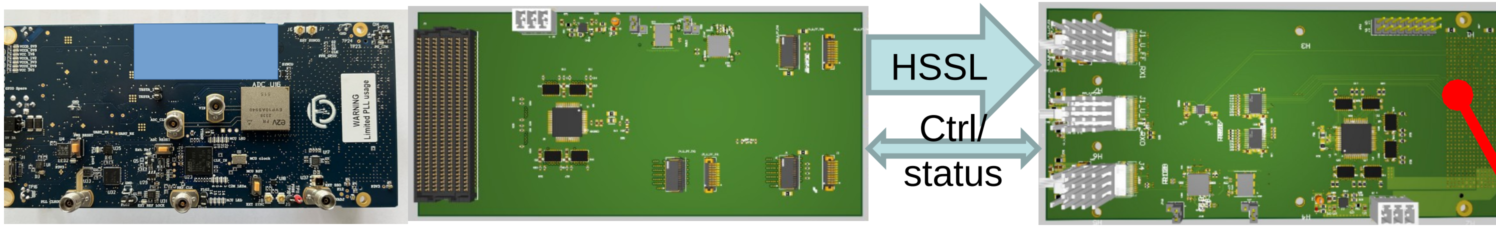
Digitizer conv+digital part (WP2330,40,50)

H

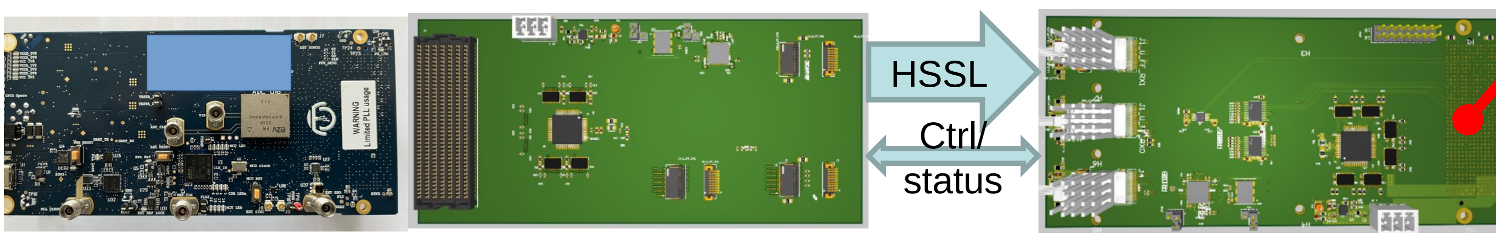


Packetizer
control I/F in
FPGA board
(WP2350)

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**

V



Optical
Fibre

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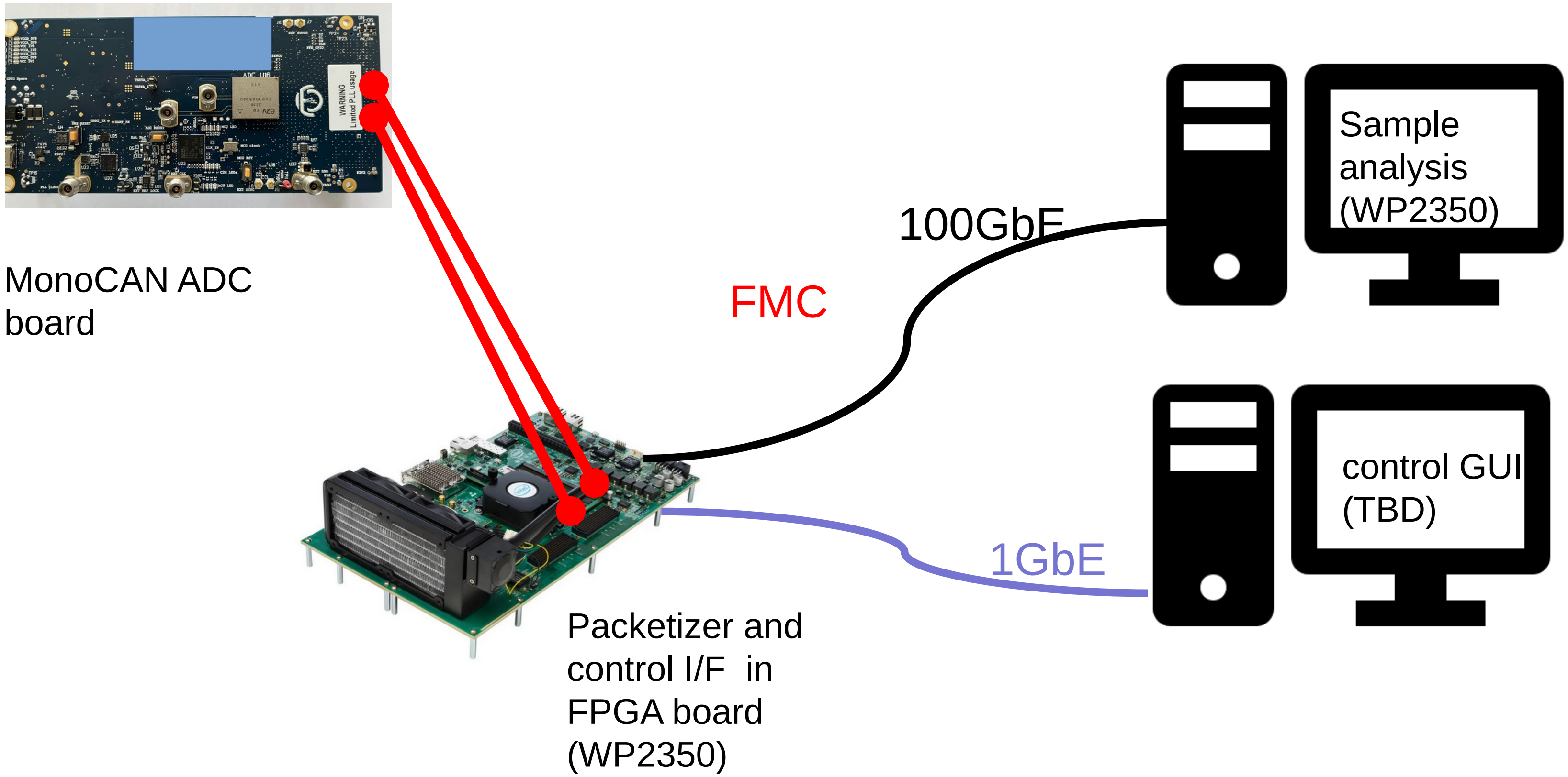
ADC-FPGA integration test @REDS (WP2350)

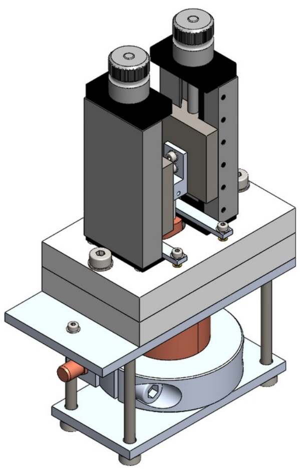


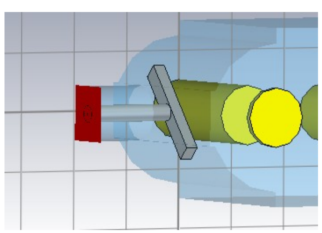
WP2360 EBB variable filter pre-study 1/2

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

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

Demo





- **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
    - **As RFI filters**
    - to continue development of a multi-cavity filter tunable filter
    - Study upper modes in an easier way (**same filter size used 3-4x higher in frequency**)

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”)

- demo operational 2024-09
- EBB operational 2024-10
- documentation
- End of project: 2024 anyway!!!

External collaborations

- Radioblocks, Horizons Europe
  - 30+ partners (MPIfR, IRAM, EVN, JIVE, ASTRON, EPFL...)
  - Project meeting in Madrid June 4-6
  - “Blocks” for radio-astronomy
    - Technological goals
    - (industry collaboration **difficult**)
    - Opensource the results (as much as possible)
  - WP2 (front-end): HES-SO: Bandstop/notch filters
    - For radio-frequency interference (RFI) rejection/attenuation
    - Use of upper modes of the filter cavities ==> automotive radar 77GHz
    - **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 :
      - Integrate digitizer in instrument for MPIfR (Bonn) (optical fibre front-end control)
      - 100GbE on FPGA and data sync (INAF, Cagliari)
      - SKC-EBB Digitizer as (lab) measurement instrument for Chalmers (SE)
- **Trying to leverage this for future SKAO MidBand 6 Engineering Model!**

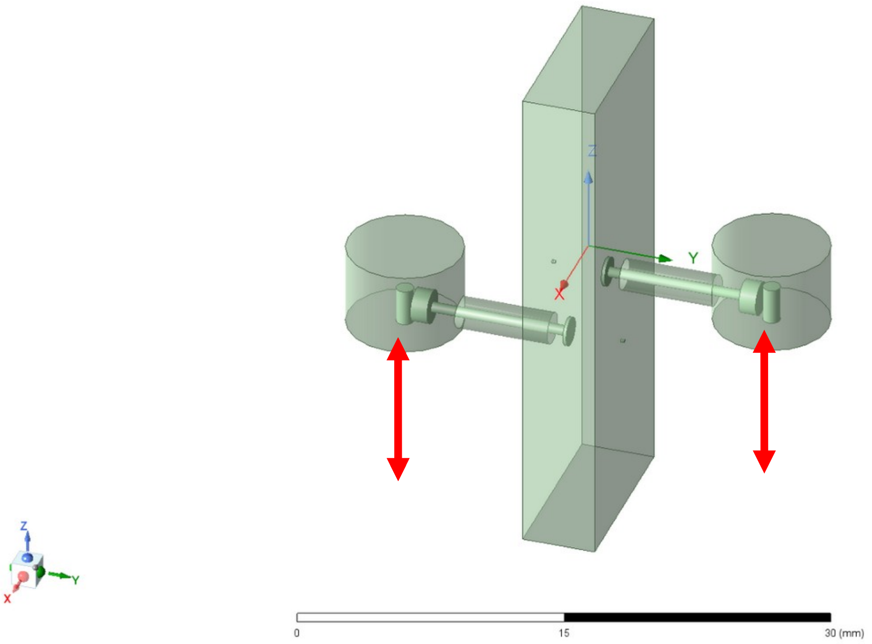
Mid-band 6: industrial colaboration

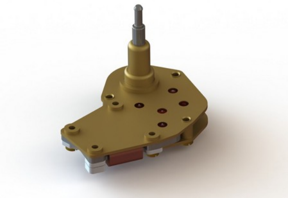
- Innosuisse project:
  - Tried with 3 companies, not interested
    - No “bandwidth” available
    - Too long term
    - Too risky
    - Despite (potential) high return
  - **Still trying to find swiss partners**
    - Refactor for quantum?
- Collaboration with ADC manufacturer
  - Interested in a demonstrator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

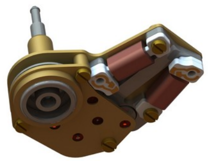
Single cavity notch 1:1 size

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







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An interesting feature of the ADC

- "Mid-band 6" ADC "magnifier"
  - 0-40GHz analog range
  - 6.4-12.8 sampling rate
  - 2.5-4GHz raw bandwidth around any center frequency in range
  - BUT it has internal digital circuitry
  - DDC digital down-converters
    - 4 available on chip, none used now for SKAO
    - Decimation ratio 2 to 1024
    - One could be used for 2.5GHz bandwidth (additional filtering)
    - Enable "zooming into signals" with up to few MHz bandwidth
  - Potential uses?
    - Astrochemistry
    - "low-doppler"
    - SETI
  - Integration into SKA architecture may be difficult
  -

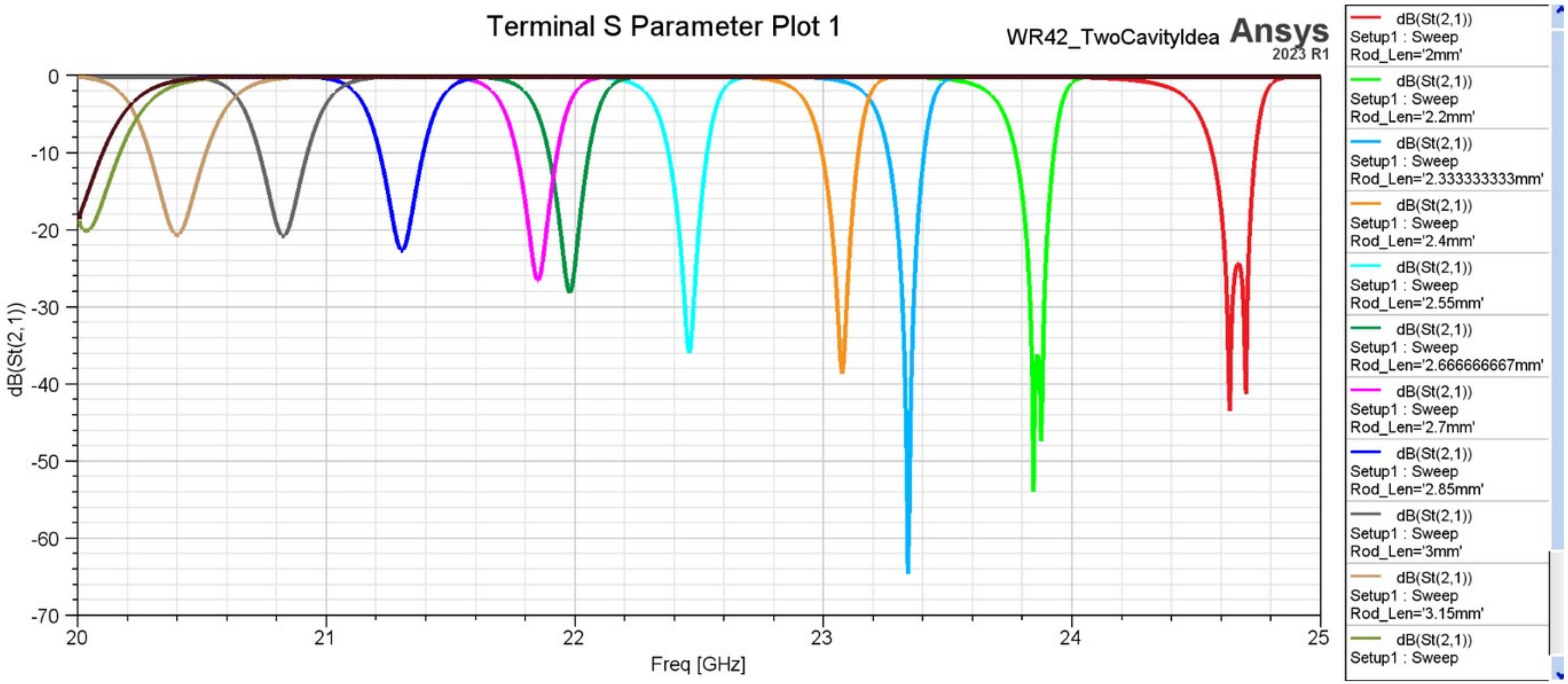
Mid-band 6: the SKACH dream team

	Micro-wave	Digital design	Electronics	SW	Mech. design	EM design	Mech. Assembly	Purchasing	System design	PM+ doc
GMH			X					X		X
ADI		X							X	X
MKI						X				
MAF						X				
ACS		X		X						
YNG		X	X							
CDL	X								X	
EPO									X	
YDO	X				X		X			
MLS					X		X			
PCZ					X			X		X
DBE	X				X				X	X
JCZ							X	X		
WHN	X								X	

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