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Haute Ecole Spécialisée
de Suisse occidentale

HE IG VD SCHOOL OF ENGINEERING AND MANAGEMENT

Swiss SKA Days 2021-09-08
Receiver systems for SKA

Innovative SDR for SKA MID bands

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Together ahead. RUAG

Presentation Outline

- SKA MID bands status
- SDR receiver with undersampling
- Proposal design (RX and frontend)
- Development process
- Benefits for SKA
- Financing
- Who are the partners

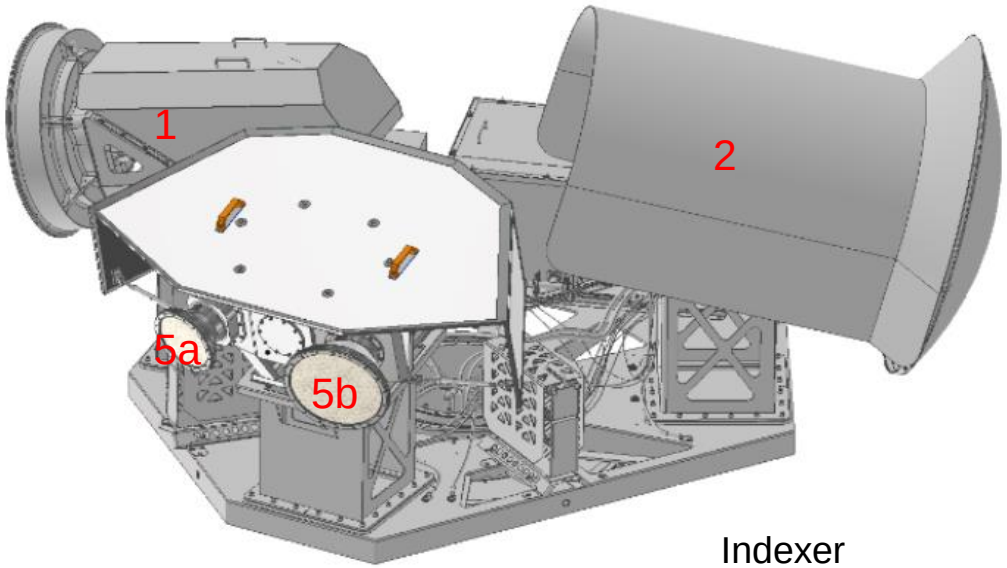
SKA MID bands status

Band	Frequency Range	Bandwidth
Low	**50 – 350 MHz**	**300 MHz**
Mid Band 1	**0.35 – 1.05 GHz**	**700 MHz**
Mid Band 2	**0.95 – 1.76 GHz**	**810 MHz**
Mid Band 3	1.65 – 3.05 GHz	1.4 GHz
Mid Band 4	2.80 – 5.18 GHz	2.4 GHz
Mid Band 5a	**4.6 – 8.5 GHz**	**3.9 GHz**
Mid Band 5b	**8.3 – 15.3 GHz**	**2 x 2.5 GHz**
65,536 channels maximum across any band, zoom windows possible		

Possible Wide-Band and/or High Frequency upgrade paths

Band	Frequency Range	Bandwidth
Mid Band A	1.6 – 5.2 GHz	2 x 2 GHz
Mid Band B	4.6 – 24 GHz	2 x 2.5 GHz
Mid Band 6	15 – 24 GHz	2 x 2.5 GHz

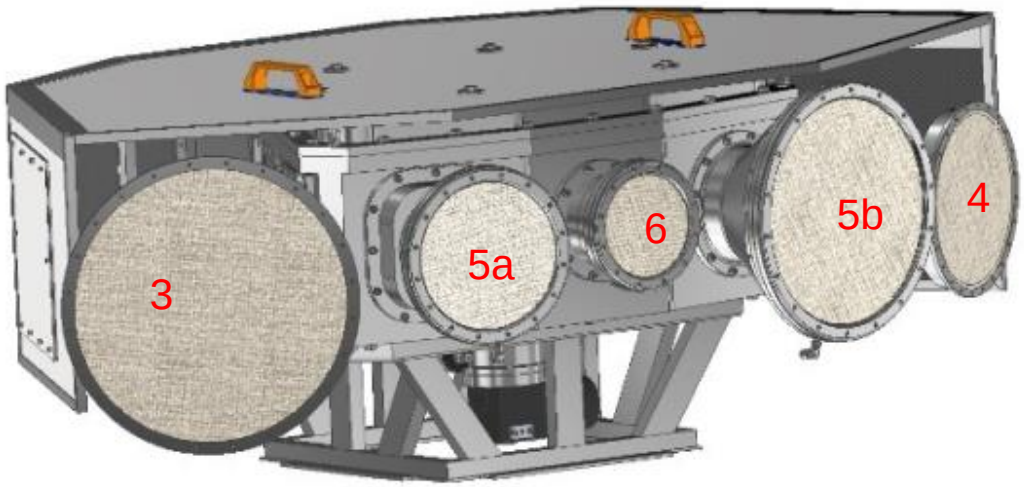
- Mid bands 1, 2, (5a, 5b?) are implemented and operating
- Mid bands 3,4, 6 have not yet been attributed



Indexer

Mid bands 3-6 full implementation

- 5 bands, 5 feeds, 5 receivers
- Single band operation («mechanical» selection by orientation of the «indexer» platform)



Detail of indexer

Software defined receivers

- Direct RF to digital conversion
  - «ADC at antenna»
- All further signal processing done digitally
  - FPGA =«software»
  - Flexibility!
- Sampling:
  - Normal sampling rate at fs>2B (Nyquist criterion)
  - MID band 6 would require >50GS/s sampling
    - Way beyond SoA!
  - Therefore we will use undersampling
    - Sampling happens on sampling clock harmonics
    - Anti-alias filtering is band pass (Nyquist criterion still applies)
  - Requires high bandwidth at ADC sample and hold (>24GHz)
  - ADC Sampling frequency at 6.4 .. 10GHz (technology limit)
- Constraints: we must be able to source the components
  - ITAR! ➔ preferably no US manufacturers
  - Long term availability: tens of years
  - Knowledge management (as in space projects)

Proposed receiver solution

- European key components:
  - ADC (UK)
    - with >30GHz sample and hold
    - >6.4GS/S (~10 effective bits)
  - FPGA (France)
    - Developed for space
  - Long-term solutions
  - HEIG-VD has design partnerships with both manufacturers
- “bonus”: Operation at lower bands is “free”
  - Can cover bands 3,4,5,6 = band D?
  - In max ~2.5GHz band
  - Change frequency bands with a change of FPGA configuration
  - Local configuration controller
- Processing
  - 10bit ADC adds flexibility in dynamics with fixed gain LNA
  - Variable decimation of data (e.g. 10➔ 3bits)
  - …

Proposed front end solution

- Wide bandwidth feed horn design
  - 4:1 bandwidth with good aperture efficiency (design goal)
  - 2 feed horns for coverage of 1.7 to 24GHz
  - Part of “Front end” Innosuisse project
- InP Low noise amplifier(s) (LNA)
  - with s**wiss company Diramics**
  - Extremely low nose from 2 to >50GHz
- Variable/switchable bandpass:
  - Needed for bandpass sampling in receiver
  - Can be used for phase equalization too (or in FPGA?)
  - Solutions to be researched in “Front end” Innosuisse project
  - RUAG Space is Innosuisse implementation partner
- Cryo assembly, horn etc. co designed and manufactured with **RUAG Space** – Switzerland
- **Open to collaboration** with academic partners

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Benefits

- **For SKAO**: simpler MID radiotelescope antennas
  - One single multiband RX (Digitizer) for covering bands 3 to 6 (instantaneous BW TBD), potentially beyond 24GHz
  - 2.5GHz instantaneous BW
  - One or several identical MBRX per indexer platform
  - 2 feed horns/Front ends for coverage of 1.7 to 24GHz in 2 bands
  - 4 indexer positions instead of 7

- **For science**:
  - More flexibility: Simultaneous (sub) bands accross MID band limits (taking in account/optimizing limited correlating power)
  - Astrochemistry
  - Many more science cases vs 2021 situation
  - …

Financing

- SERI contribution for SKA (Swiss Confederation)
  - Direct funding (*under contracting)*
  - Initial funding 2021-2023
  - With RUAG, Diramics
- Innosuisse (Swiss Confederation)
  - Academic-private partnership in applied research
  - For a small co-financing (10%), implementation partner owns the research result and must finance its industrialisation
  - Targeted for true innovation (risky, beyond pure development) with demonstrated Industrial/Business potential
  - 2 projects *to be submitted , and to be won*:
    - «RX» and «Front end»
    - 2022-2023/4
    - Result: EBB/EM
- SKA financing (*wishes*)
  - The following phases (2023+) *might* be directly financed by SKA
  - Co-financing of industrialisation (200 systems)

Together ahead. RUAG

RUAG Space contribution

- Support at System level with requirements definitions, documentation and project review organization
- Mechanical design
- Thermal design and analysis
- Assembly and cryogenic tests

HEIG-VD past and present projects

- Space
  - www.astrocast.com radio (S band)
  - http://www.clearspace.today navigation radar (X band)
  - SDR makerspace (X band direct sampling)
- Medical devices
  - implanted devices with RF control
    - ARTUS for urinary incontinence https://www.affluentmedical.com/artus/
    - NeoCARE for newborns with heart malformations
  - Other
    - FOCAL ONE ultrasound generator for prostate cancer treatment https://www.edap-tms.com/en/products-services/prostate-cancer/focal-one
    - Hyperthermia RF cancer treatment
- Industry and IoT:
  - digitalization of products

HEIG-VD competences and experience

- Electronics
  - Wireless from 125kHz to >20GHz (*Microwave*)
  - Delivering full proto series (to TRL6)
- Embedded SW
  - ARM, DSP
  - RTOS, Linux
  - **FPGA**
  - **CI/CD**
- Mechanics:
  - Design
  - Thermal
  - Vibration
- System design

- Team/project organization increasingly based on strongly structured processes
  - **European Space Agency (ESA)** standards and processes
  - **Medical Device Regulations (MDR)**
- Core team of 10+ professionals
  - Long-term contracts
  - Industrial experience and mindset
  - Passionate!

➔ **More an engineering group than your usual university lab!**

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HEIG-VD infrastructure

- Microwave/high-speed instrumentation
  - Spectrum analyzers to 30GHz
  - Vector network analyzers to 20GHz
  - High-bandwidth oscilloscopes, RF generators
  - **X-Microwave rapid prototyping for HW**
- Software
  - **Git + CI/CD remote testing**
  - **Cameo SysML: system modeling**
  - SystemVue 2020 RF system simulation, Matlab…
  - ANSYS suite
    - EM: Microwave and circuit simulation
    - Thermal/Mechanical
  - Optenni
    - RF Circuit synthesis (matching networks)
  - SDR frameworks (demos and implementation)
  - FPGA design and simulation
- Microwave Anechoic room
  - At HEIG-VD
  - Access to EPFL/MAG room
  - GTEM (EMC)
  - Armasuisse 10x4x4m

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