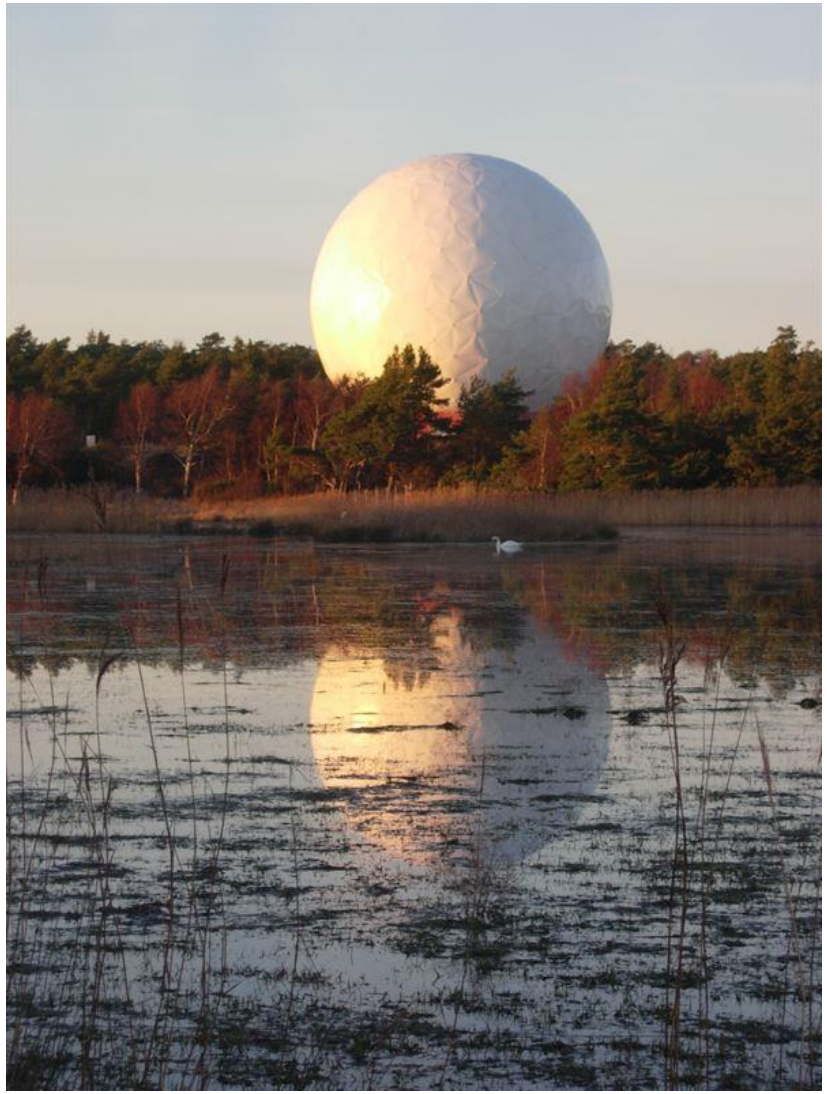
Tri-band receiver for Onsala Space Observatory



IVTW 2025 leif.helldner@chalmers.se magnus.dahlgren@chalmers.se

CAMERA

OSO 20m Tri-Band ~~Receiver~~ Project

Leif Helldner*, **Magnus Dahlgren****
Denis Meledin*, Mugundhan Vijayaraghavan**
Onsala Space Observatory

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**GARD: Max Behrens, Victor Belitsky, Mathias Fredrixon, Sven-Erik Ferm, François Joint. Igor Lapkin, Avan Mirkhan, Alexey Pavolotsky, Magnus Strandberg, Erik Sundin*

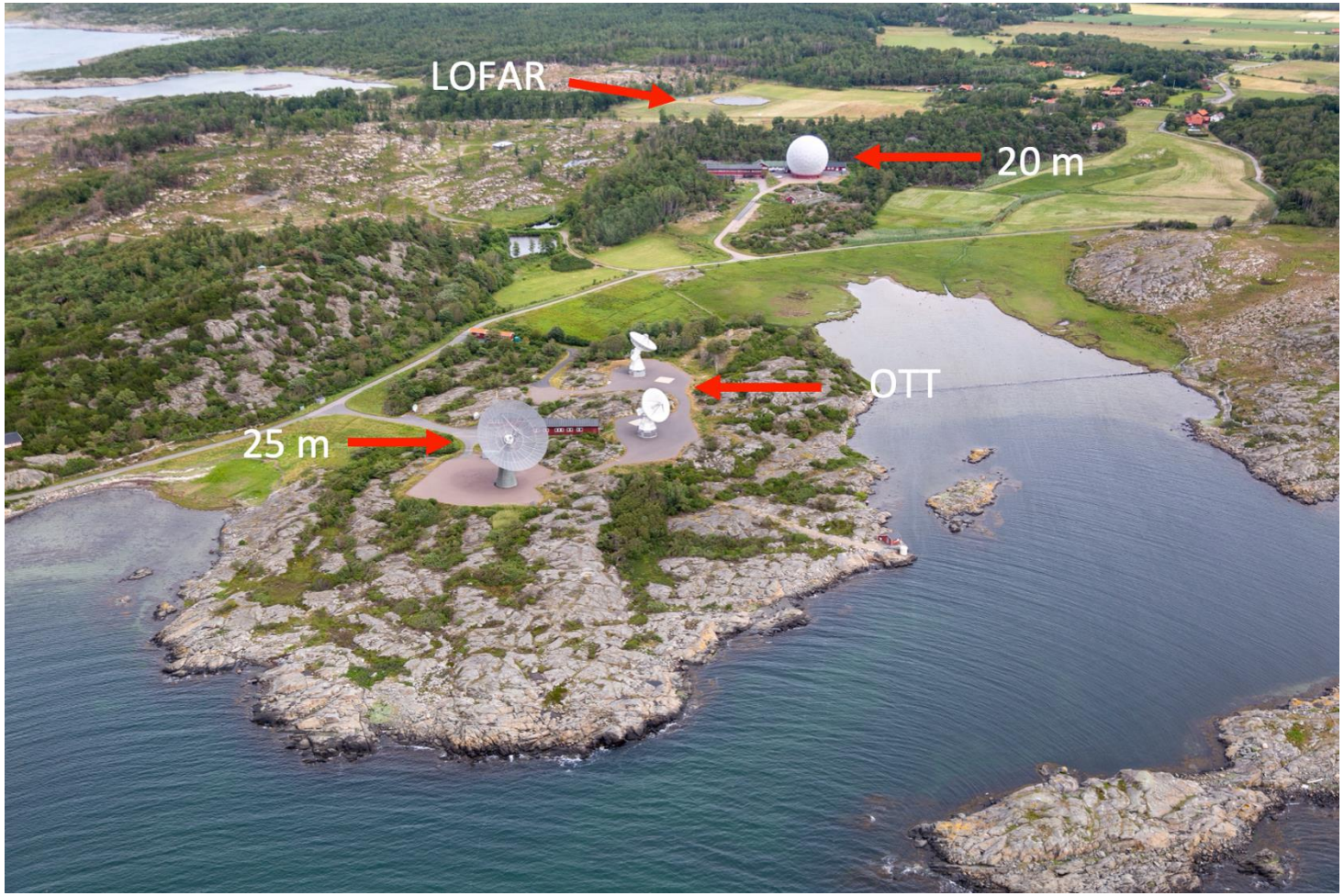
***TSG: Rolf Ahlman, Simon Casey, Lars Eriksson, Jan Karaskuru, Magnus Kjerling, Peter Hillerström, Rebekka Handdirk, Mikael Lerner, Johannes Reldin*

10th International VLBI Technology Workshop (IVTW)

21–25 Oct 2025
Veras gräsmatta, Chalmers, Gothenburg
Europe/Stockholm timezone

Onsala Space Observatory

Swedish National Infrastructure for Radio Astronomy. Hosted by Chalmers and is operated on behalf of the Swedish Research Council.



Chalmers University of Technology

Organisation

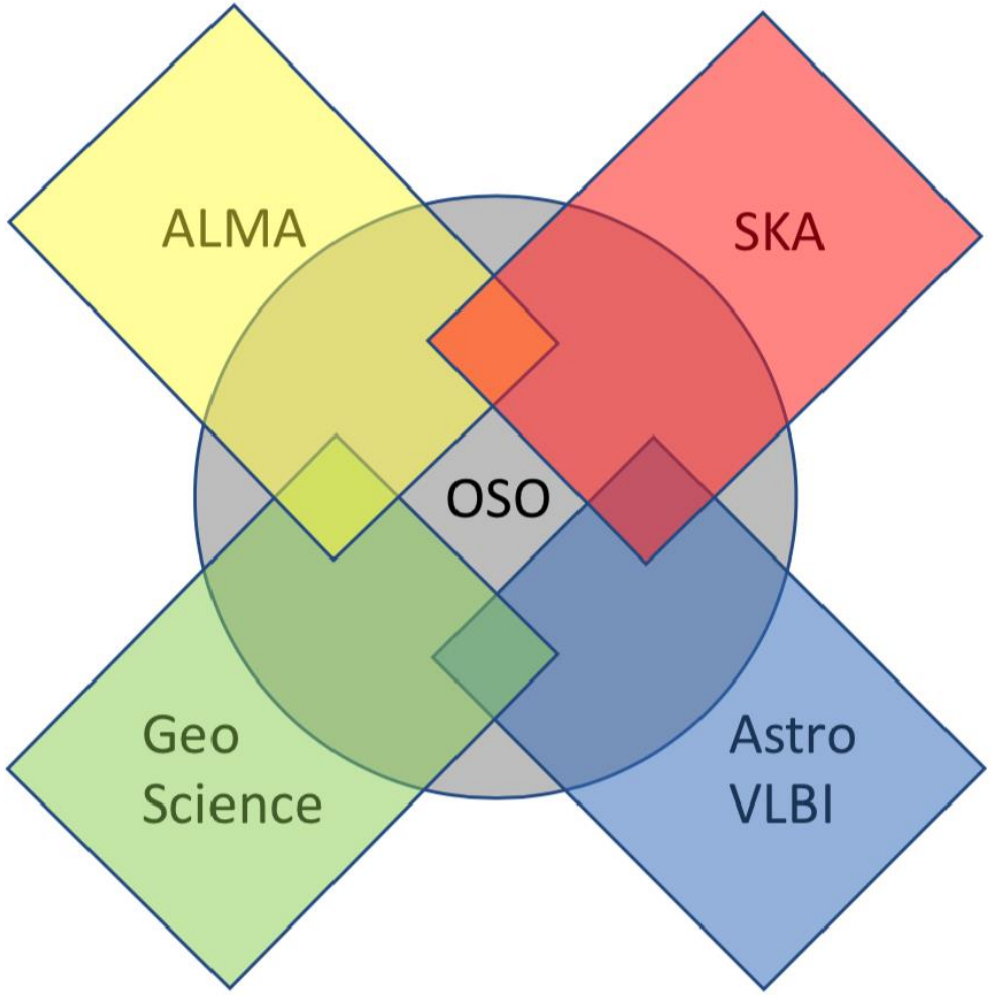
The department of Space, Earth and Environment was formed on May 2, 2017 through merging the former department of Earth and Space with the divisions of Energy Technology and Physical Resource Theory from the department of Energy and Environment.

The department consists of five research divisions:

- **Astronomy and Plasma Physics**
- **Energy Technology**
- **Microwave and Optical Remote Sensing**
- **Onsala Space Observatory**
- **Physical Resource Theory**

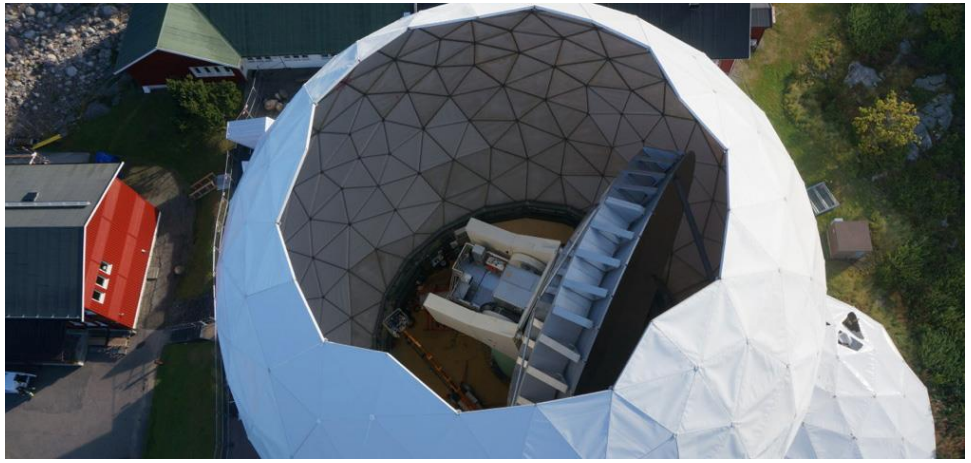
- Group for Advanced Receiver Development (GARD)
- Space Geodesy Group (SGG)
- Observational support group (OSG)
- Technical Support Group (TSG)

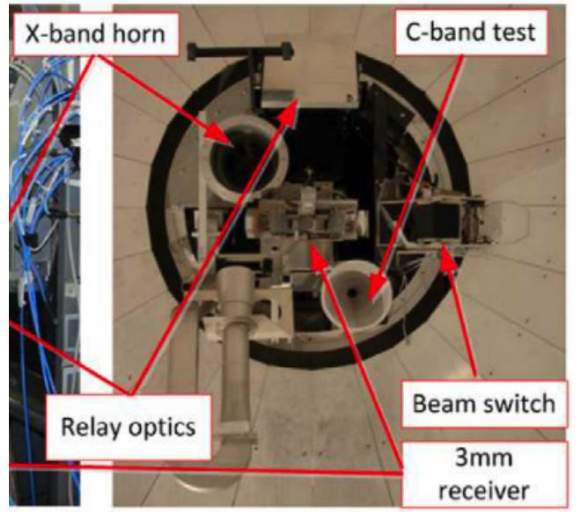
Onsala Space Observatory - strategy



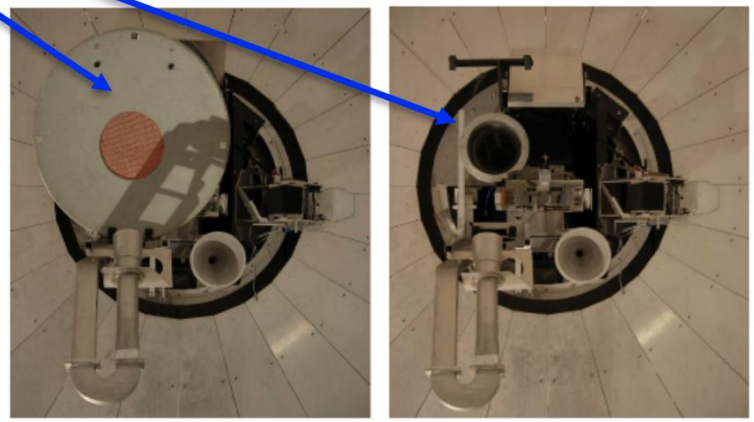
EVN
GMVA
LOFAR

Onsala Space Observatory 20 m





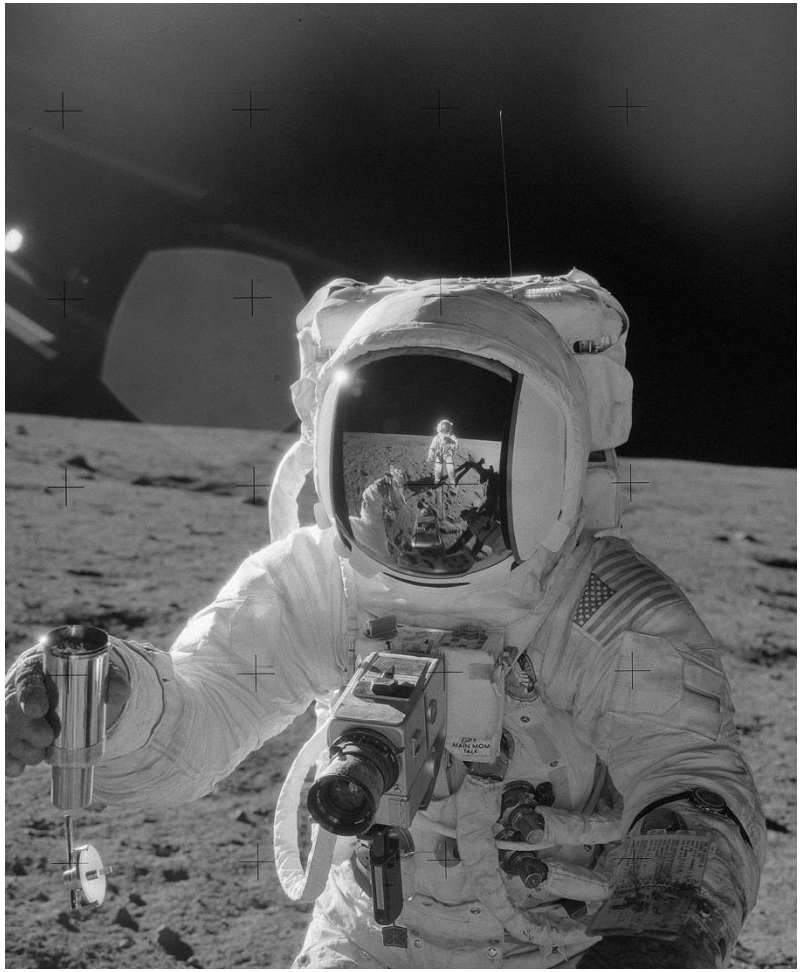
S-band



Tri-band project initiated 2024

- Replace existing K, Q and W-band single pixel receivers with a new tri-band receiver system in operation @ OSO 20 m antenna.
- (Any) New system must be simple to operate.
- Dependent on funding.

Funding secured – Hasselblad foundation



Hasselblad foundation contribution

- Full funding
- Includes 1 FTE x 2 years

Onsala Space Observatory's contribution

- Project management
- GARD - 1,5 FTE x 3 years
- TSG - 2 FTE x 3 years
- Receiver commissioning

Requirements, specifications & trade-off's

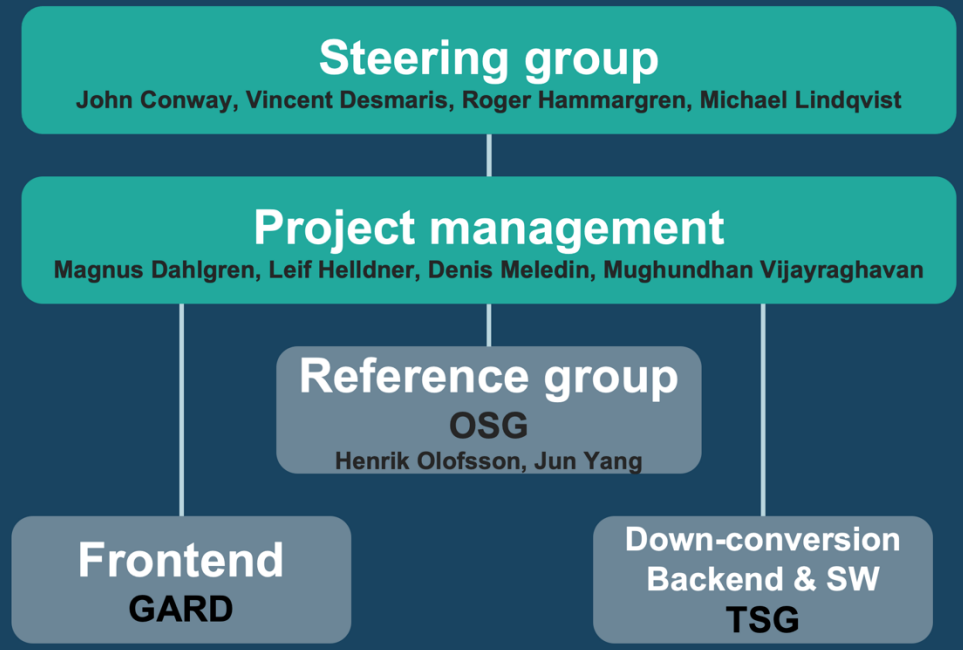
Specifications	K VLBI / SD	Q VLBI / SD	W VLBI	W* Single Dish	Comment
Dual linear polarisation	H+V USB	H+V USB	H+V 1SB	H+V 2SB	Circ. pol "wished"
RF Frequency (GHz)	18 – 26*	37 – 50*	70 - 95	67 -116*	Target frequency
IF bandwidth (GHz) (e-VLBI upper bitrate (Gbps))	2x 4 0,3 – 6* (32)	2x 8 0,5 – 16* (64)	2x 8 2x 16 (64/128)	4x 16 0,5 – 16* (256)	
Filter characteristics	-	HPF 35	HPF 70	None	
Quasi optical edge taper (passed power fraction %)	D x 3,2 (99,4)	D x 4,2 (99,98)	D X 5,0 (99,99)	=	Trade-off, space
Cross polarisation (dB)	< -15	< -15	< -15	=	Total @ secondary
Calibration	N-diode	N-diode	N-diode	Load	
Estimated T-rec (K)	< 25	< 45	< 65	< 60	High end numbers

Project organisation

Utilizing a new project organization model (PPS-Modellen)

Joint project; OSG + TSG + GARD

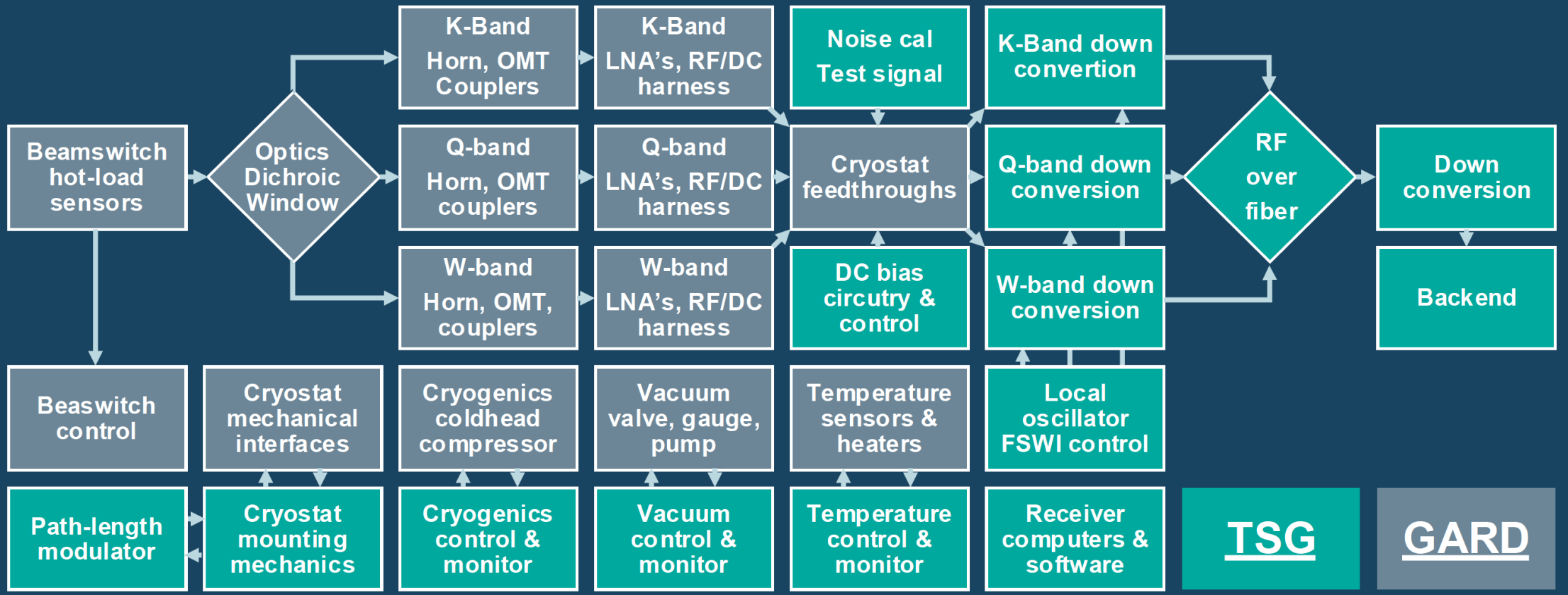
- FRONTEND - (GARD)
- DOWN-CONVERSION BACKEND & SW - (TSG)
- TESTS – (GARD/TSG)
- INSTALLATION – (TSG/GARD)
- COMISSIONING – (OSG)



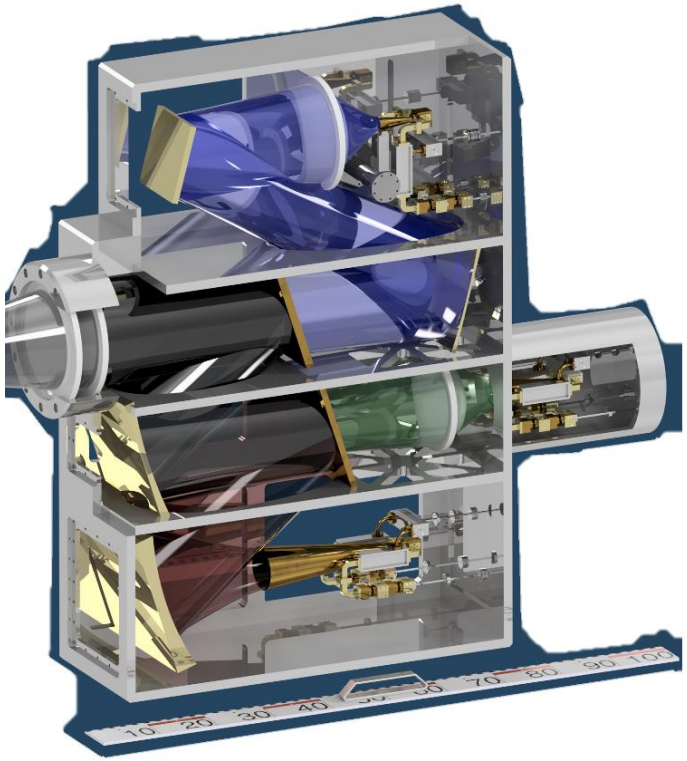
PPS project steering model: https://www.tietoevry.com/en/create/pps/pps-model/pps-project-steering/

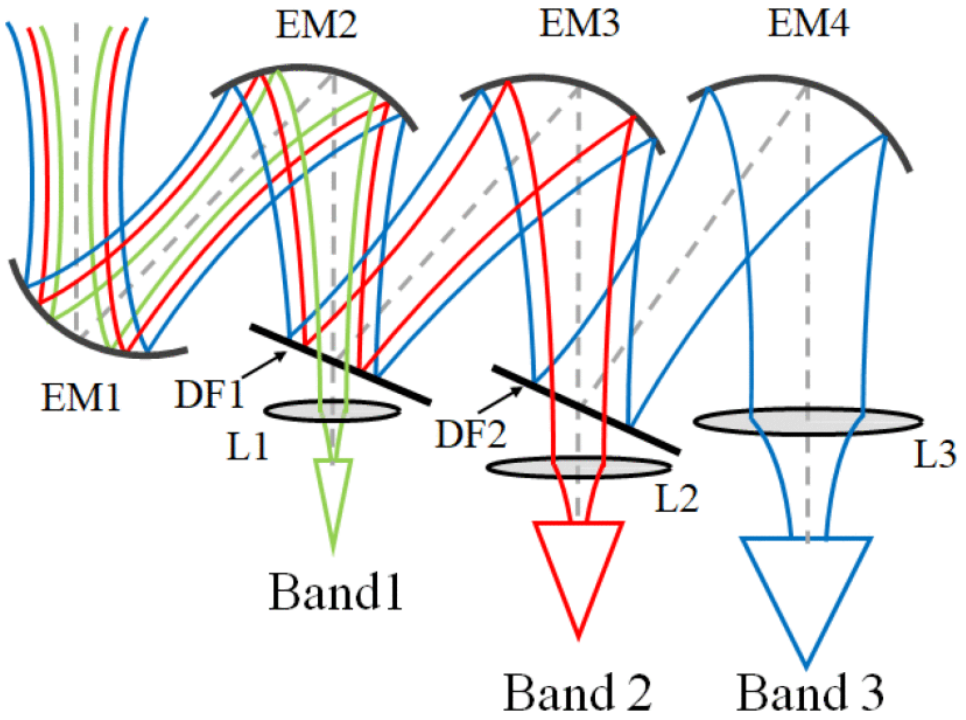
Technical solution

Top level block diagram of the OSO Tri-band receiver



Frontend

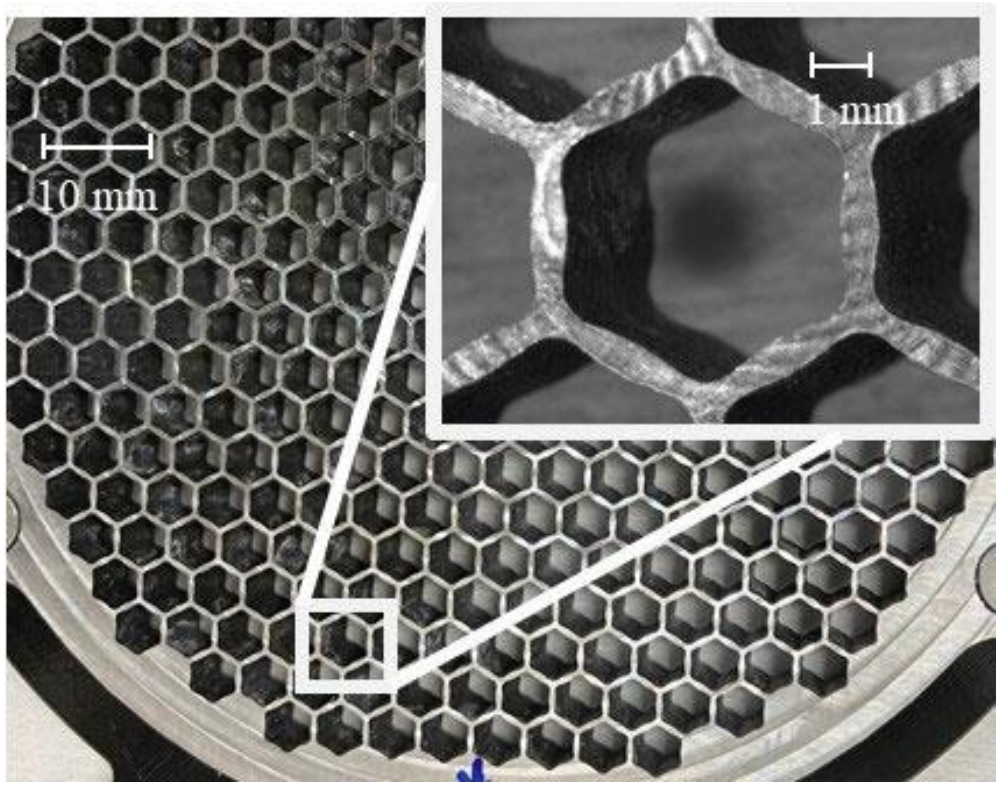


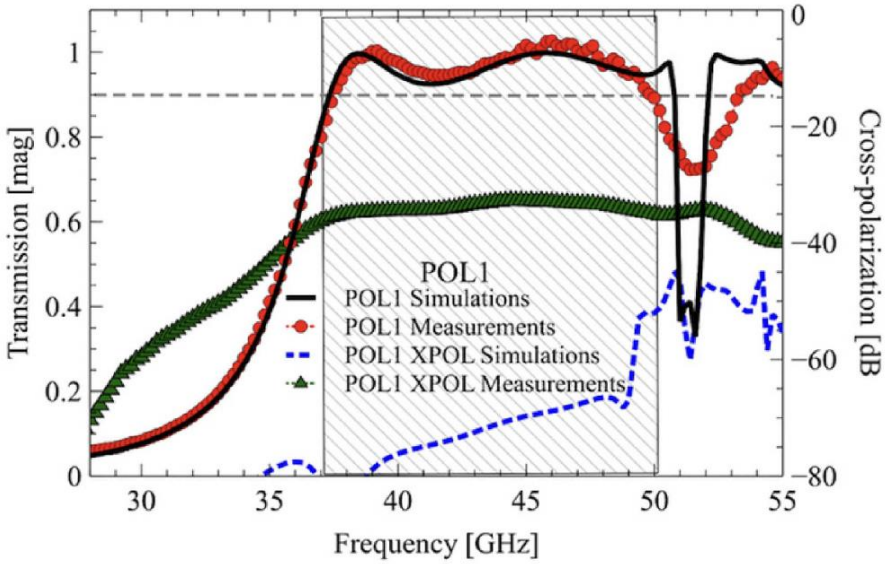


- Insertable beam switch for single-dish
- All optics cooled
- Selectable W-band high pass dichroic (in/out) for wide W-band single-dish.
- Fixed Q-band high pass dichroic
- ALMA B2 based W-band receiver
- LNA based K and Q-band receivers

- Principal optical layout. The following components are marked:
  - ✓ EM1-EM4 - ellipsoidal focusing mirrors;
  - ✓ DF1 and DF2 - dichroic filters
  - ✓ L1–L3 - focusing lenses.

Frontend



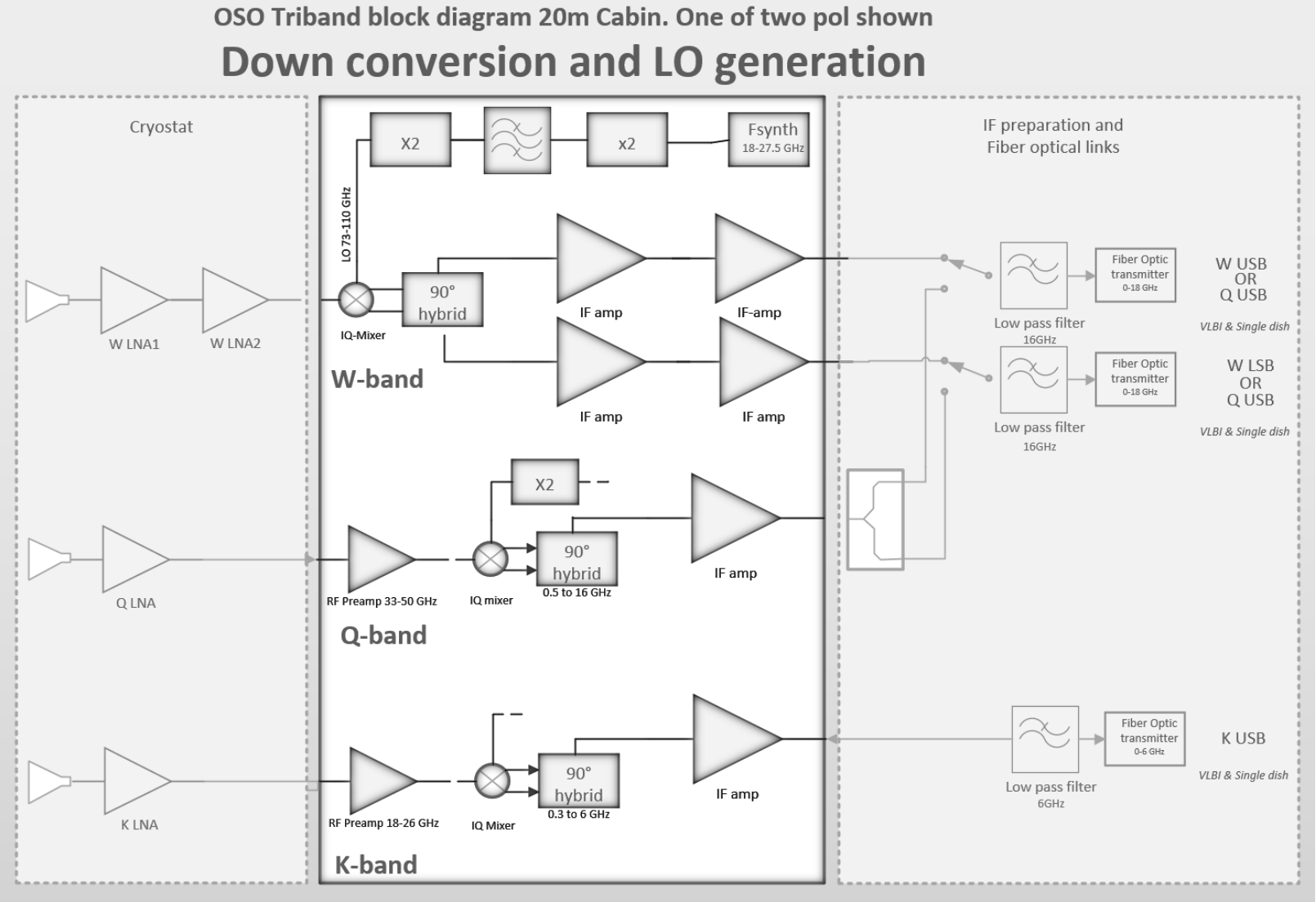


- The hatched area in the graph indicates the frequency range with transmission exceeding 90 %.
- Black solid and blue dotted lines show simulated values of the transmission and cross-polarisation.
- Red circles and green triangles depict the measurement data of the transmission and cross-polarisation.

ISSTT-2024: https://www.nrao.edu/meetings/isstt/papers/2024/2024048.pdf
IEEE-TTST-2024: https://ieeexplore.ieee.org/document/10337754

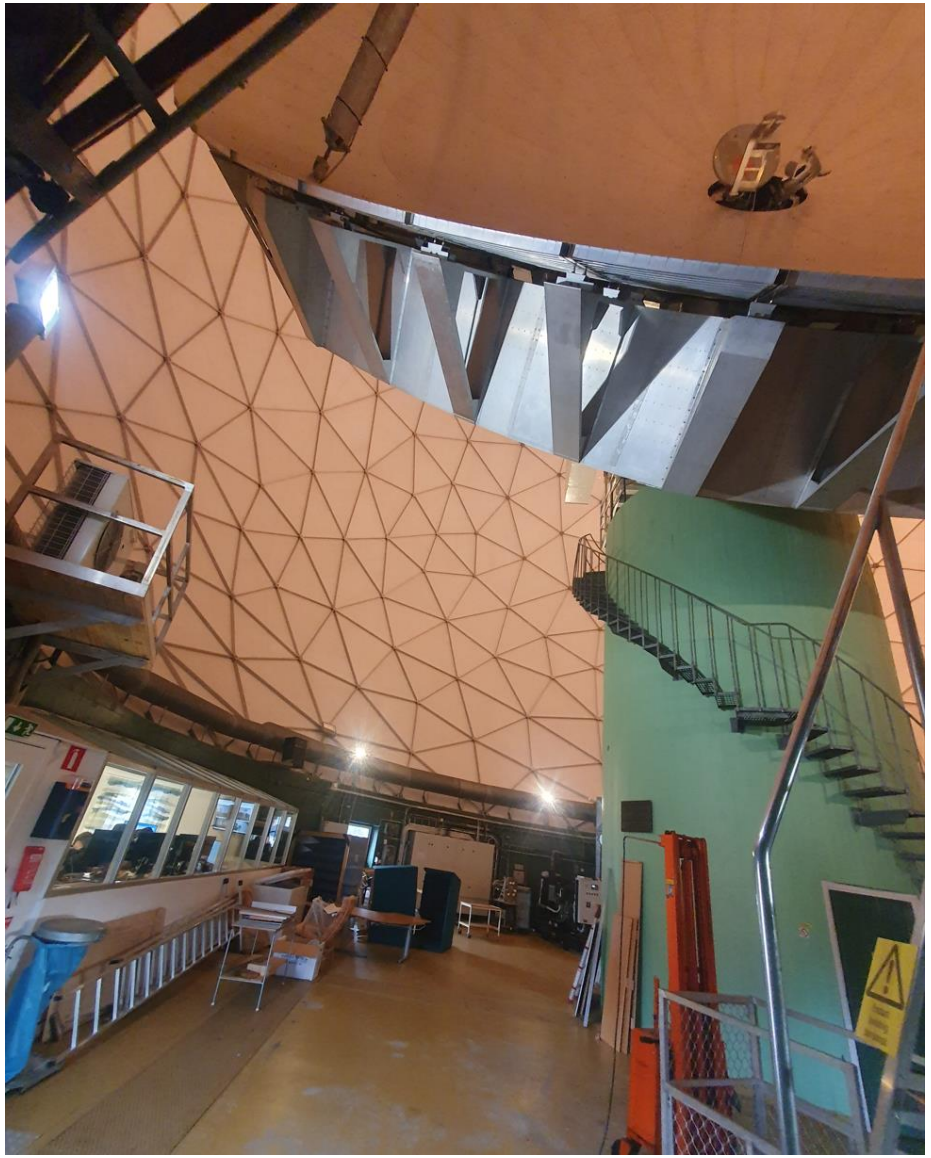
Down-conversion

- Wideband down-conversion to 16 GHz IF frequency for Q&W.
- IQ-mixers combined with IF hybrids to achieve sideband suppression.
- A single synthesizer provides fundamental LO for K and uses multipliers for Q and W.
- Down-converters for Q and K build with commercial building blocks.
- Down-conversion for W may be built by an external company.



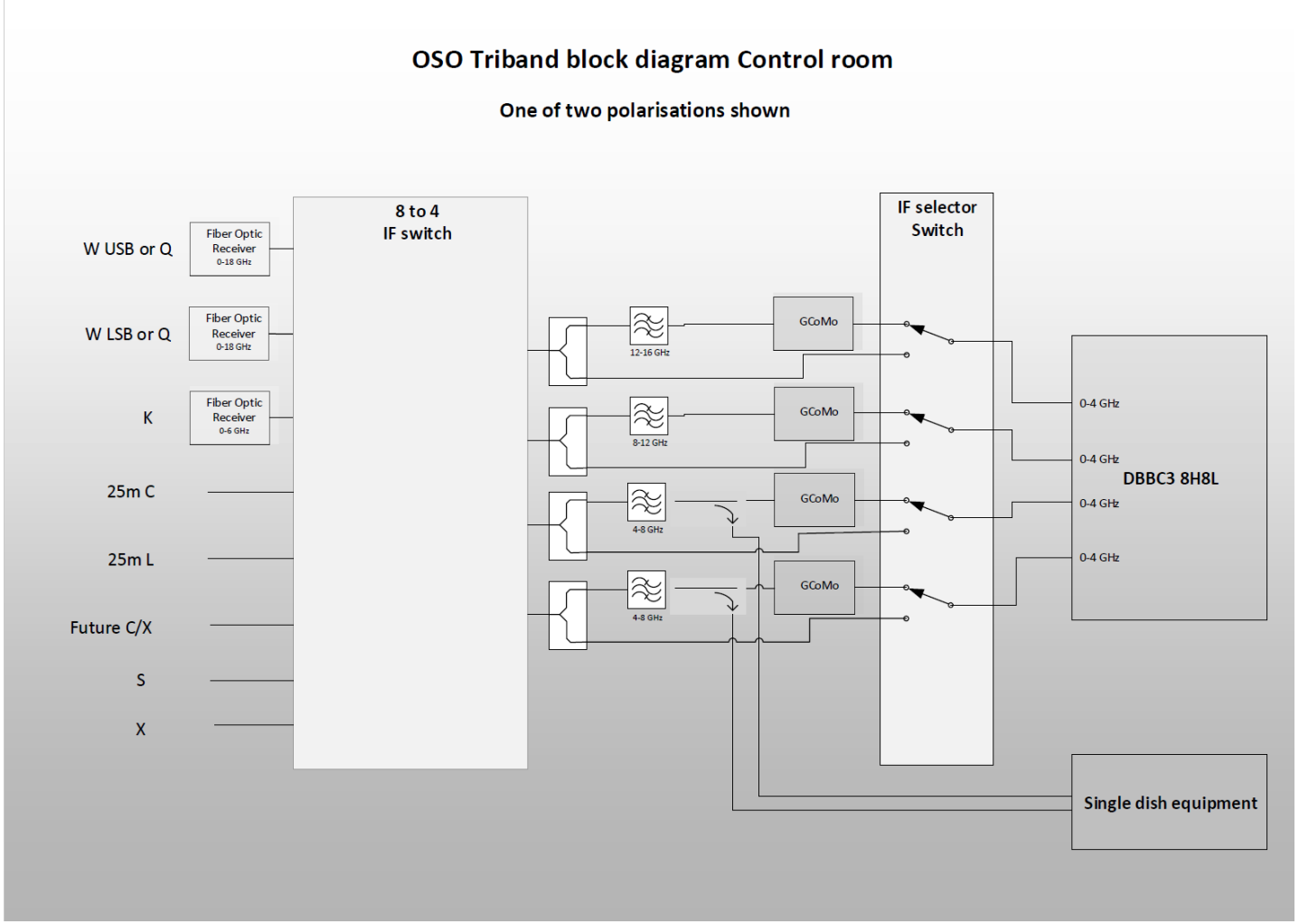
IF-transport

- IF signal transported to backend in control room
- W-band and Q-band will use four 0-16 GHz radio over fibre links
- K-band uses two ”low” cost 0-6 GHz radio over fibre link



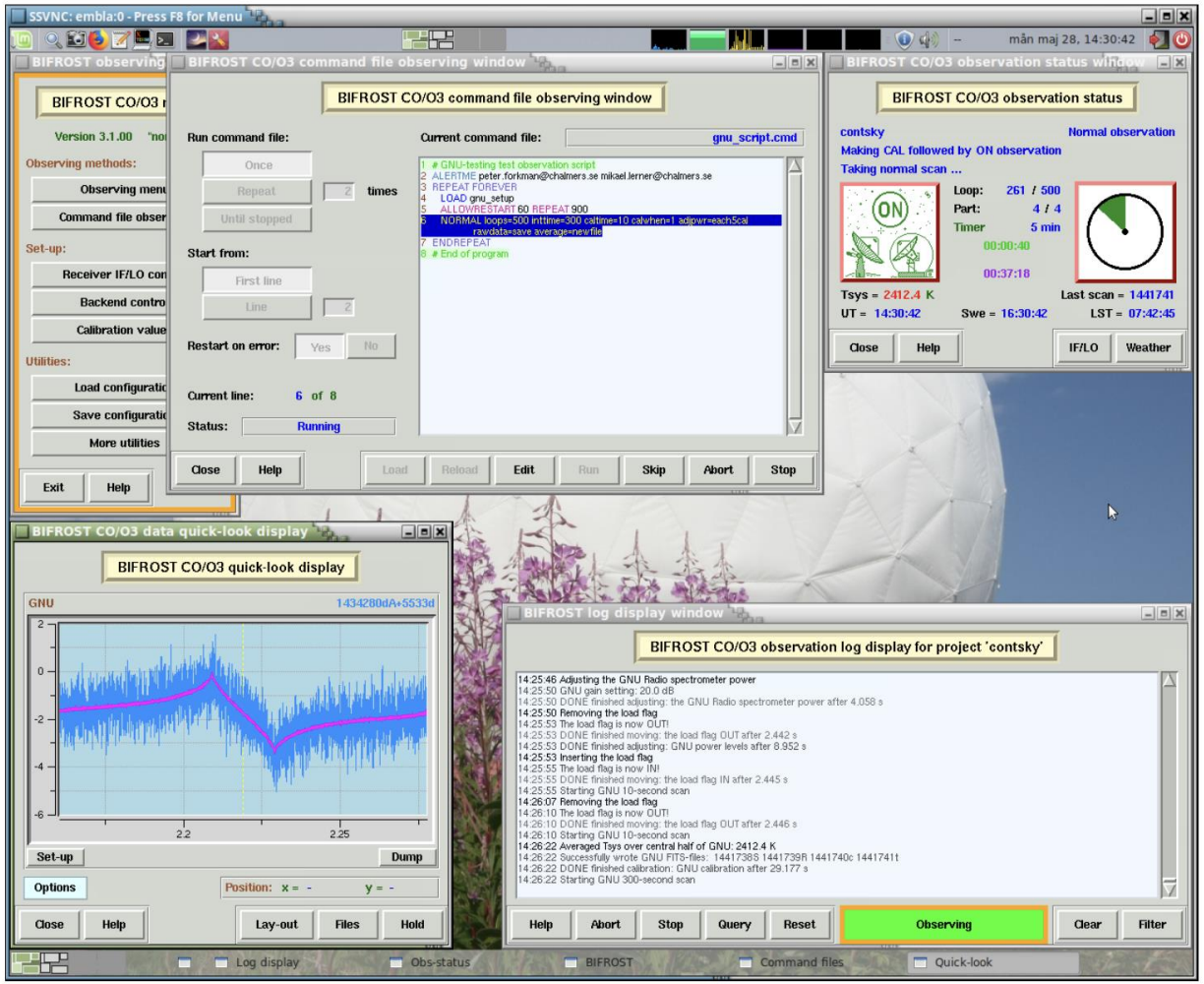
IF distribution and Backend

- DBBC3 used as backend
- 8-to-4 IF Switch to support various frontends
- IF selector switch allowing selection of baseband or down converted input to backend.
- Will support a large variety of configurations. E.g. W-band 16 GHz or 4 GHz for K and Q-band and 8 GHz for W-band.



Software

- Low-level software for commanding and reading out data (ASCII-based TCP/IP) E.g. frequency set-up, mixer set-up, mirror positions, KOS control, PLM control, IF-switches, cryo control and environmental sensors
- Distribution of data & logging and monitoring displays
- Watchdog and alarm system
- Integration into BIFROST observing system
- Modifications to local FS (Field System) code controlling VLBI observations



GARD

Group for Advanced Receiver Development

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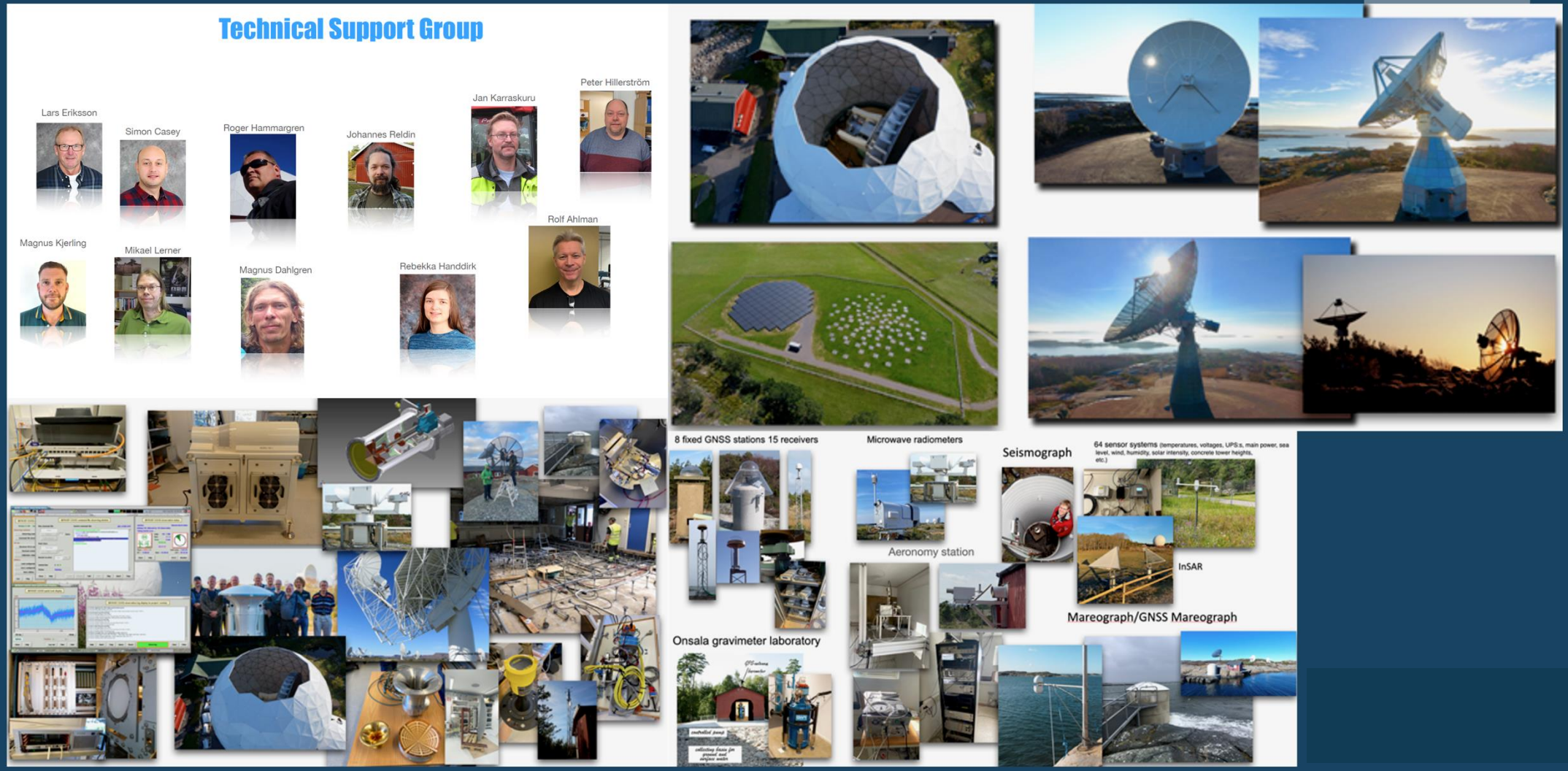
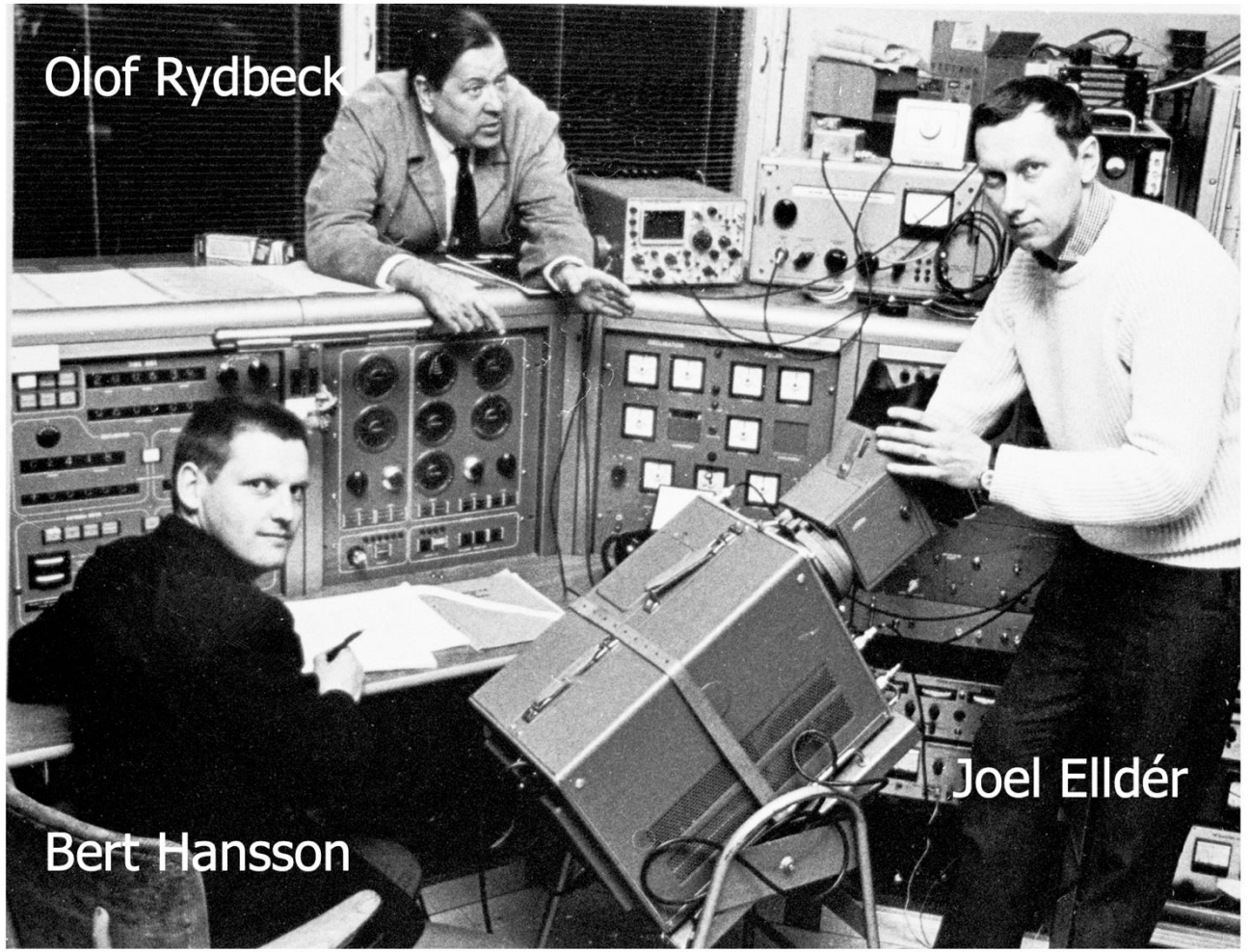
Erik Sundin

CHALMERS

Onsala Technical Support Group, TSG



Thank you for your attention! Any questions?



First transatlantic VLBI, 1968