Design of the Band 345(6) Single-Pixel Feed Package

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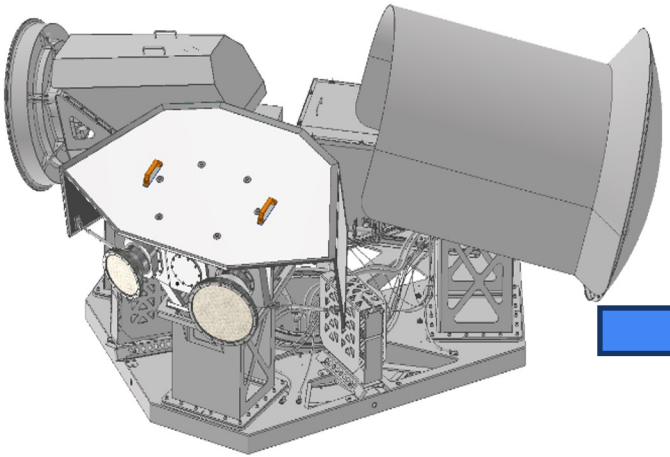
A brief history…

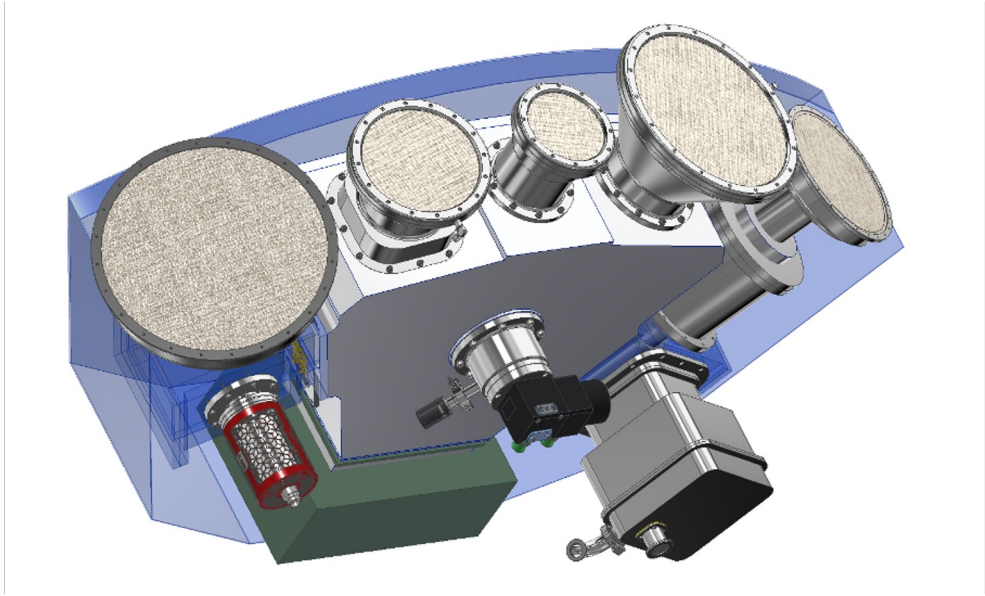
- SKA-Mid was originally ~3 GHz max frequency…but after the loss of SKA-High, this crept up to 15 GHz
- 2013 Early decision that all SKA Bands 3+ (1.6 GHz+) share a single cryostat to save cryogenics power and complexity
- Initially Band 345 not in first light deployment so background design work only
- 2014 SKA Science Review reinstated Band 5 (4.5 – 15 GHz) as first light instrument
- 2015 UK takes on role as Band 345 lead
- Design analysis shows huge sensitivity gain from splitting Band 5 in two. Change proposal to SKAO takes >1 year…
- 2016 Design work begins – Band 5a and 5b but provision for Band 3, 4 and 6 – however no full specification for Band 6 exists other than ~15-24 GHz
- 2017 Preliminary Design Review
- 2019 Detailed Design Review
- 2020-2022 COVID!
- 2023 Critical Design Review (December), build of 4 systems for Array Assembly 0.5
- 2024 Deployment of AA0.5

Dish and indexer

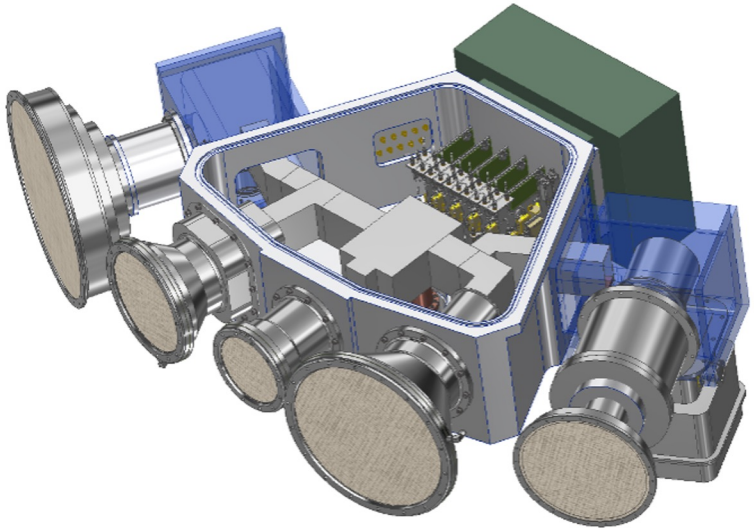


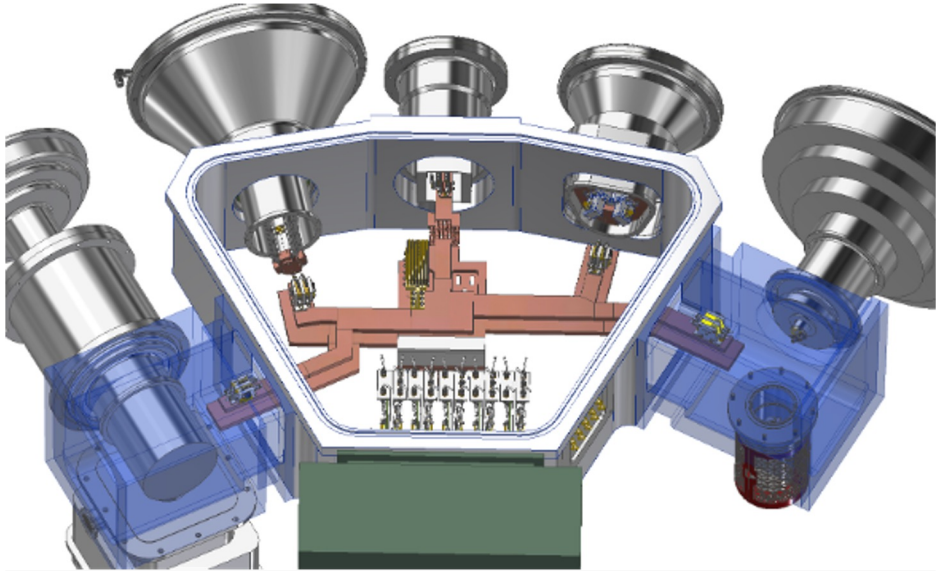
Overview of Band 346 Design - figures all from DDR document 317-030000-006

(minor changes since DDR will be documented in upcoming CDR docs)



General arrangement of the B345 cryostat (external view) in its fully-populated configuration, showing the side bolt-on modules for Bands 3 and 4, and Band 6 in the central position. The weather shield is highlighted in blue.

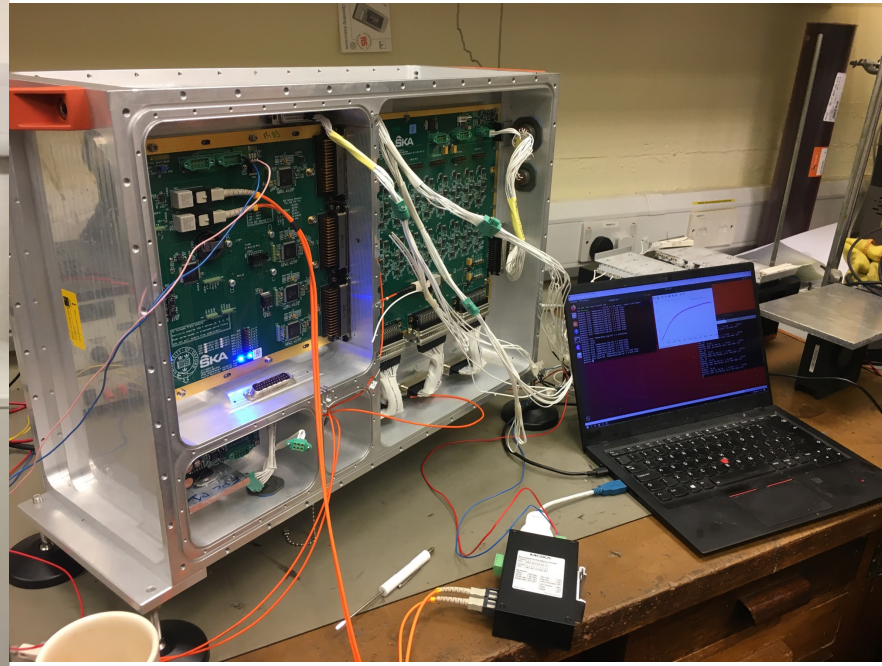




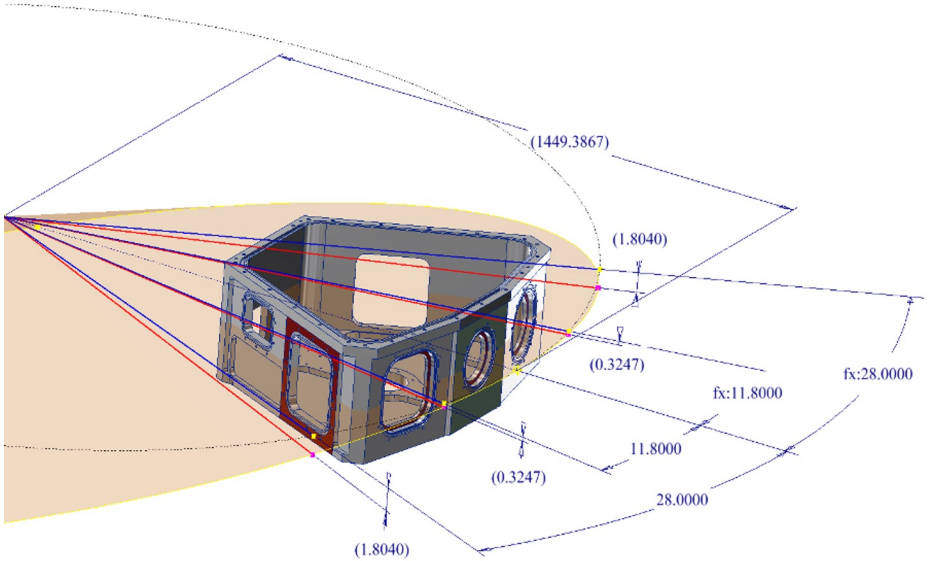
General arrangement of the interior of the B3456 cryostat showing the distributed cooling system providing ~15 K and ~85 K cooling to all five feeds together. Also shown is the warm RF electronics hub.

Detailed design and analysis of feed positioning, shadowing and window design uses a Band 6 horn design based on a scaled version of 5a and 5b. This is now fixed.

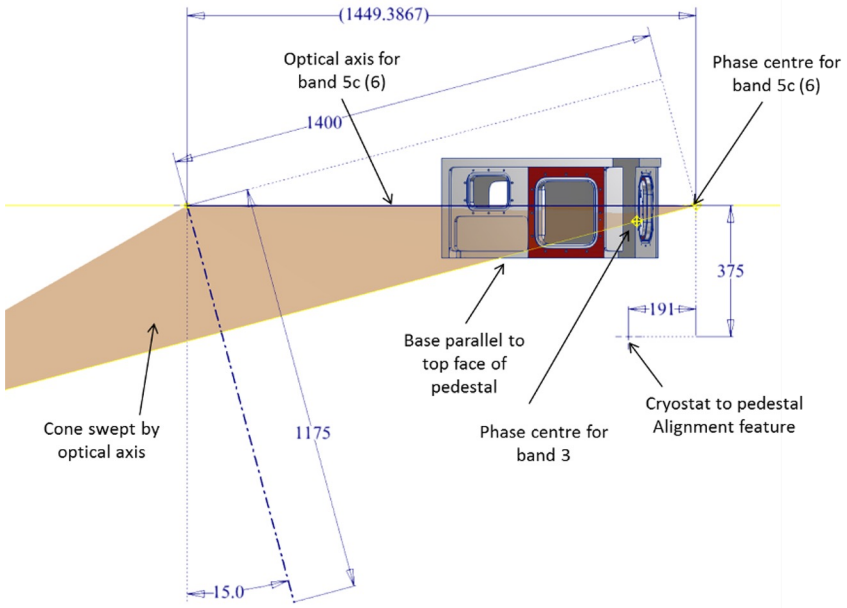
Band 3456 - First light configuration



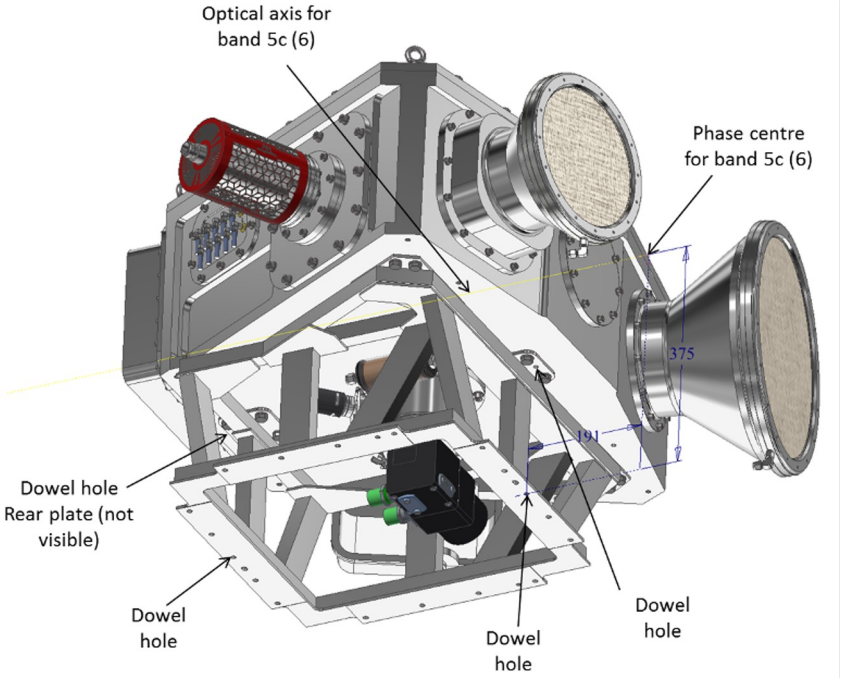
Alignment and placement of datum for Band 3456 optics



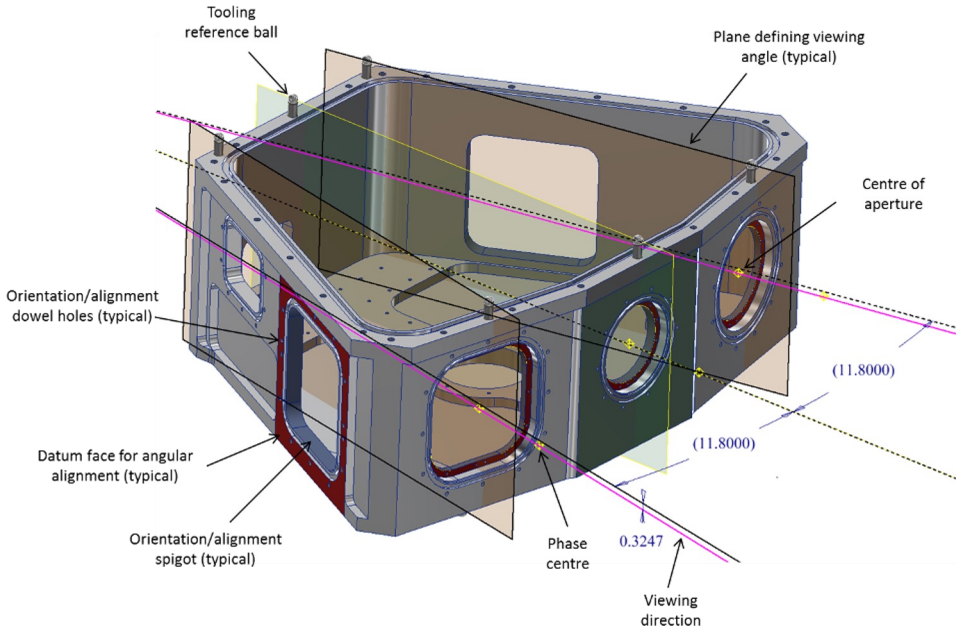
View of the vacuum enclosure showing the in-plane angles β and the out-of-plane angles γ used to lay out the cryostat. The datum surfaces for mounting the feeds are shown in red.



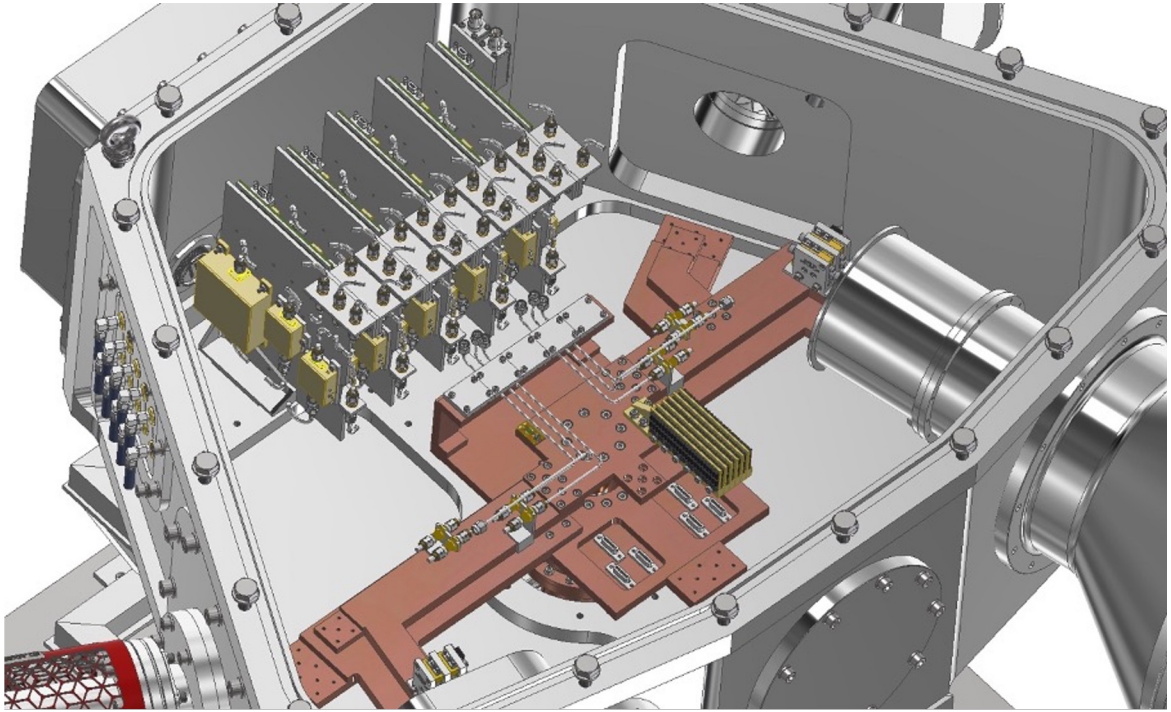
Viewing and alignment geometry showing the position of the cryostat relative to the alignment feature (front dowel hole) on the standard pedestal.



View showing the support frame's upper and lower alignment dowel holes.



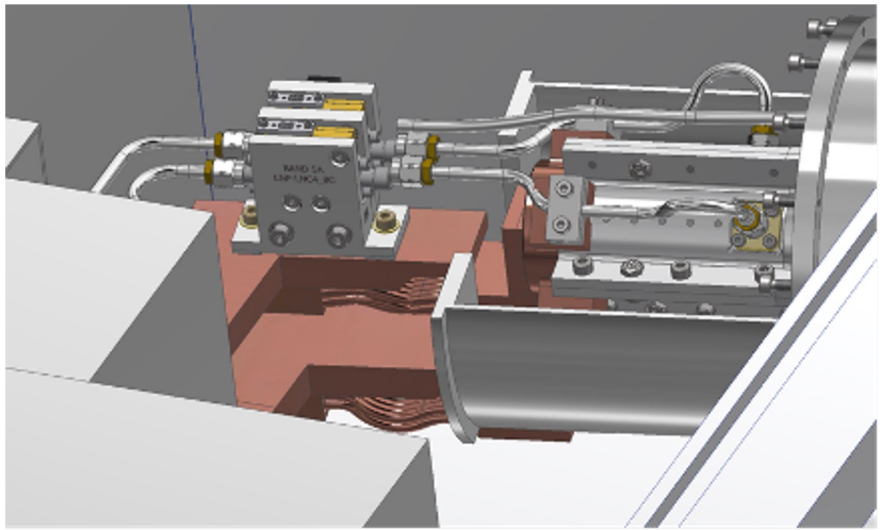
View showing tooling reference balls and the typical alignment features for each band

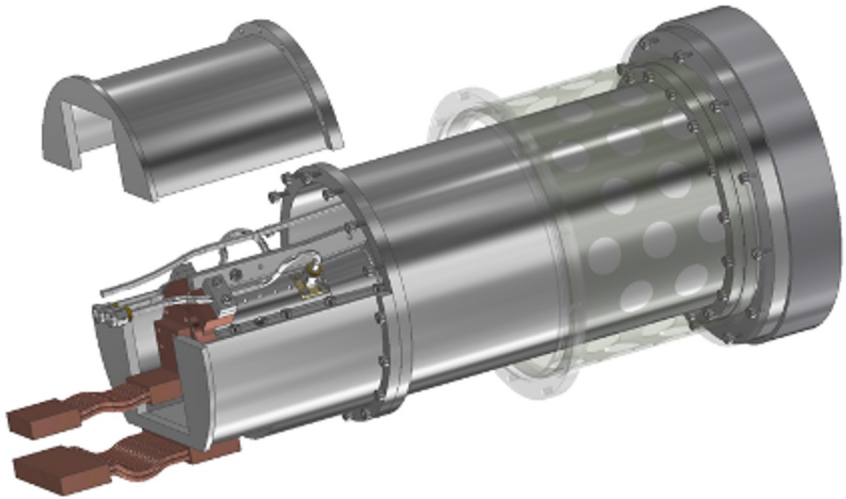


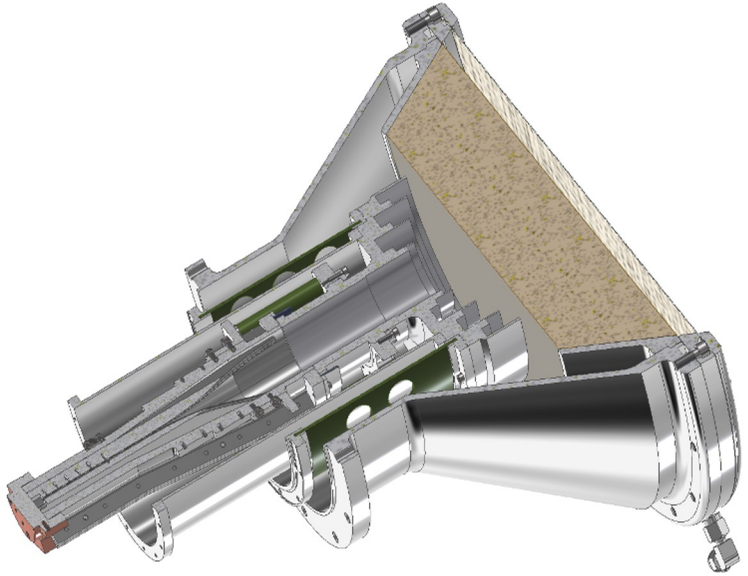
- Close-up view of the copper bus-bars of the thermal plumbing, with the aluminium heat shields removed.
- Note provision for warm RF electronics (gain and filtering) for all bands and separate noise sources for Band 345 and Band 6.

Example of feed assembly for Band 5a

- Assembly includes feedhorn, OMT, radiation shield, thermal spacing and links to cold plumbing through to LNAs.
- Band 6 would have to follow a similar scheme

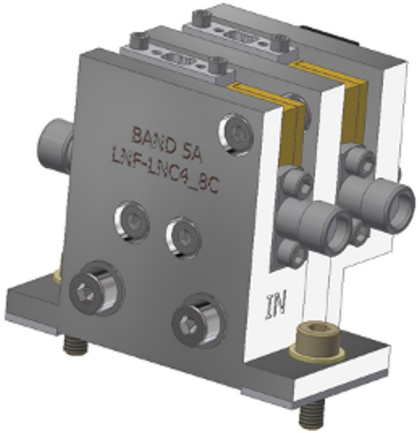






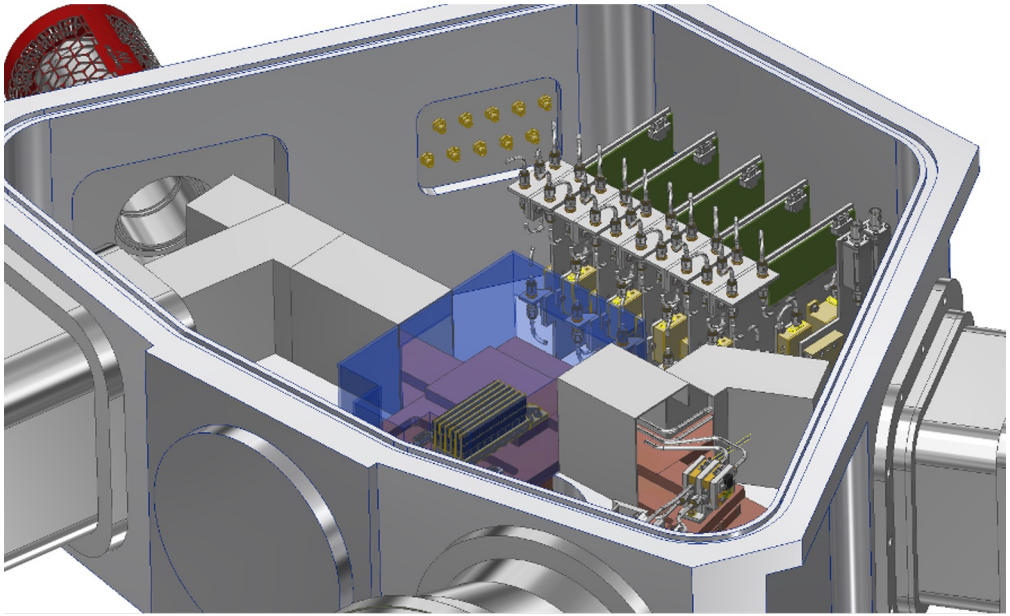
- The Band 5a vacuum podule housing the feed assembly (horn + OMT)
- It provides an extension to the main vacuum hub with both vacuum and weather windows.
- Band 6 is assumed to be a scaled version, fitting within tight pre-determined mechanical constraints.
- OMT:
  - Band 5a and 5b OMTs are quad-ridge designs (Oxford).
  - **Band 6 OMT could be a scaled version of 5a/5b or a new design e.g. turnstile.**
  - **This still needs detailed design but will need to be closely coupled with the complete feed assembly and fit within mechanical constraints..**

Low-noise Amplifiers



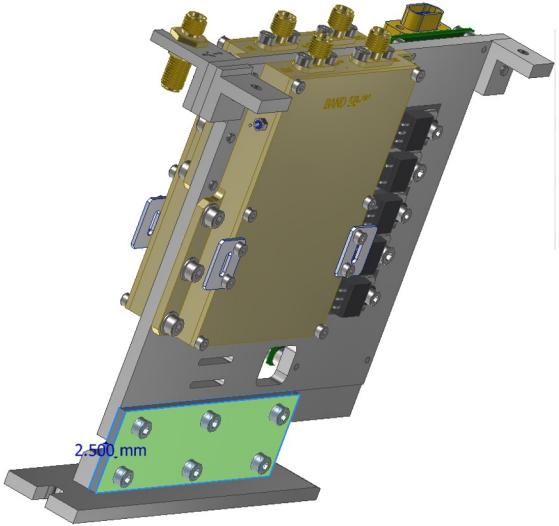
- Both Bands 5a and 5b use Low Noise Factory LNAs
- Default for Band 6 would be LNF-LNC15_29B (15-29 GHz, 7 K)
- **Other LNAs possible if they have equivalent or better performance.**
- They would need to fit within the mechanical envelope.
- Bias circuit is on a daughter-board so can be specific to the LNA, but only 3 bias wires per LNA available.

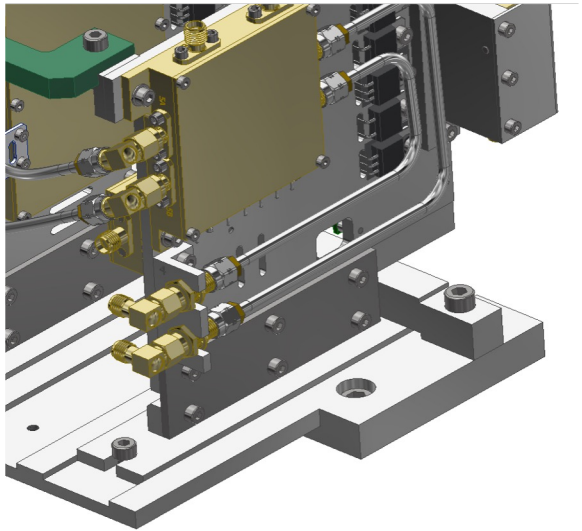
Warm RF electronics, monitoring and control

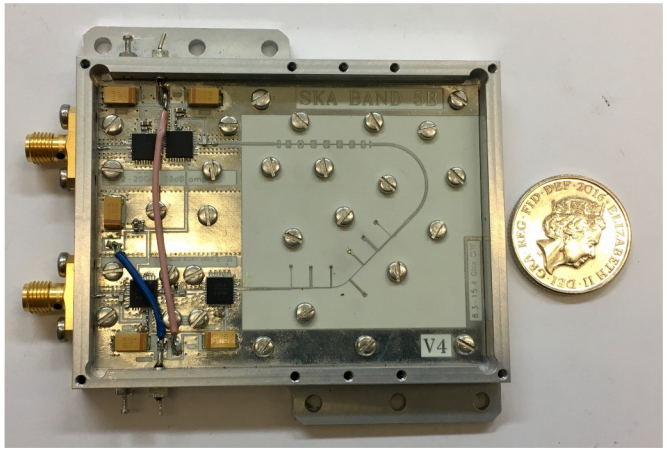


- Space is provided for a Band 6 noise source (not yet sourced).
- Each band has provision for a warm RF (gain +filtering) board per polarization.
- Provision for sufficient cryogenic temperature monitoring, control of noise sources and control of temperature stabilized RF (and LNA) plates.

Warm electronics module and noise source plate







- Footprint of warm electronics box is specified.
- Band 6 assumed to be similar to Band 5a/5b with minimal changes
- **Band 6 Noise source still to be selected/designed**

Band 3456 Summary

- In order to ensure that the design will accommodate the future bands as well as bands 5a and 5b, it has been necessary to make reasonable assumptions about the design of the feeds for these bands.

- The default design for Band 6 is a scaled version of band 5b, with the feed components (OMT, horn, shields etc) assembled as a self-consistent and precision aligned sub-subsystem for integration with the vacuum hub, similarly to bands 5a and 5b.

- The Band 6 feedhorn had to be specified early as a scaled version of 5a/5b to allow full optical and mechanical design to continue.

- Band 6 OMT requires detailed design within the existing constraints
- Band 6 LNAs are to be selected/designed respecting the mechanical and electronic interfaces
- Band 6 noise source to be selected
- Band 6 warm electronics (gain + filtering) detailed design needed, but likely only a small deviation from 5a/5b design
- Band 6 digitizer (‘receiver’ in SKA terminology) not specified – Band 4/5 receiver not directly compatible with Band 6