Mid Dish System status update

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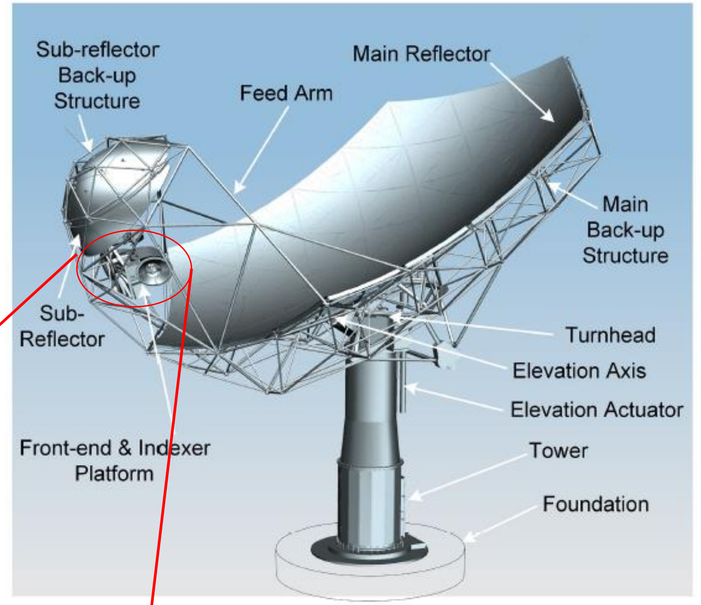
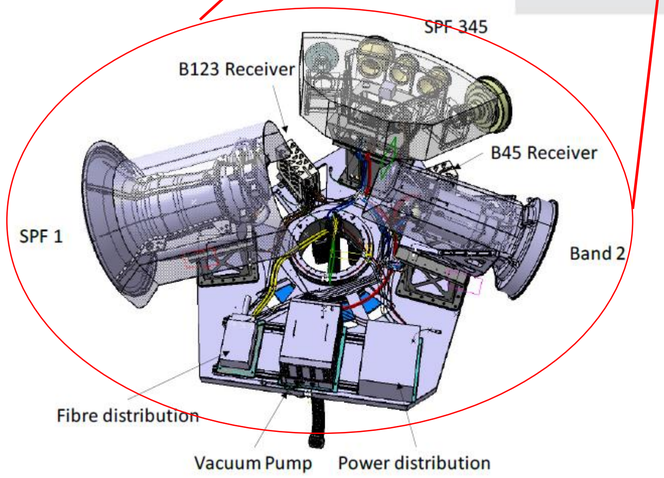
MID Dish System

An overview of the status and progresses of the Dish system and sub-systems development is shown in this presentation.

The MID Dish system consists of the following sub-systems:

- Dish Structure
- Band 1 Single Pixel Feed (SPF B1)
- Band 2 Single Pixel Feed (SPF B2)
- Band 345 Single Pixel Feed (SPF B345(6))
- Helium services
- SPF Services (SPF Controller & Vacuum Services)
- Dish Fibre Network (DFN)
- Local Monitoring & Control (LMC)
- SPFRx





Dish System Verification (for Dish B1 & B2 CDR)

- Dish Qualification Test Readiness Review (TRR) is planned for May 2022 and tests in July 2022
- Dish Emulator in Black River Park set-up in progress:
  - To be used for SPF B1 – SPFRx123 signal path testing, SPFRx123 RFI site acceptance testing, Dish functional demonstrations and later this year SPF B5 RFI qualification (when the system will be expanded with SPF Helium and Vacuum)
  - SPF B1, LMC, NSDN switch, SPFC, SPFRX and DFN integrated and set to work ongoing
- SPF B1 and SPF B2 on-dish test completed 2021, QTR in progress
  - L3 evidence of compliance completed (with the exception of DS and SPFRx)
  - He system L4 compliance matrix to be finalised (dependency on SPF345(6))

Estimated Single Dish Performance

- Sensitivity, efficiency and feed and receiver noise of the single SKA dish have been estimated
- Band 1 and Band 2 data are estimated around the mid-band frequency at an elevation of 45°
- Band 5 data are averaged across the band with the dish pointing at zenith

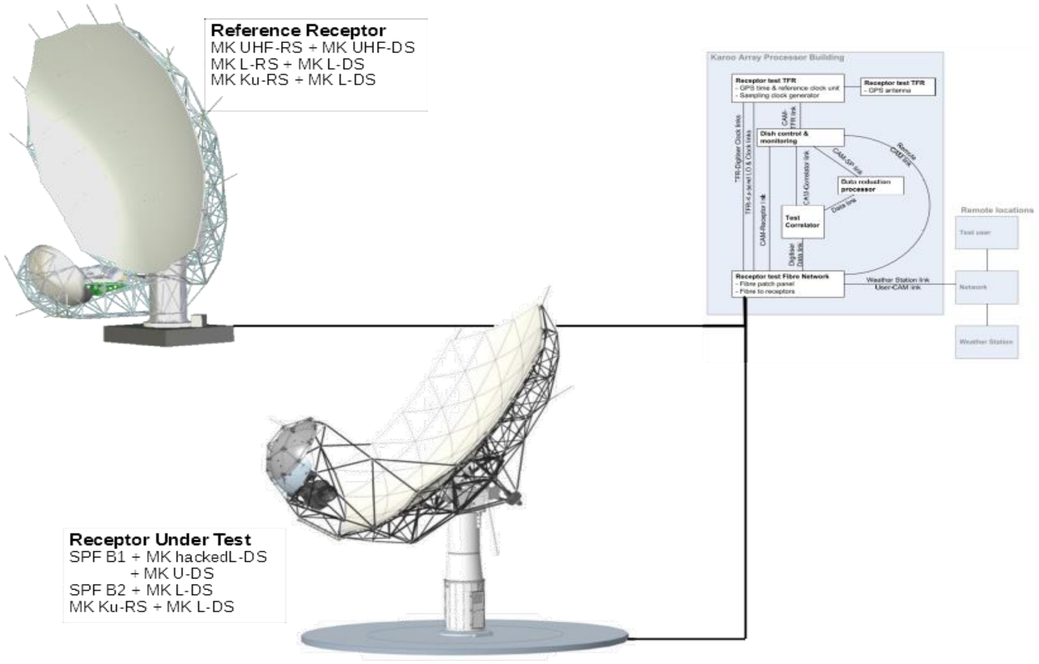
Parameter	**Band 1**	**Band 2**	**Band 5a**	**Band 5b**
Frequency (GHz)	0.7	1.4	Average	Average
Cosmic Background (K)	2.73	2.73	2.73	2.73
Galactic (K)	4.53	0.67	0.01	0.002
Atmosphere (K)	2.2	2.6	2.0 [a]	4.3 [a]
Spillover (K)	3	0.9	0.8 [a]	0.2 [a]
Total $T_{antenna}$ (K)	12.5	6.9	5.5 [a]	7.2 [a]
$T_{receiver}$ (K) [b]	13.5	5.6	7.4	9.2
$T_{structure\ and\ backend}$ (K)	1	1	1.6	1.6
T_{System} (K)	27	13.5	14.5 [a]	18.0 [a]
Aperture Efficiency, η [c]	0.81	0.90	0.84	0.83
Effective area, A_e, (m^2)	143.1	159	148.4	146.7
A_e/T_{sys} (m^2/K)	5.3	11.8	10.2 [a]	8.1 [a]

a Referred to zenith
b Includes the feed and vacuum window contributions
c Assuming perfect optics, i.e. excluding mechanical tolerance of the structure and surface extensions resulting from mechanical considerations

Dish Structure - RF

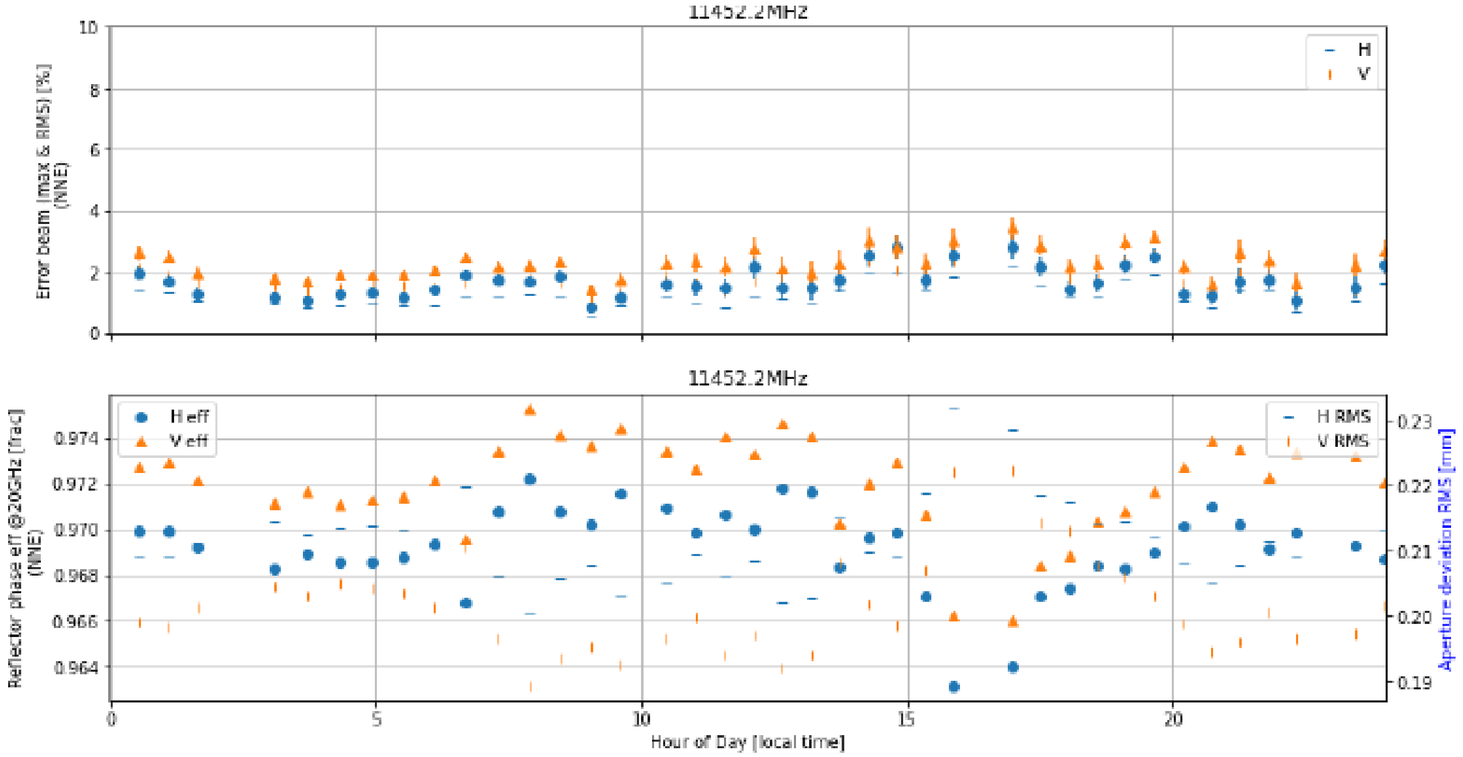
- Holography tests over 24 hour performed by SARAO on the SKA-MPI dish to verify Error Beam (EB) and Phase Efficiency (PE) requirements including solar loading.
  - EB and PE measurements performed over GEO satellites
  - Ku-band uncooled receiver
  - MeerKAT Receptor Test System (RTS).

- Alignment and photogrammetry procedure has been performed by CETC54 on SKA-P and SKA-MPI.
  - EB and PE have been calculated from the measured points cloud maps at the required frequency via GRASP.



Dish Structure – RF performance

- Holography tests over 24 hour period performed to evaluate EB and PE

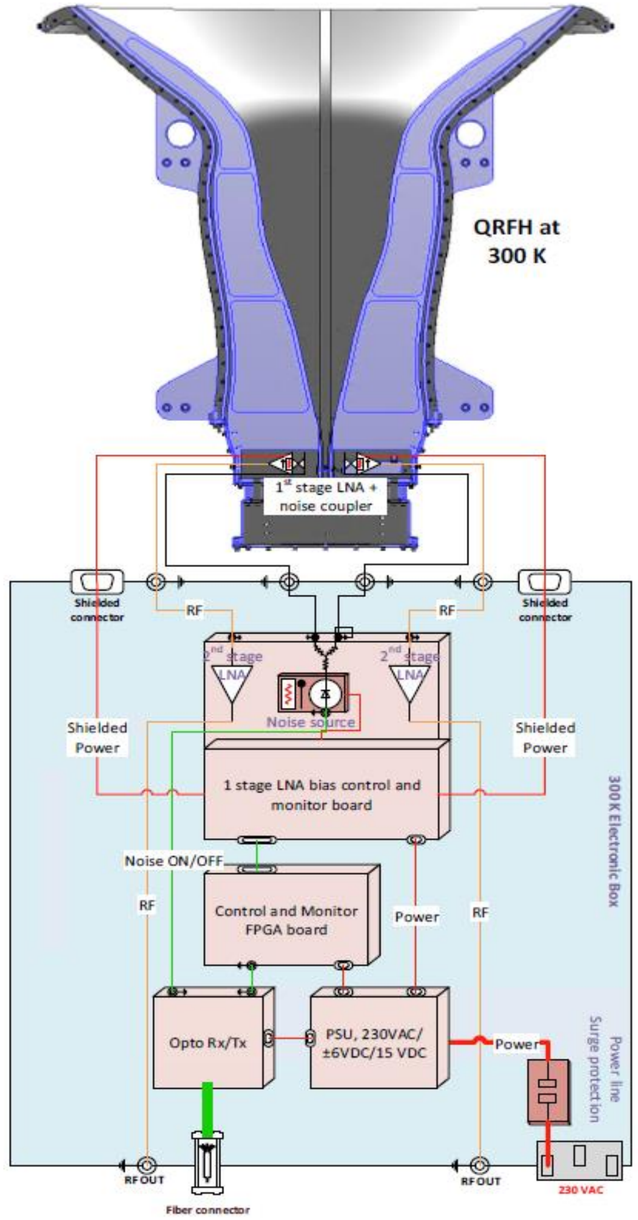


$$E(\theta,\phi) = \frac{D_{real}(\theta-\theta_r,\phi)}{D_{real}(\theta_r)} - \frac{D_{nom}(\theta,\phi)}{D_{nom}(0)}$$

$$eff0\_phase = \frac{\left|\sum_{r,\theta\in A_g} \Lambda_{r,\theta} \cdot e^{j\Phi_{r,\theta}}\ \delta A\right|^2}{\left(\sum_{r,\theta\in A_g} \Lambda_{r,\theta}\ \delta A\right)^2}$$

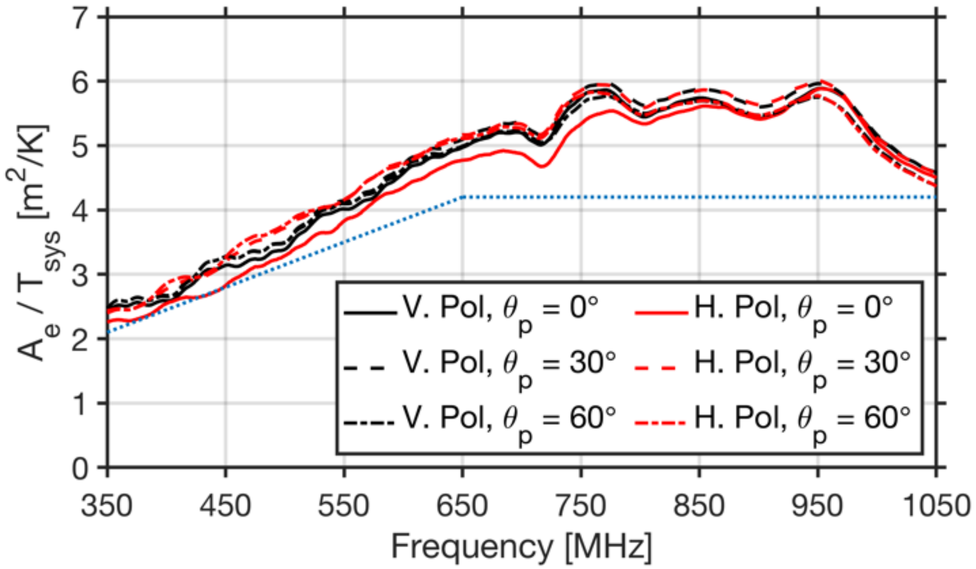
SPF Band1

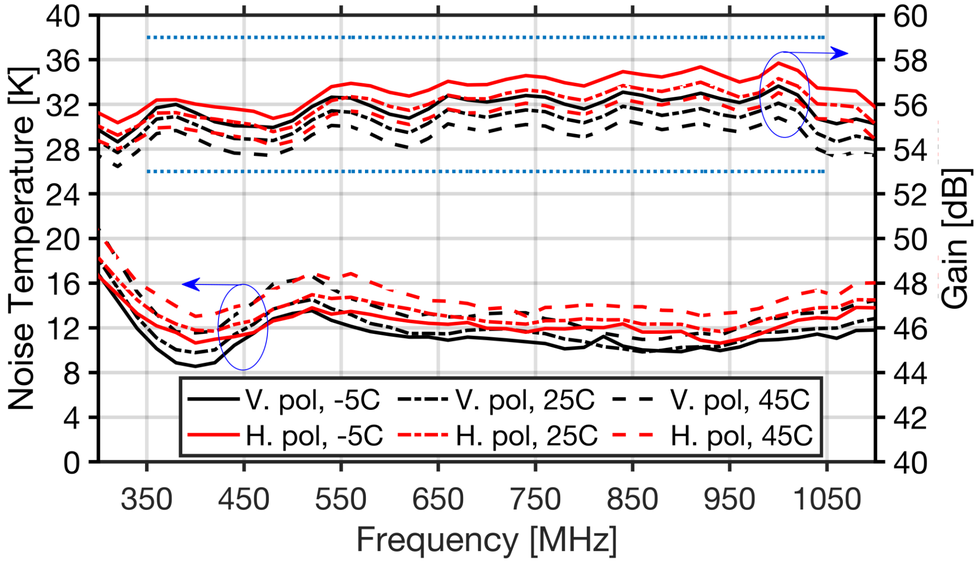
- SPF Band 1, developed at Onsala Space Observatory (OSO), is a room temperature system operating over the frequency band 0.35 to 1.05 GHz
- Dual linear pol Quad Ridged Feed Horn (QRFH) of overall length of 1.5 m.
- Two room temperature LNAs (Low Noise Factory) integrated in the ridges close to the feed pins of the two orthogonal polarisations.
- Noise-injection coupler and LNAs are combined in single assembly. The calibration signal is injected prior to the first amplification stage.
- 2nd stage LNAs, calibration noise diode, monitor and control electronics, etc. are located in the feed-controller enclosure mounted on the rear of the feed horn.
- A polycarbonate radome protects the aperture of the horn, while the feed is made moisture proof. An environmental shield protects the feed package from rain and direct sunlight.



SPF Band1 – expected performance

- Prototype fully qualified
- Due to the size of the feed package, customized equipment developed to carry out some of the qualification tests (e.g. RFI and environment tests).
- Dish system sensitivity estimated by combining lab measurements and simulations of the feed on the SKA dish.
- Measured receiver noise temperature below 18 K for both polarisations. Receiver gain compliant with the SKA requirements
- Installation, integration and verification of the Band 1 SPF on the SKA-MPI dish has been completed -> awaiting test report.
- Lab integration with the SPFRx123 at Black River Park are planned for July 2022
- Initial tests performed with the Band 1 SPF installed on a MeerKAT antenna [1] and on the Dish Verification Antenna 1 (DVA-I) [2].

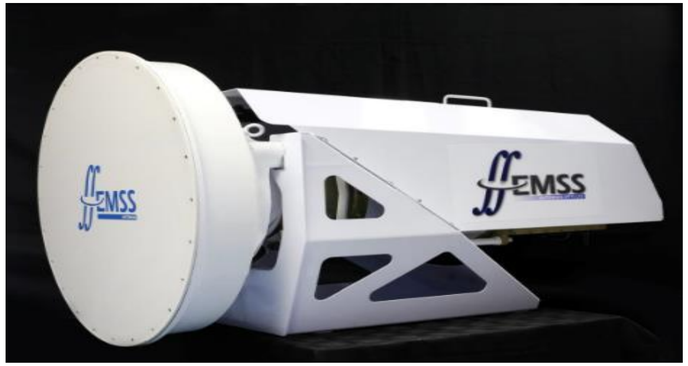


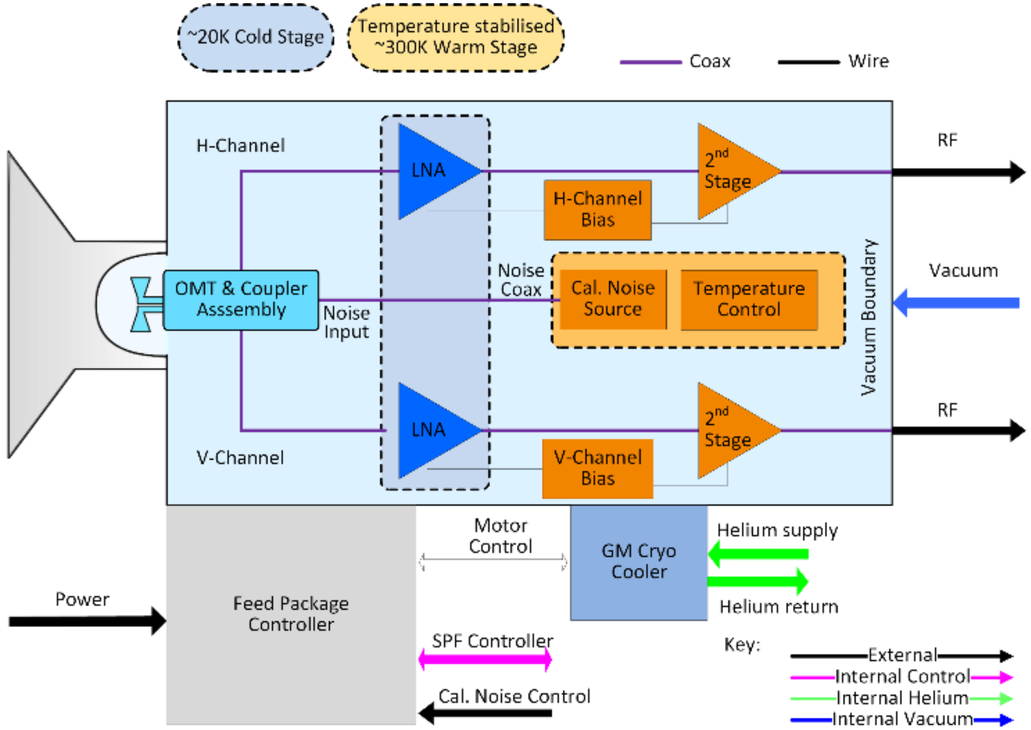


1. J. Flygare et al., "Sensitivity simulation and measurement of the SKA Band 1 wideband feed package on MeerKAT," in *Proc. 13th Eur. Conf. Antennas Propag. (EuCAP)*, Krakow, Poland, 2019.
2. J. Flygare et al., "Beam pattern measurement on offset Gregorian reflector mounted with a wideband room temperature receiver for the Square Kilometre Array," in *2018 IEEE International Symposium on Antennas and Propagation & USNC/URSI National Radio Science Meeting*, Boston, MA, 2018.

SPF Band2

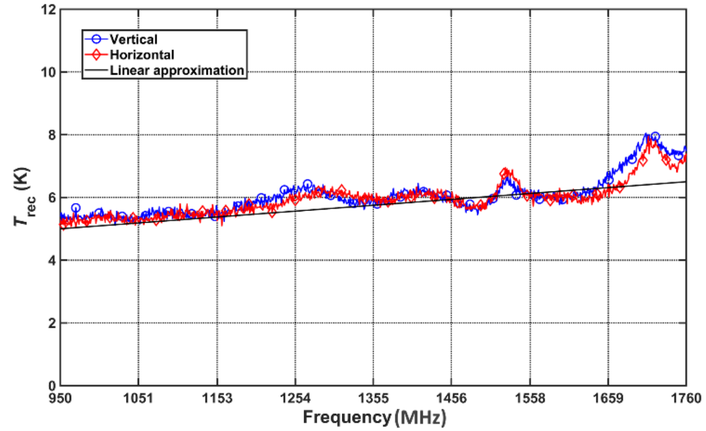
- SPF Band 2, developed by EMSS Antennas, operates over the frequency band 0.95 GHz - 1.76 GHz.
- The feed package consists of:
  - an ambient temperature wide flare angle axially corrugated conical horn,
  - a cryogenic OMT (pair of orthogonal dipoles),
  - LNAs cooled to below 20 K and a room temperature amplification and matching stage.
- The waveguide is at ambient temperature with a High Density Polyethylene (HDPE) dome over the cryogenic dipoles. The calibration noise source is thermally stabilized at ambient temperature inside the cryostat.
- A sun shield reduces solar heating and provides protection against direct rain. Moisture collection is limited by protecting the horn aperture with a hydrophobic radome membrane and desiccator breather

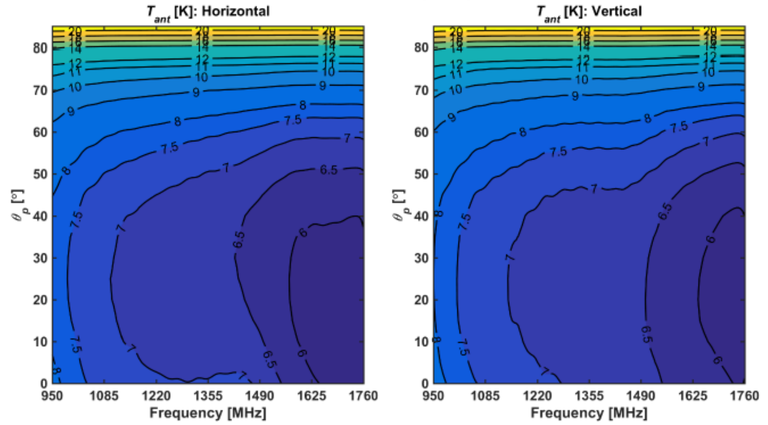


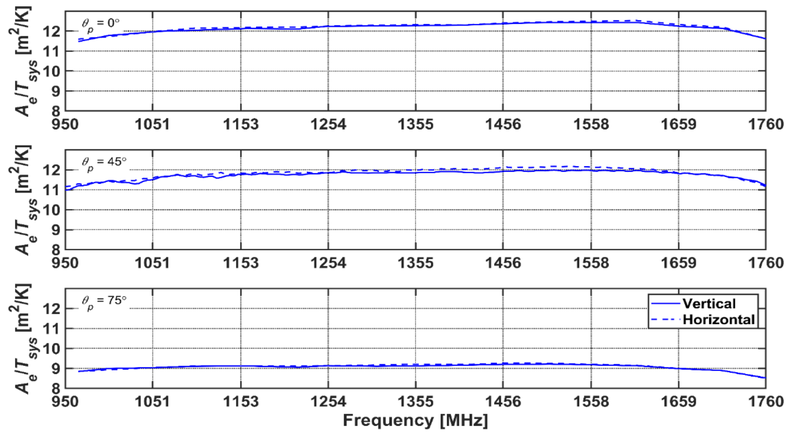


SPF Band2 – expected performance

- Band 2 SPF prototype fully qualified
- The receiver temperature has been evaluated by using the Y-factor method.
- A linear increase from 5 K at the lowest frequency end to 6.5 K at 1760 MHz has been used to evaluate the sensitivity.
- System temperature calculated as the sum of the receiver temperature, a 1 K contribution allocated to all other effects and the antenna temperature.
- Extensive simulation work has been carried out to evaluate the dish system sensitivity at various zenith angles
- Installation, integration and verification of the Band 2 SPF on the SKA-MPI dish has been completed -> awaiting test report.

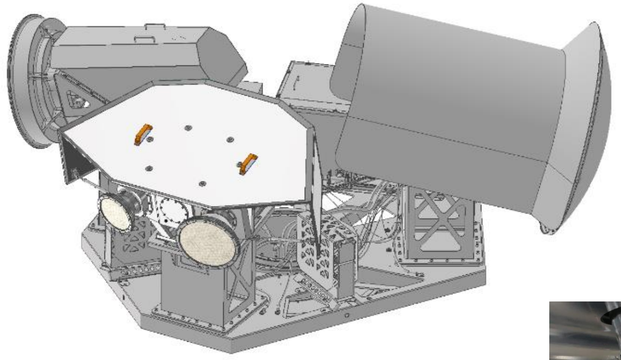


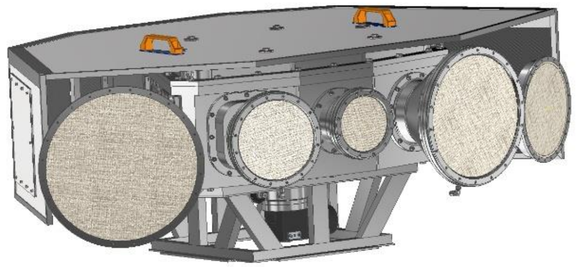


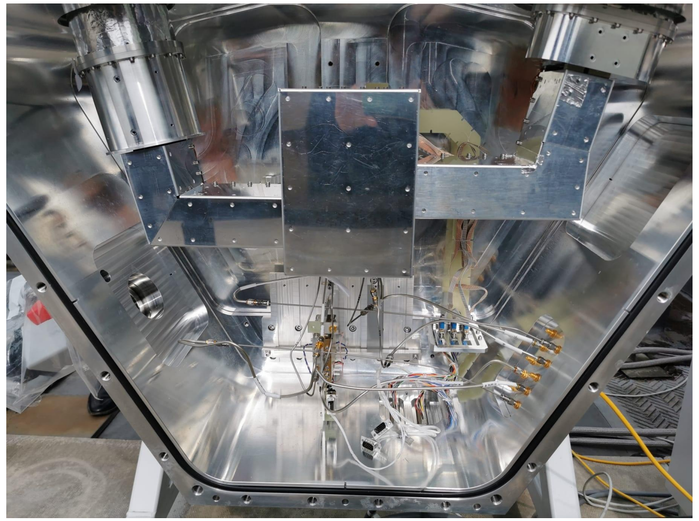


SPF Band345(6)

- SPF Band 345(6) feed package, designed at University of Oxford
- Provision to house up to 5 horns for Band 3 (1.65-3.05 GHz), 4 (2.80-5.18 GHz), **5a (4.60 – 8.50 GHz), 5b (8.30 – 15.40 GHz)** and 6 (15.00-24.00 GHz) in a single modular cryostat.
- Currently populated with higher science priority Band 5a and 5b feed horns, OMTs and RF chains.
- Band 5a OMT (quad-ridged finline), Band 5b OMT (waveguide turnstile) and horns were designed and manufactured by JLRAT/CETC54, China. An alternative design (quad-ridged type) of the Band 5a and Band 5b OMTs currently being manufactured by University of Oxford.
- Wide flare-angle corrugated horns are cooled to ~80K. OMTs and LNAs cooled to ~12 K (second stage). Warm RF chain and noise source are temp controlled
- Horns placed behind a Mylar sheet supported by polyethylene foam. Weather/sun shield in place

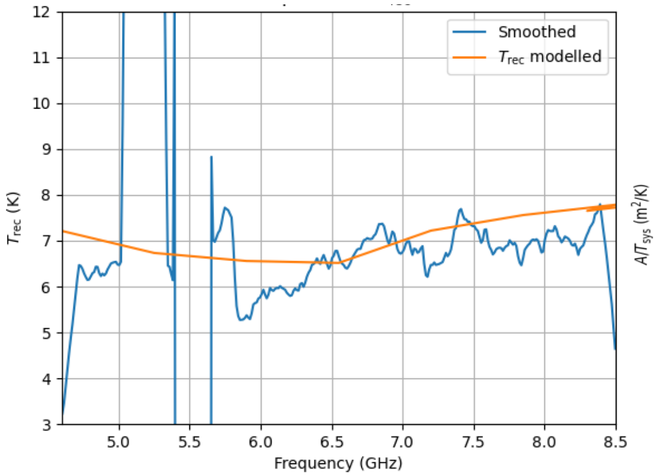


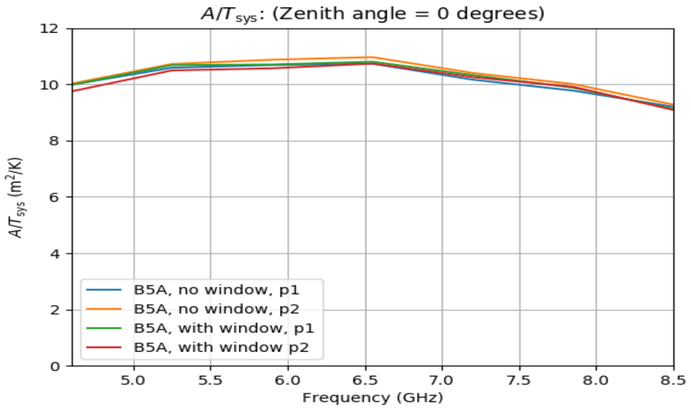


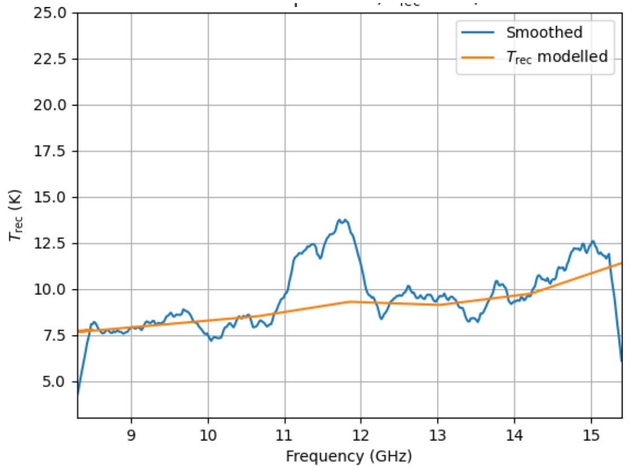


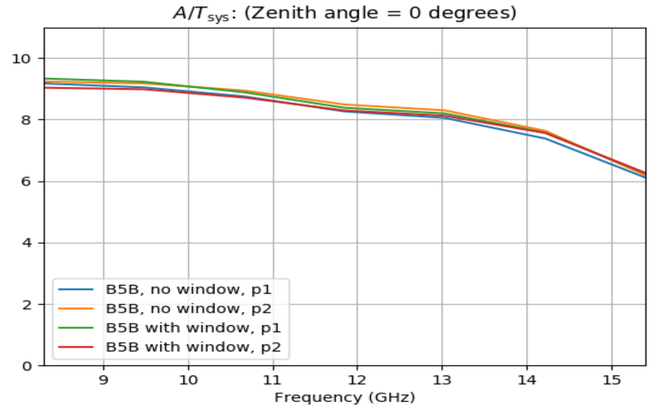
SPF Band345(6) – expected performance

- Noise performance of the 5a and 5b RF chains modelled and preliminary receiver noise performance (Trec) measured.
- System noise temperatures expected to be between 8.2 - 9.5 K for band 5a; and 9.4 - 13.2 K for band 5b.
- Full-wave analysis performed on the feed including optimisation of the window aperture and position to maximise the A/T
- Full beam patterns for each feed and window on the SKA-MID dish calculated in GRASP.
- Beam patterns used to calculate the expected spillover contribution (Tspill) to the system noise temperature (Tsys = Trec + Tspill).
- System temperature estimates used to calculate the expected single antenna point source sensitivity (Ae / Tsys)



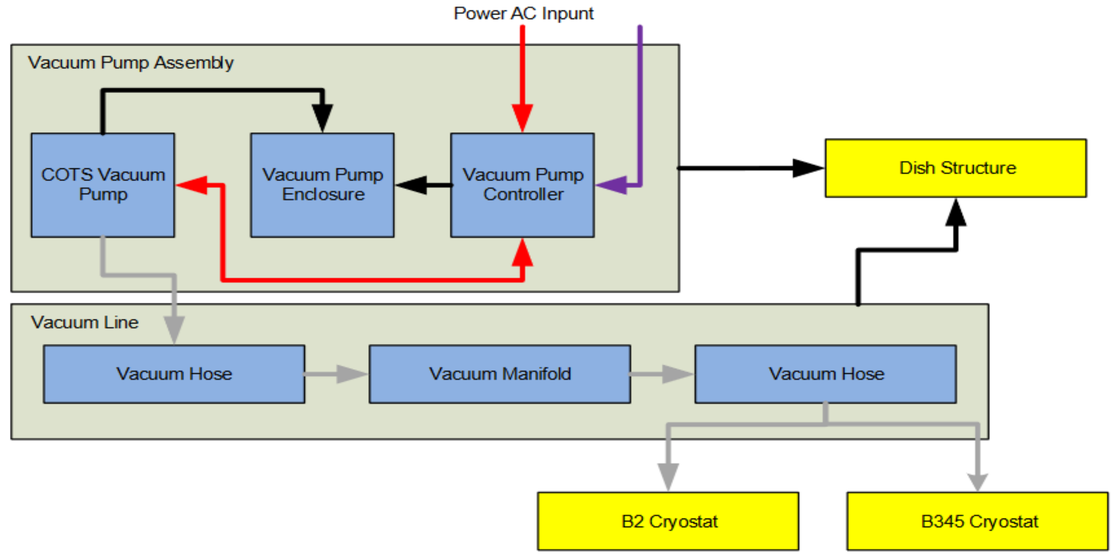


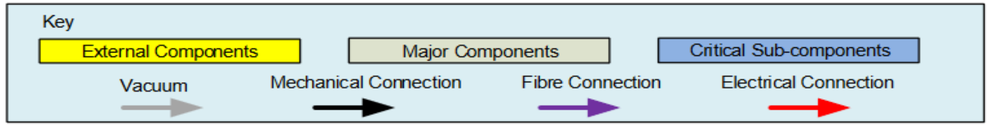




SPF Services (SPFC + Vacuum)

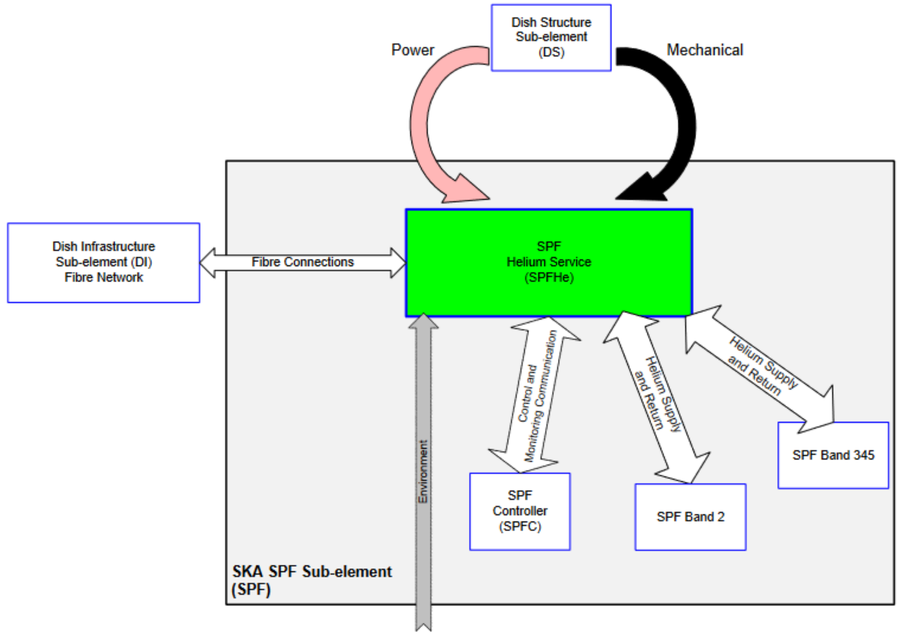
- SPF Services (designed by EMSS Antennas) consist of:
  - The SPF vacuum – with main function of evacuating the cryogenically cooled feeds to a sufficiently low pressure to allow operation of the cryocoolers. Located on the feed indexer
  - The SPF Controller - microprocessor-based design with the primary function of controlling and monitoring the entire SPF system of the antenna (including the vacuum and helium services). All monitored parameters are independently logged per receiver feed package (FP) and sent to the end user when requested. The SPFC has an optic fibre Ethernet interface that provides feedback of each FP via the Tango protocol. It is located in the shielded cabinet of the pedestal.
- Installation, integration and verification of the SPF Services on the SKA-MPI dish has been completed. The SPF Services are currently operational on SKA-MPI in support of MPG single dish science.





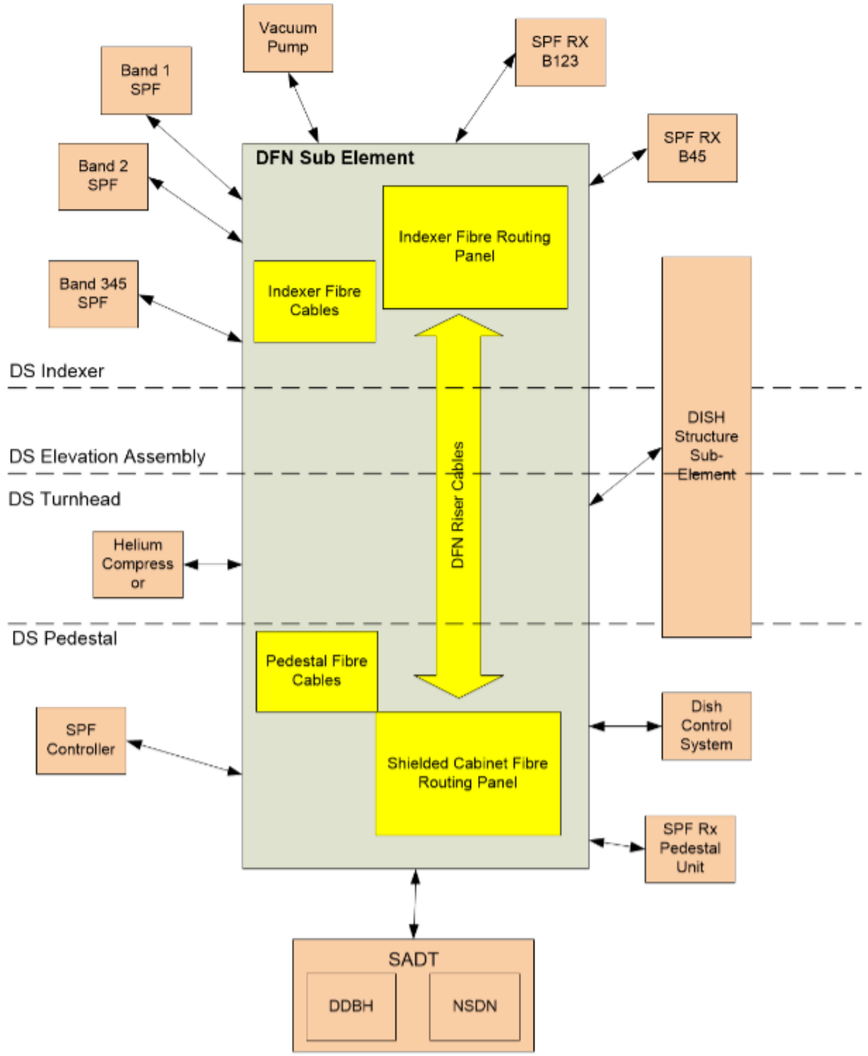
Helium Services

- The main function of the SPF helium service is the supply of high pressure high purity helium to allow proper operation of the Gifford-McMahon cryocoolers located in the respective cooled feeds.
- The SPF helium service main components are:
  - He compressor and He bottle assembly - located on the dish turnhead
  - He manifolds and feed He hoses – located on the feed indexer.
- The SPF helium service is operated continuously for as long as cooling is required
- EMI/RFI compliant
- Installation, integration and verification of the SPF Helium Service (first qualification model) on the SKA-MPI dish has been completed. The SPF Helium Service is currently operational on SKA-MPI in support of MPG single dish science.



DFN

- The Dish Fibre Network (DFN) is a sub element of Dish Structure (DS) and provides the optical fibre connectivity between elements at the DS.
- As an interconnecting element, it transports control and monitoring signals, digitised data and time and frequency signals between elements at the indexer and elements at the pedestal.
- It also provides the optical links between the DS sub elements and the SADT elements.
- DFN CDR held in 2021
- MK+ and part of SKA riser fiber cables in procurement



Technical Reviews

Item	Date	Status
SPF B345 TRR (Docs)	May 2021	done
SPF B345 TRR (Cryostat)	June 2022	Planned
SPF B345 TRR (FPC)	June 2022	Planned
SPF B345 CDR	September 2022	Planned
DFN CDR	March 2021	Done
DS CDR	April 2022 and July 2022	In progress/planned
SPF Band 2		Done
SPF Service - SPF Controller PRR	October 2020	Done
SPF Service - Vacuum PRR	December 2020	Done
Delta Cryo system CDR	July 2021	Closure in progress
Dish B1 & B2 System level CDR	July 2022	Planned
Dish B345 System level CDR	June 2023	To be confirmed

Thank you - Questions?

We recognise and acknowledge the Indigenous peoples and cultures that have traditionally lived on the lands on which our facilities are located.

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