On-Ground Calibration of the MetOP-SG Ice Cloud Imager

Axel Murk, Mikko Kotiranta, Tobias Plüss, Marc Bergadà, Massimo Labriola, Ana Beivide, Jaione Martínez, David de Castro, Daniel Döring, Kevin Pike, Richard Wylde

University of Bern, Institute of Applied Physics, Switzerland
Airbus Defence and Space, Madrid, Spain
Industrieanlagen-Betriebsgesellschaft IABG, Ottobrunn, Germany
Thomas Keating, Billingshurst, UK

Ice Cloud Imager ICI on MetOP-SG

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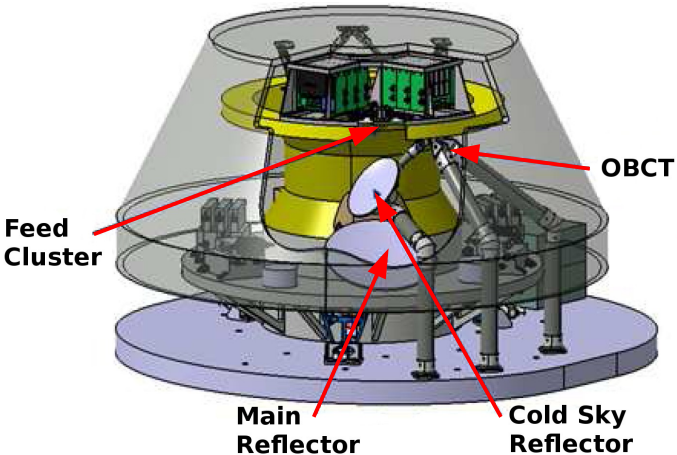
- Submillimeter wave radiometer for 180–670 GHz with 255 mm aperture
- Conical scanner with On-Board Calibration Target (OBCT) and Cold Sky Reflector



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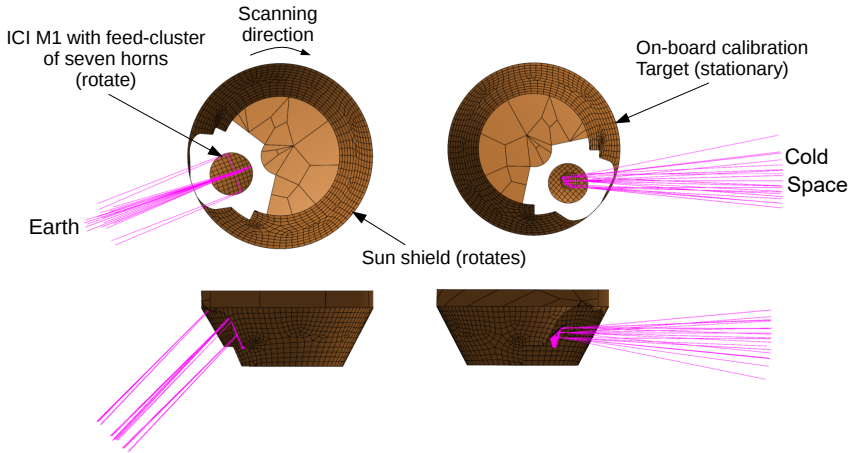
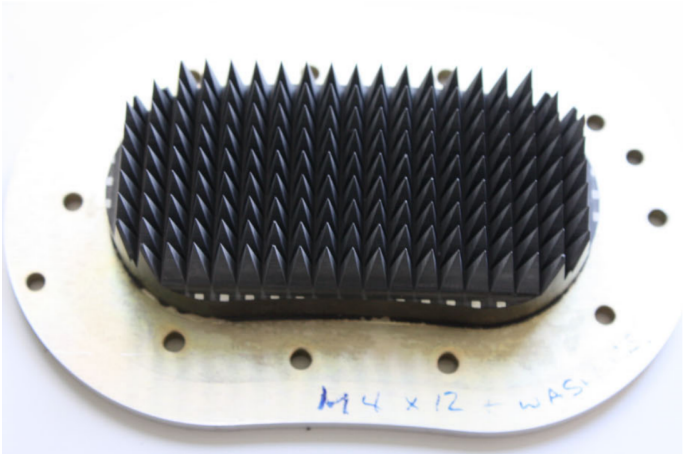


ICI On Board Calibration Target OBCT

- Pyramidal blackbody developed by UniBe and TK
- Measured S11 below -50 dB in all ICI frequency bands



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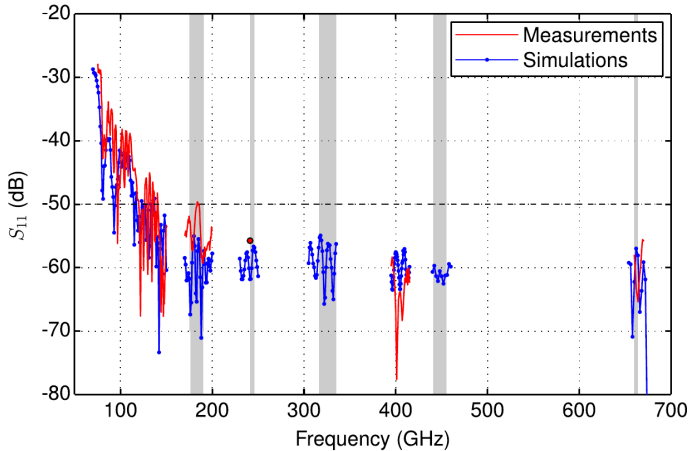

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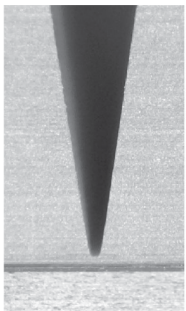
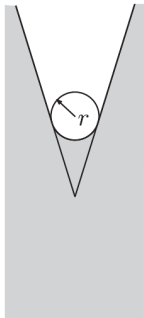
- RF performance improved by slots at the base of the pyramids

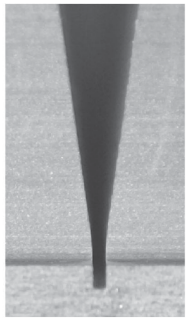
Initial Prototype

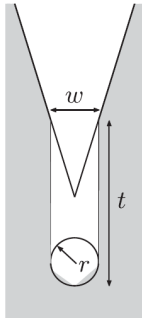




1mm

Improved Prototype





1mm

ICI On Ground Calibration Target OGCT

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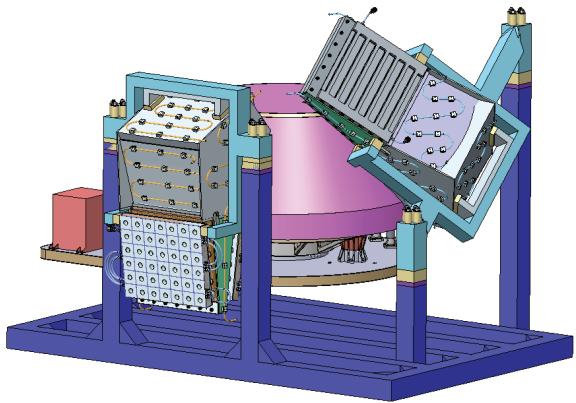
- Needed to verify RF performance of ICI during TVAC test campaign
- Fixed Temperature Target **FTT** 78 K and Variable Temperature Target **VTT** 80–335 K
- Requirements more stringent than for on-board target OBCT:
  - S11$<$-50dB
  - Emissivity $>$0.9995
  - $\Delta T_B < 0.1$ K
  - ICI rotation $\pm 2.5°$
  - Non-polarized



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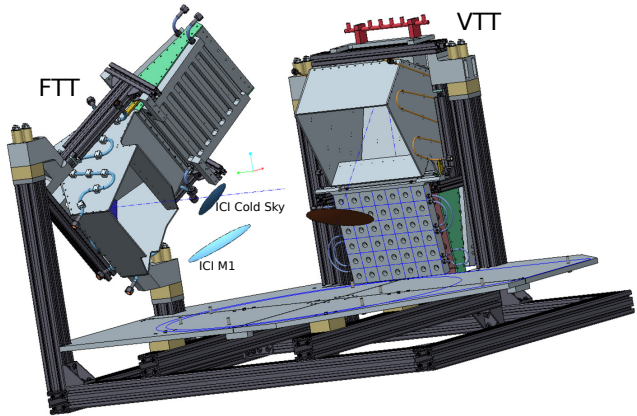

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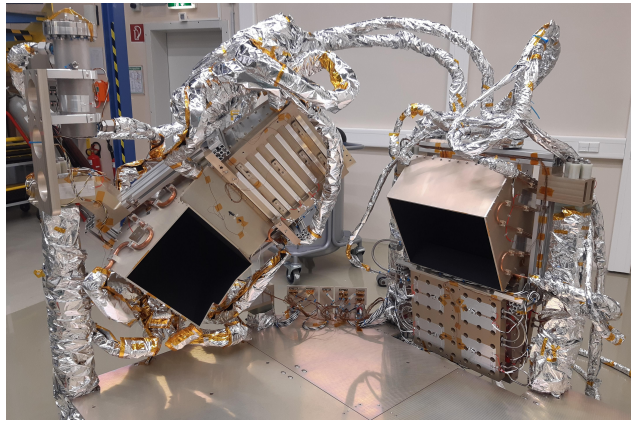
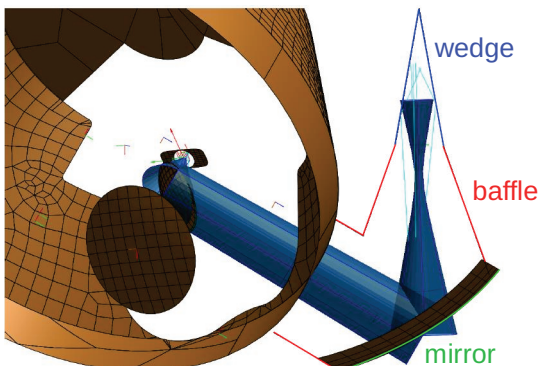


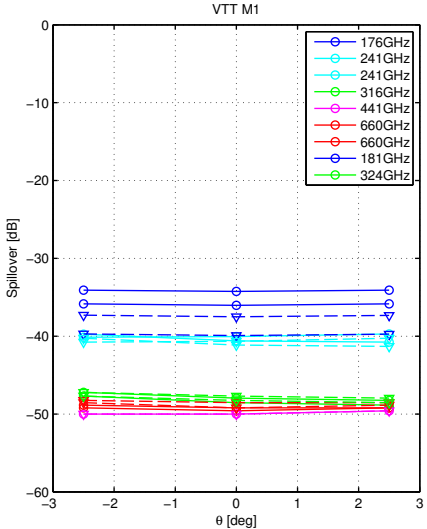
OGCT Optical Design

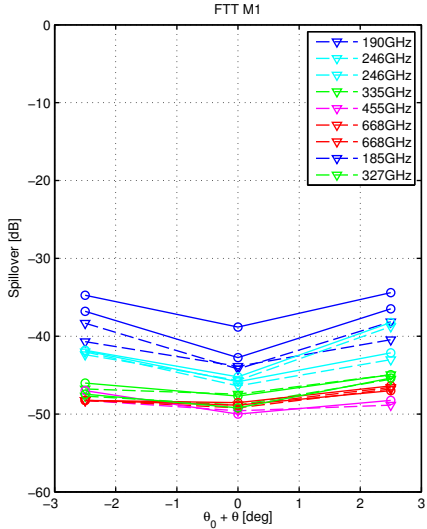
- Wedged cavity coated with RF absorber ⇒ better RF performance than pyramids
- Parabolic mirror focuses FOV to cavity aperture ⇒ high coupling efficiency
- Mirror and baffle coated with IR black paint ⇒ low thermal gradients in RF absorber
- GRASP antenna simulations of spillover and illumination of the wedge and mirror
- RF loss in the absorber cavity estimated with ray-tracing model



GRASP Simulation Examples: Spillover OGCT

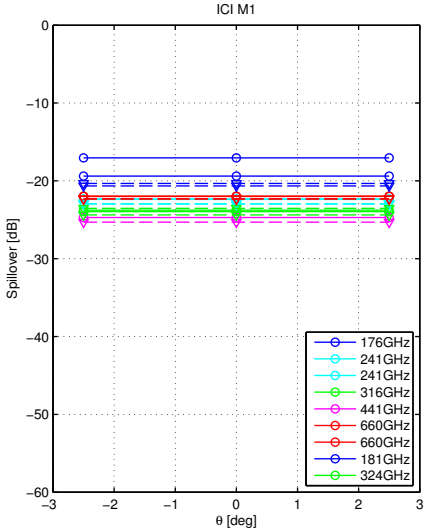
- Spillover loss between ICI and VTT/FTT reflectors

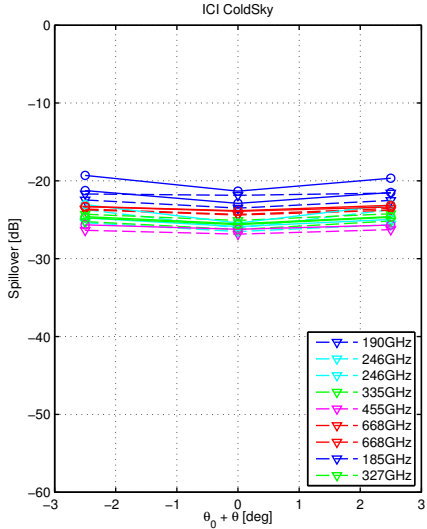




GRASP Simulation Examples: Spillover ICI

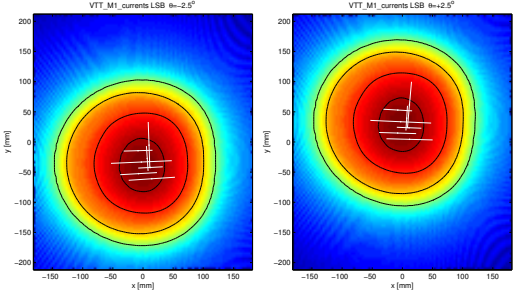
- Spillover loss between feeds and ICI reflectors orders of magnitude higher



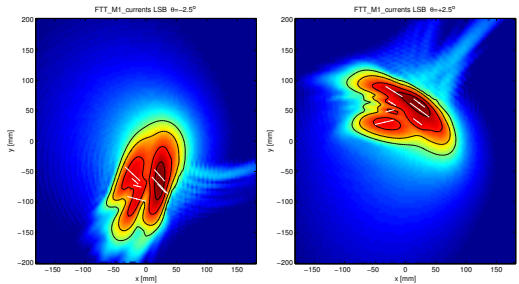


GRASP Simulation Examples: VTT + FTT Reflector Illumination

VTT at $\Delta\theta = \pm 2.5°$



FTT at $\Delta\theta = \pm 2.5°$



Color scale -60 to 0dB, Contours to -30dB

GRASP Simulation Examples: VTT + FTT Wedge Aperture

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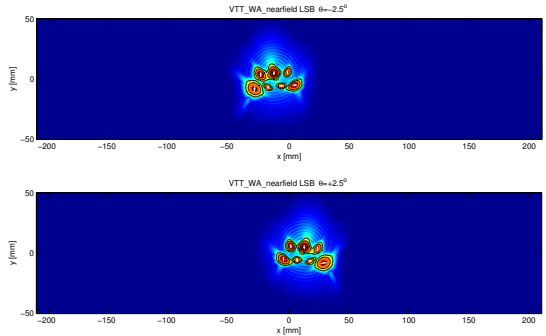
VTT at $\Delta\theta = \pm 2.5°$



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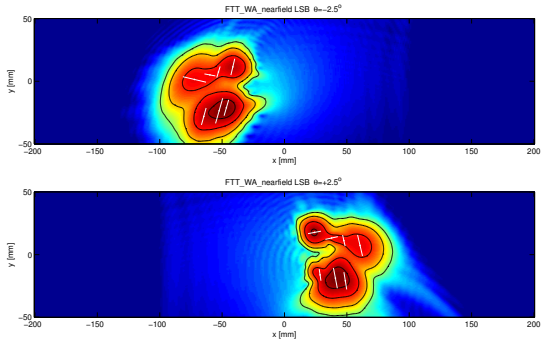
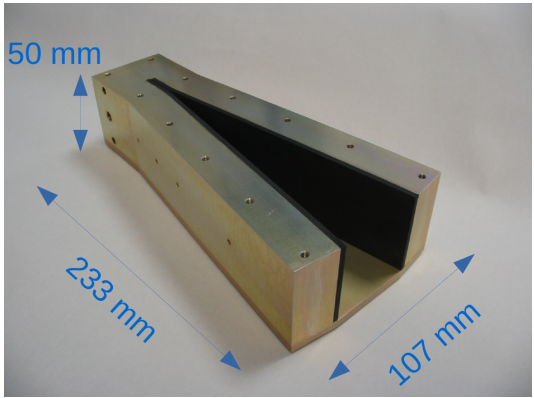
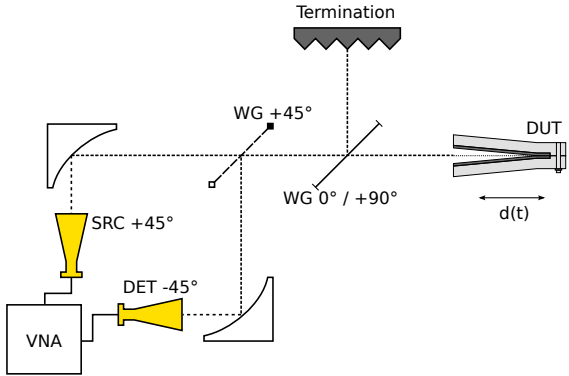


RF Tests of a Breadboard Model

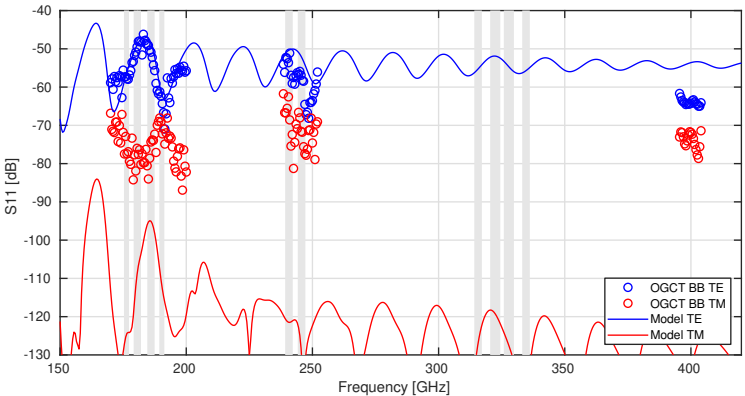
- S11 measurements of a small breadboard model using a submm VNA, quasi-optical directional coupler with polarizing grids, and sliding load calibration technique.





RF Tests of a Breadboard Model

- Ray-tracing model predicts much better RF performance for TM instead of TE polarization
  ⇒ OGCT orientation selected that most ICI channels are TM

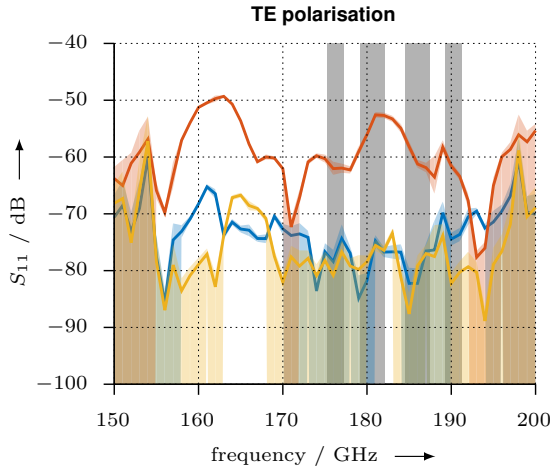


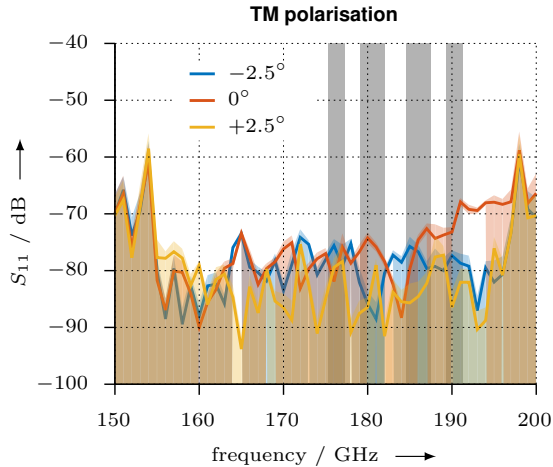
TE polarization:
- Close to ray-tracing results

TM polarization:
- Higher S11 than predicted
- Sill at about -70 dB
- Intrinsic diffuse scattering?

RF Test Results VTT 150–200 GHz

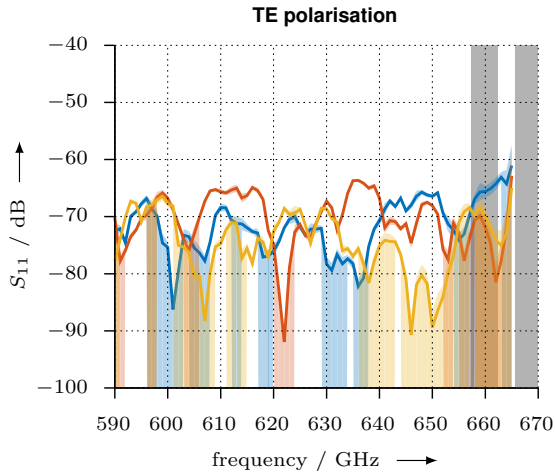
- Measurements repeated in TE+TM polarization and at 0 to ±2.5° rotation
- Worst performance at TE incidence and 0° rotation below -50 dB

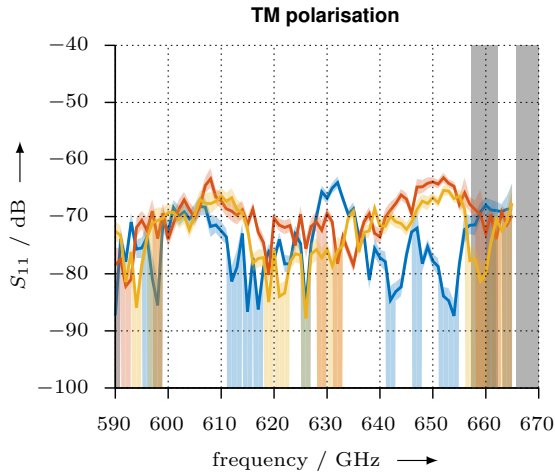




RF Test Results VTT 590-670 GHz

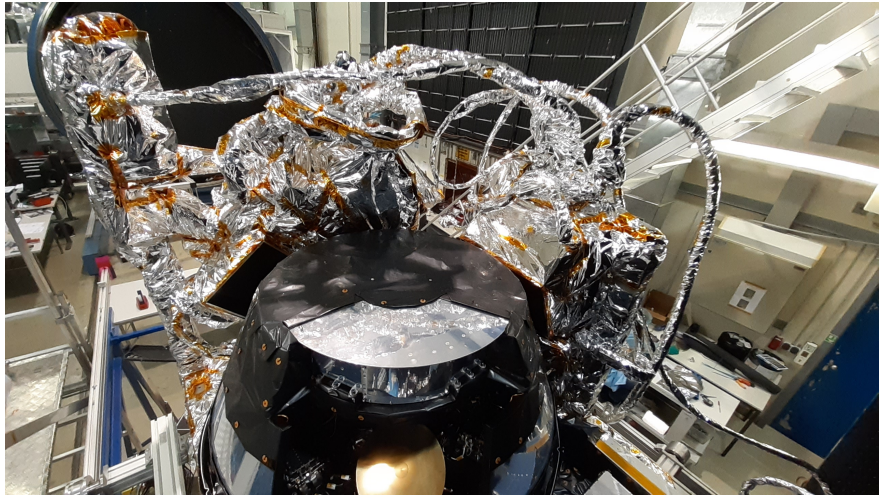
- Measurements repeated in TE+TM polarization and at 0 to ±2.5° rotation
- Worst performance at TE incidence and 0° rotation below -50 dB





ICI Radiometric Calibration Campaigns

- ICI Engineering Model 12/20201 at IABG, Ottobrunn
- ICI Proto Flight Model 05/2022 at Airbus DS, Toulouse



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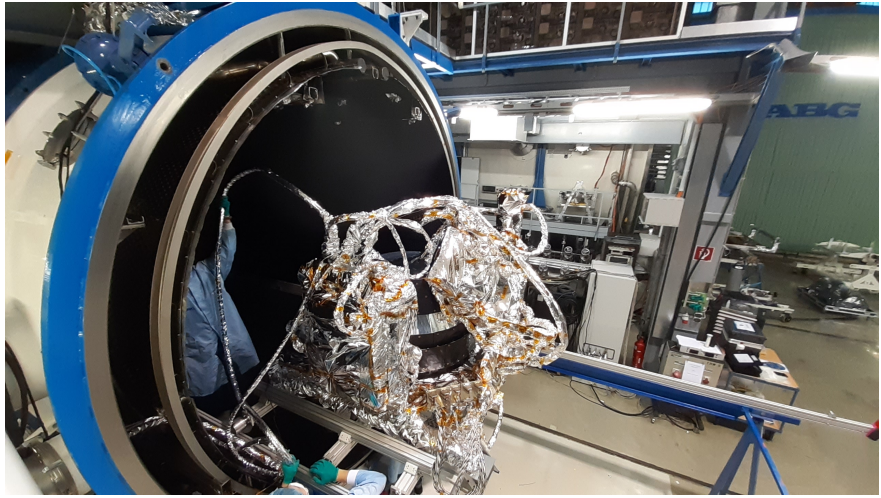
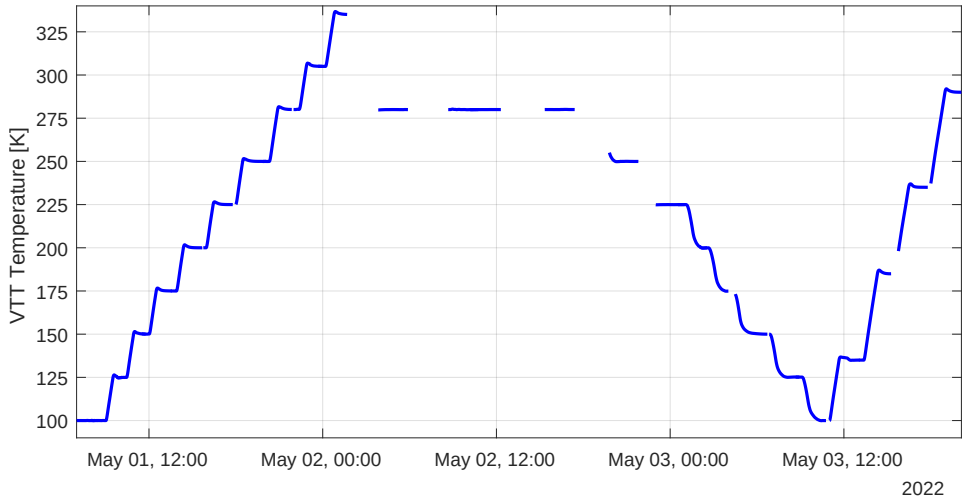


ICI PFM Test Campaign: Temperature Readings

- VTT Temperature is ramped up and down in 25 K steps



ICI PFM Test Campaign: Temperature Readings

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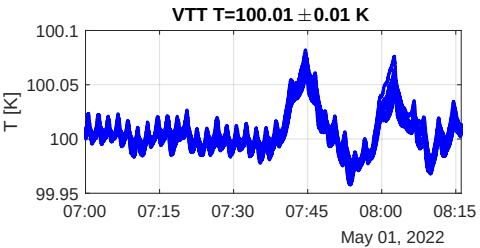
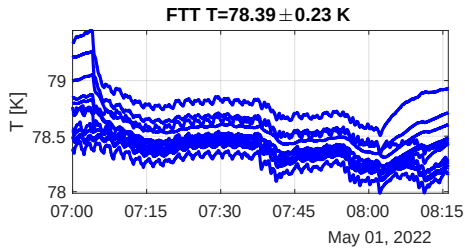
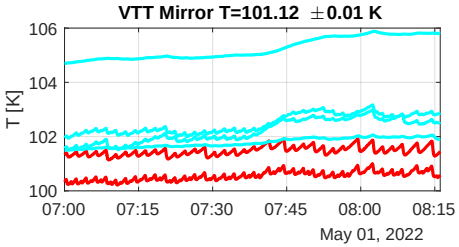
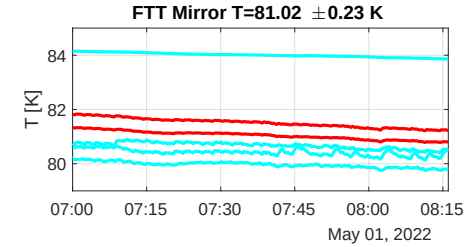
- VTT Temperature stability and uniformity better 50 mK





Absorber Cavity 12×PT100

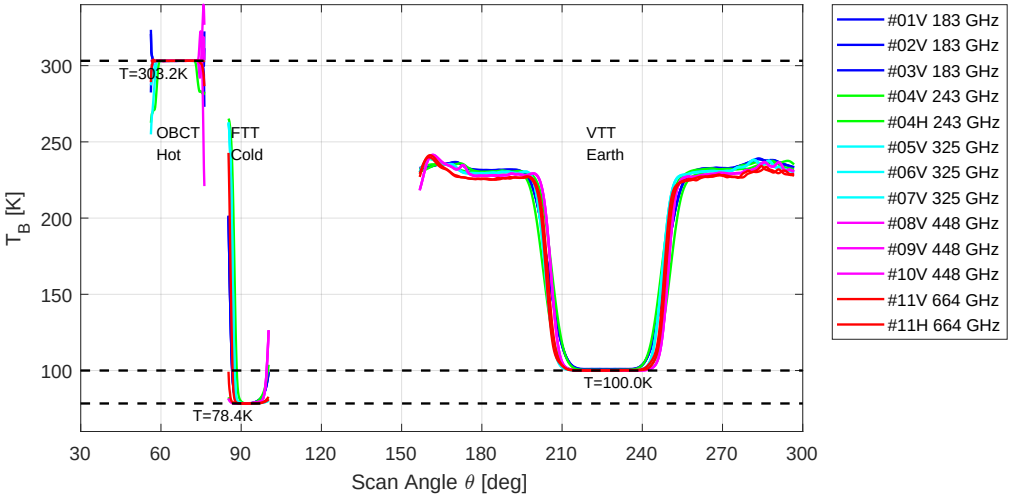




Reflector Baffle

ICI PFM Brightness Temperatures

- Simple calibration with Rayleigh-Jeans approximation



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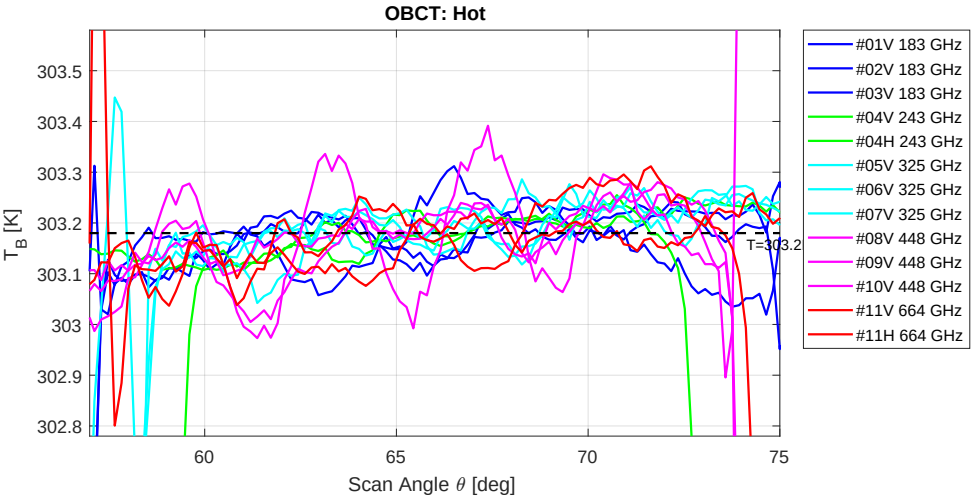

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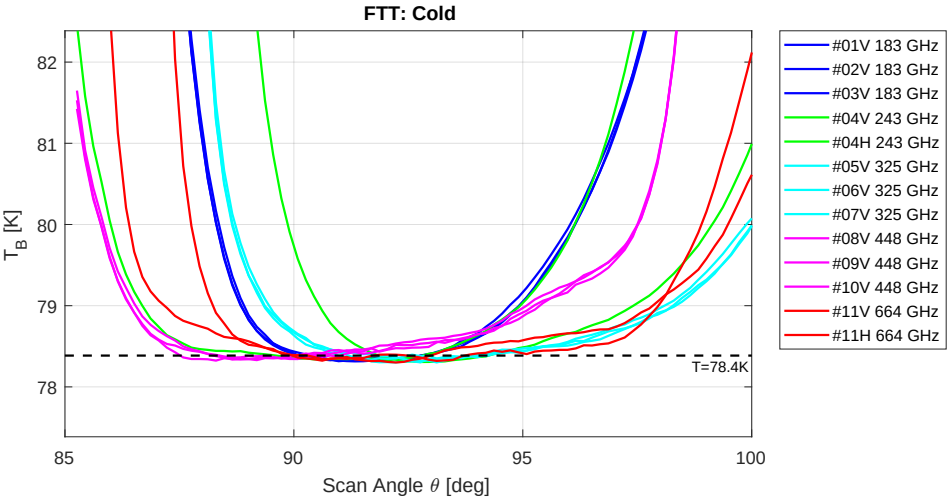

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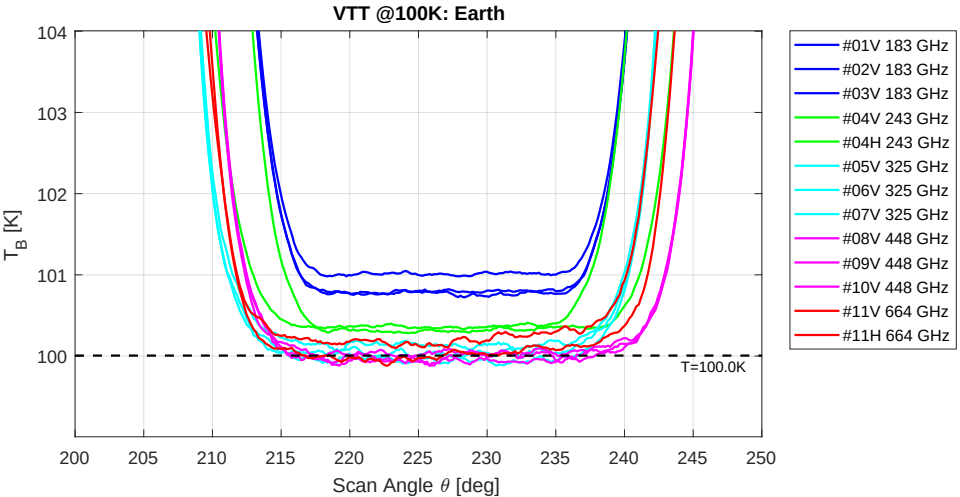

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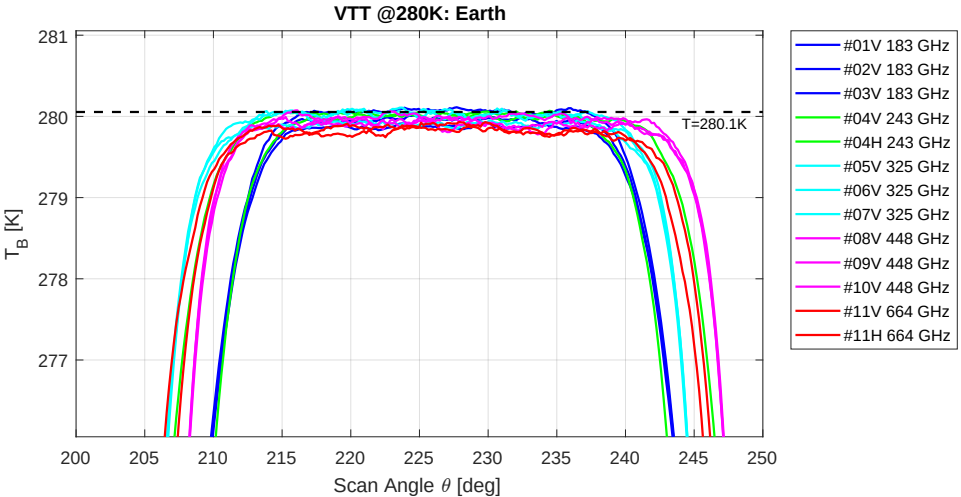

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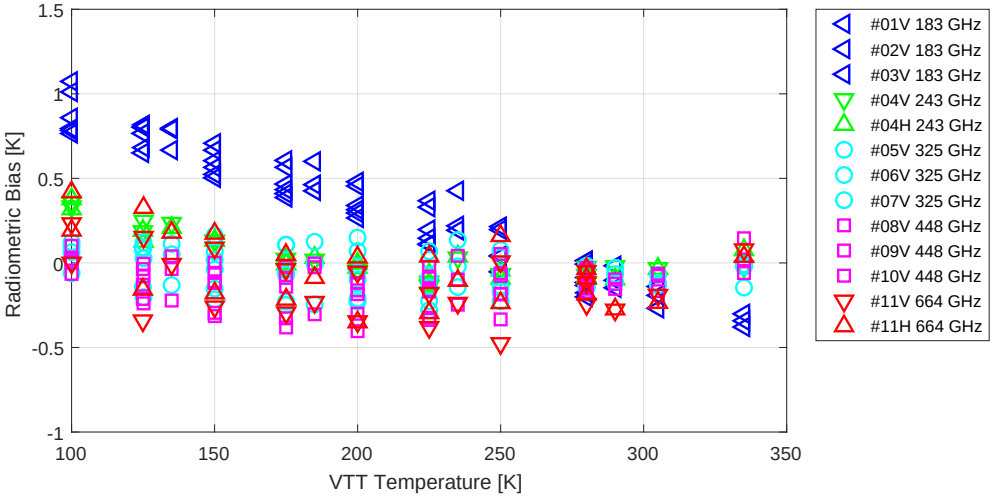
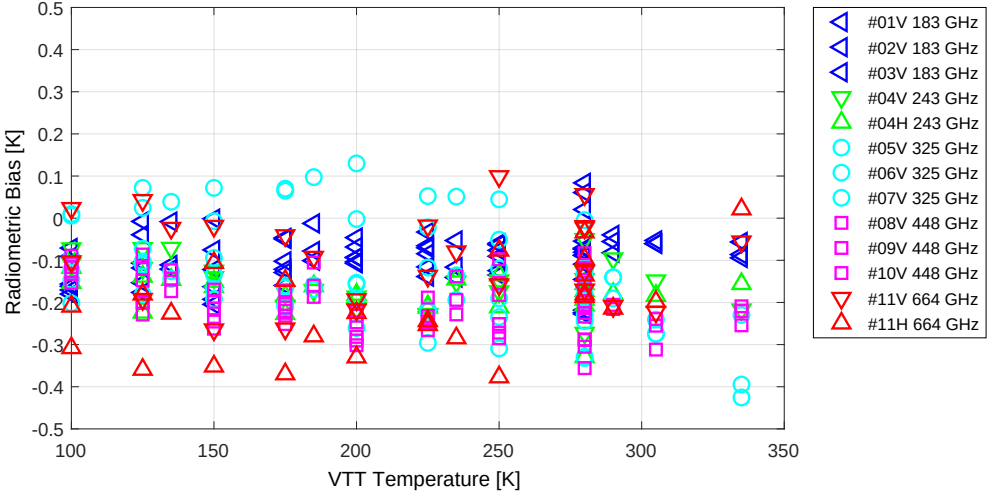


ICI PFM Radiometric Bias

- Detailed calibration with Planck equation and reflector + spillover loss corrections



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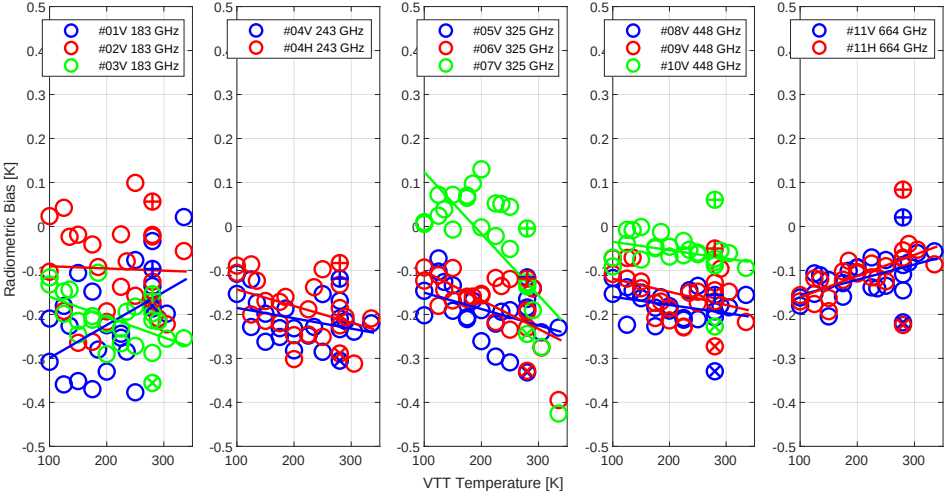

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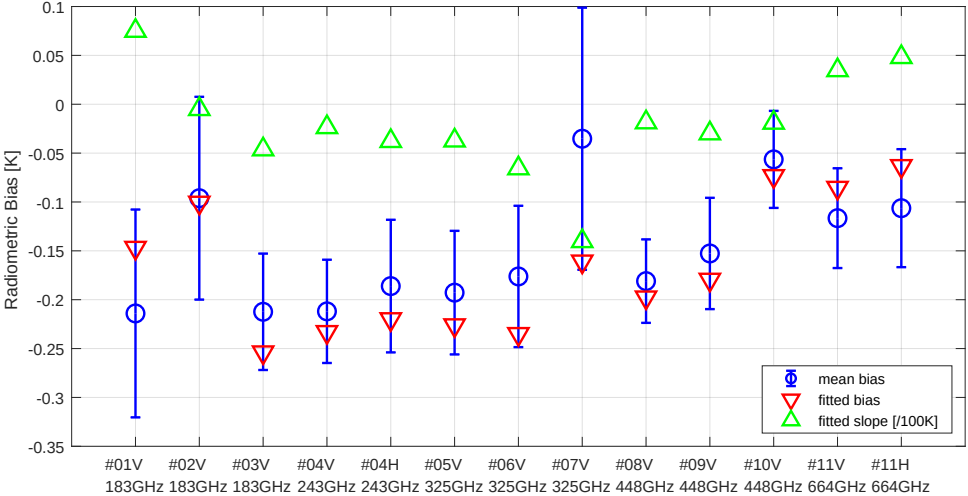

Conclusions

- On Ground Calibration Targets for the ICI instrument:
  - Wedged absorber cavity with S11 $\leq$ -60 dB
  - IR black coupling mirror + baffle to reduce radiative heat transfer
  - Dual stage thermal control system achieved $<$50 mK stability and uniformity
- Calibration campaign with ICI PFM instrument demonstrated $\leq$0.4 K bias
- Accurate calibration requires detailed error model, in particular for the spillover losses
- ICI launch on MetOP-SG satellite B1 scheduled in Q1/2025