Development of Microwave Calibration Targets for Upcoming ESA Missions

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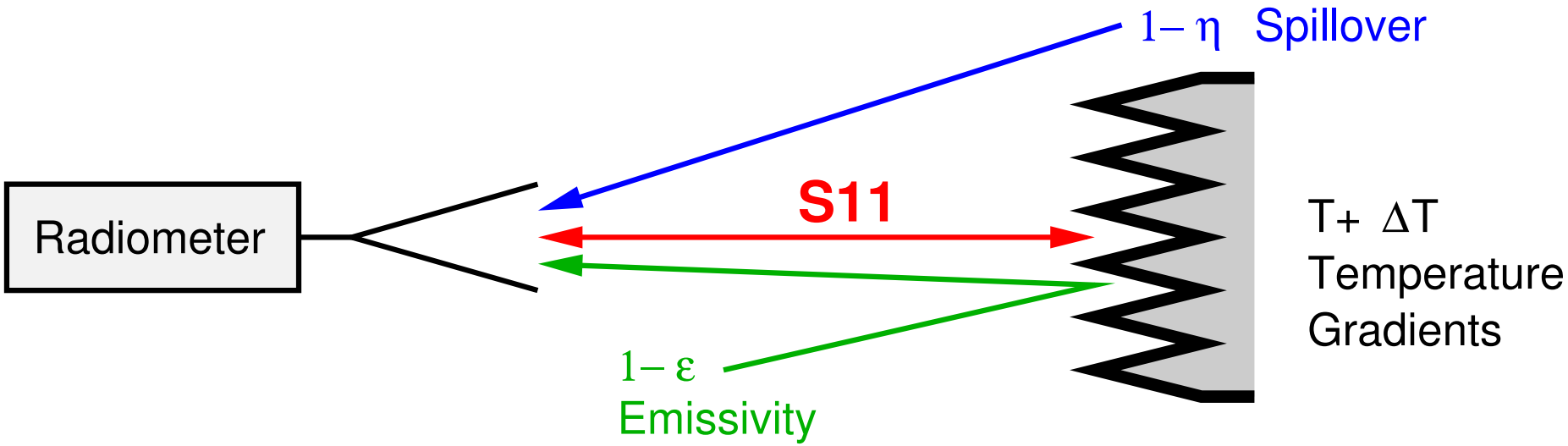
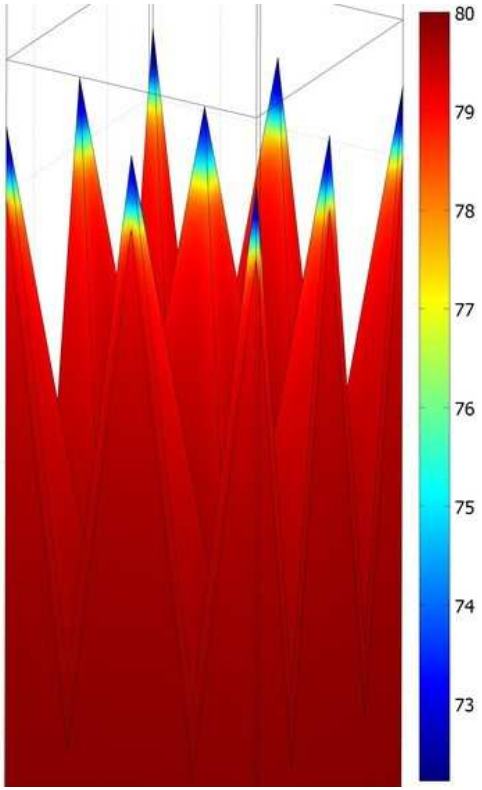
Requirements for Microwave Calibration Targets

- Low temperature gradients ΔT
- High emissivity $\epsilon \geq 99.99\%$
- Low coherent return loss S11 $\ll$-40dB
- High coupling efficiency $\eta \geq 99.99\%$



Temperature Gradients

- Microwave absorbers have relatively lower thermal conductivity $\Rightarrow$ temperature gradients, depending on thermal environment.
- Pyramidal targets are more affected than other designs.
- Examples of a heated target for ALMA with gradients up to 5K:



Thermal simulation

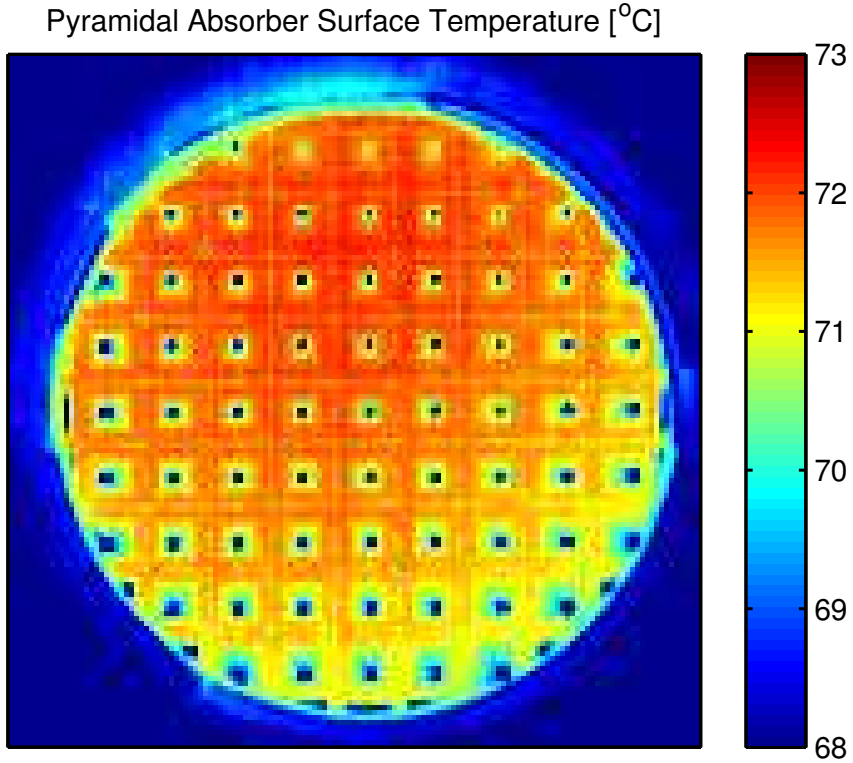
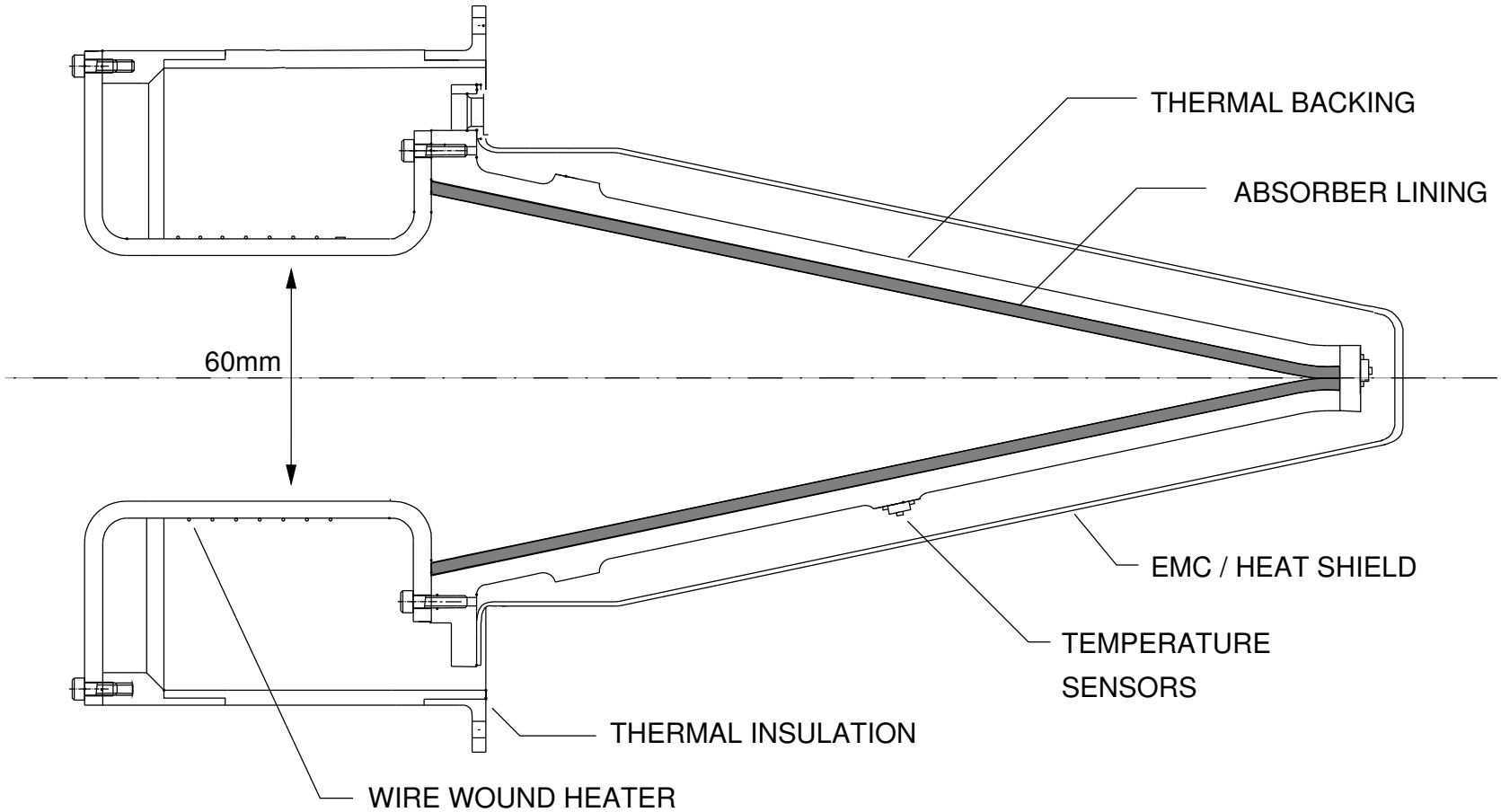


Image with thermal IR camera

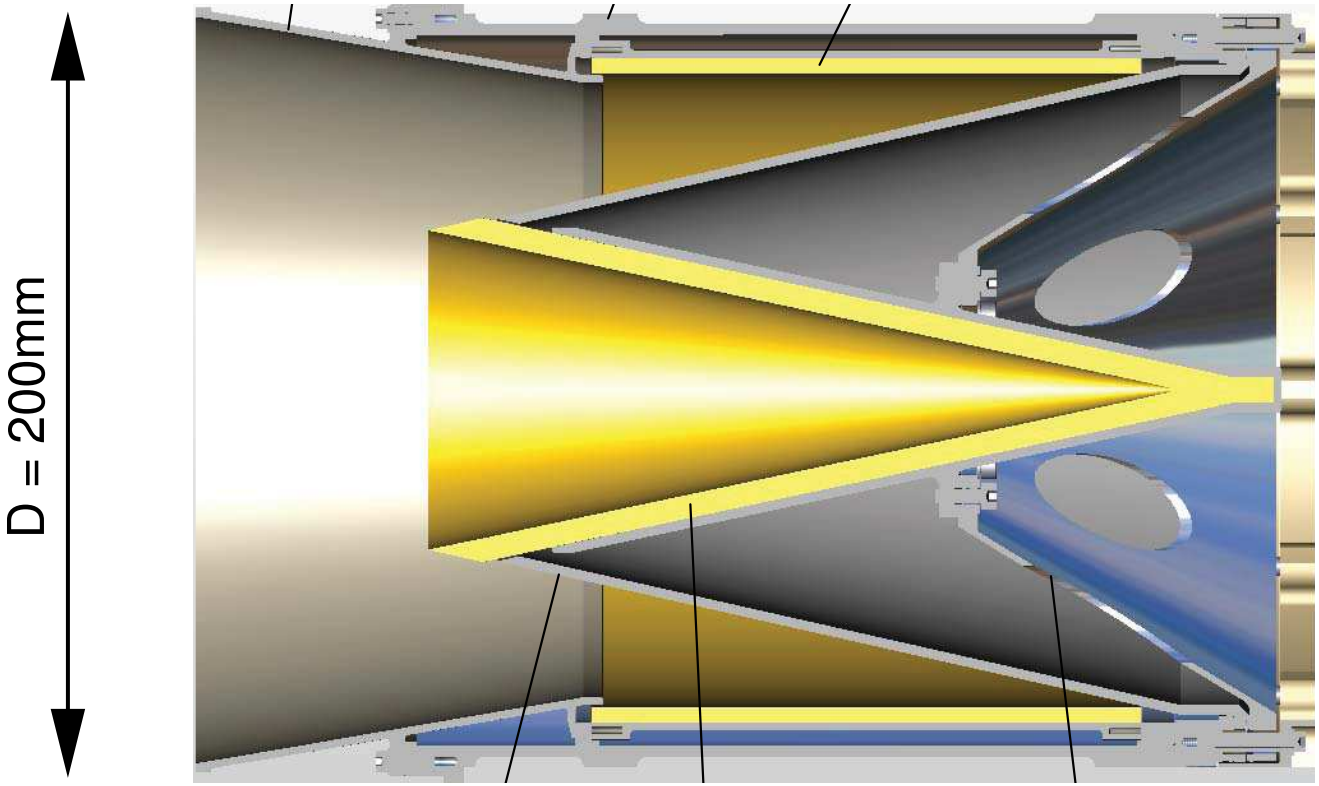
Conical Hot Load (CHL)

- Initially developed for ESA submm-wave limb sounder >300GHz
- Successfully flown on various air- and balloon-borne instruments
- Lower temperature gradients and S11 than pyramidal targets



Conical Hot and Ambient Targets for ALMA

- Frequency bands between 30-950 GHz
- Tuned multilayer absorber in a folded cone geometry



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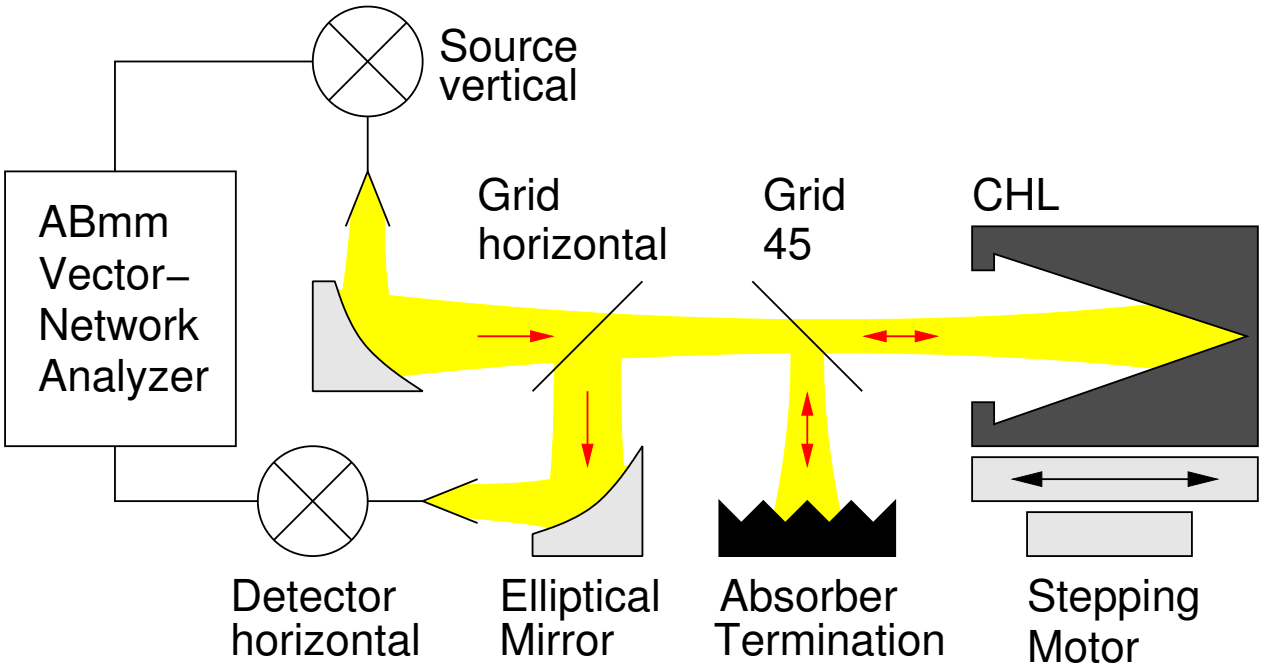
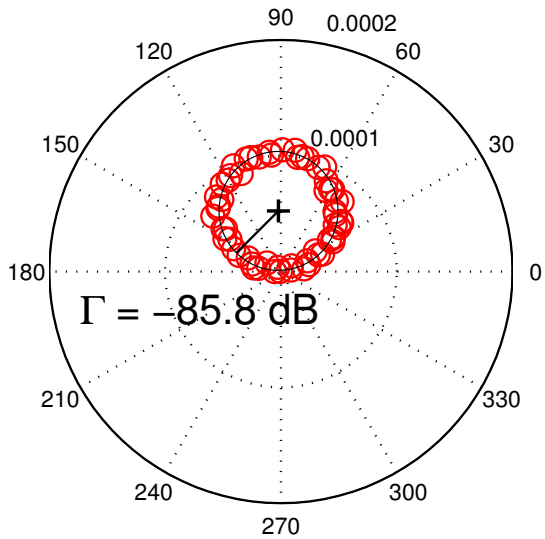
S11 Test Setup

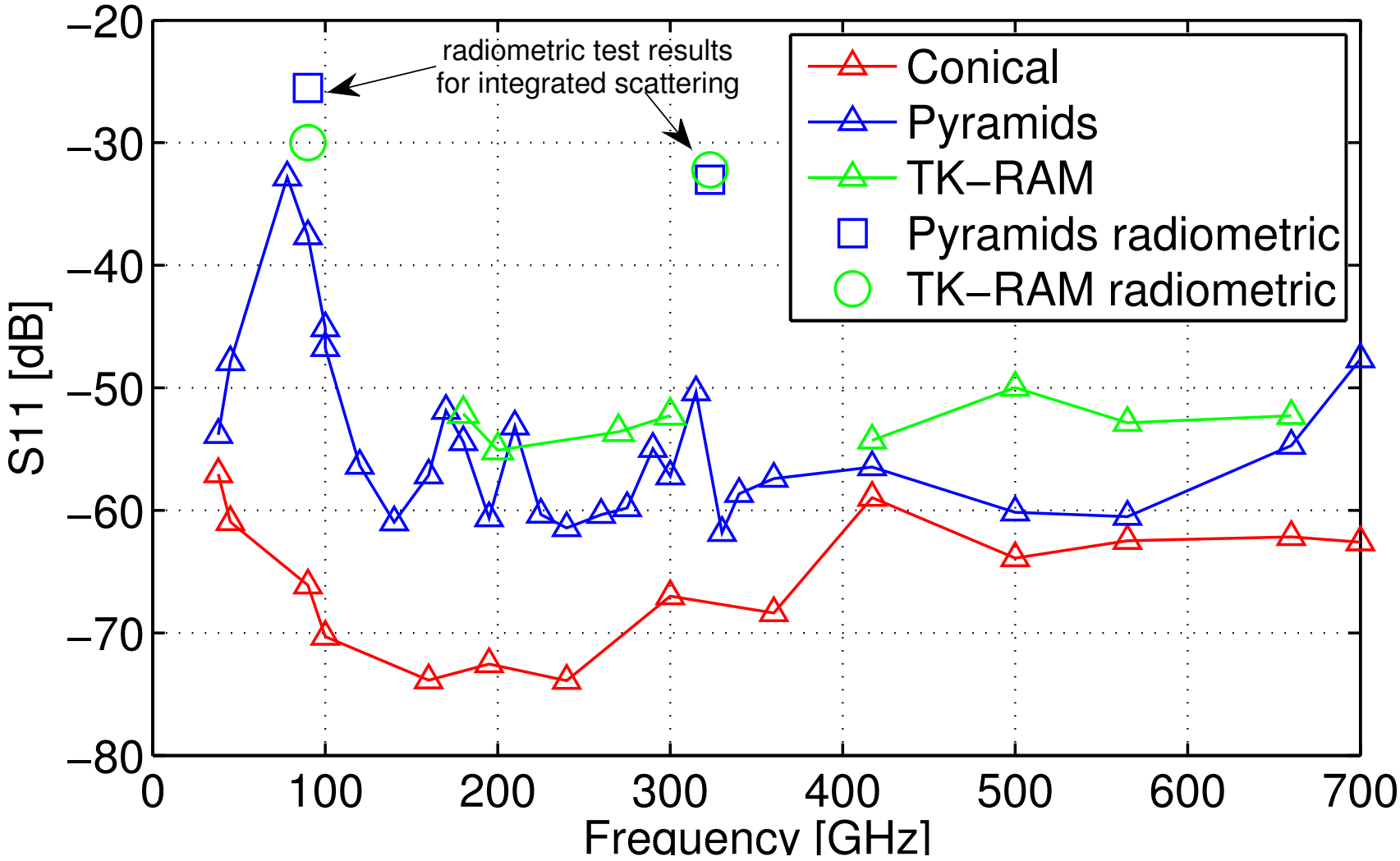
- S11 measurement with VNA
- Directional coupler up to 100 GHz, quasi-optics above.
- Test object measured at different distances d to calibrate directivity of the test setup $\Rightarrow$ phase changes, fit of a circle to the complex data





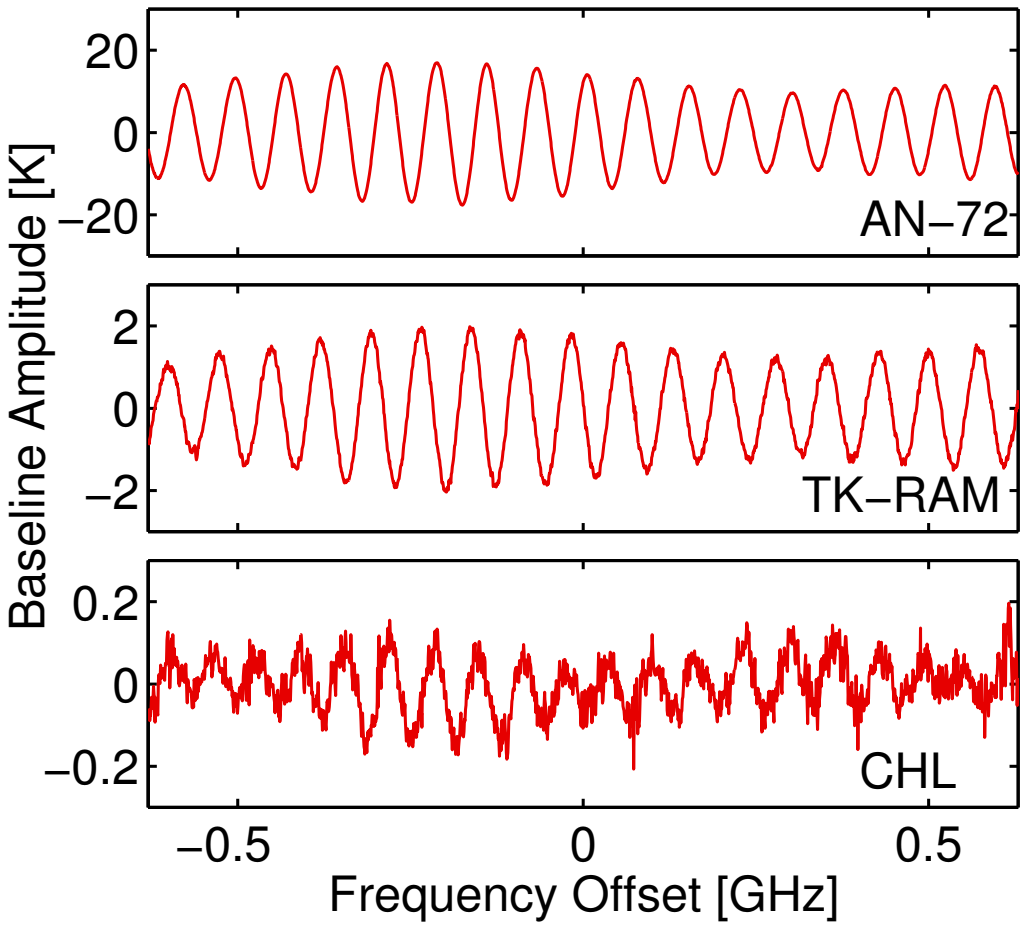
S11 Test Results for Conical and Pyramidal Targets

- S11 backscatter measurements for different targets



Standing Wave Baseline Ripple

- Spectroscopic baseline of different ambient temperature targets observed with a cryogenic 300 GHz receiver.



- Flat foam absorber:
  S11 = -25dB
  $\Delta T_B = 20\text{K}$
- Pyramidal plastic absorber:
  S11 = -50dB
  $\Delta T_B = 2\text{K}$
- Conical Target:
  S11 = -65dB
  $\Delta T_B = 0.2\text{K}$

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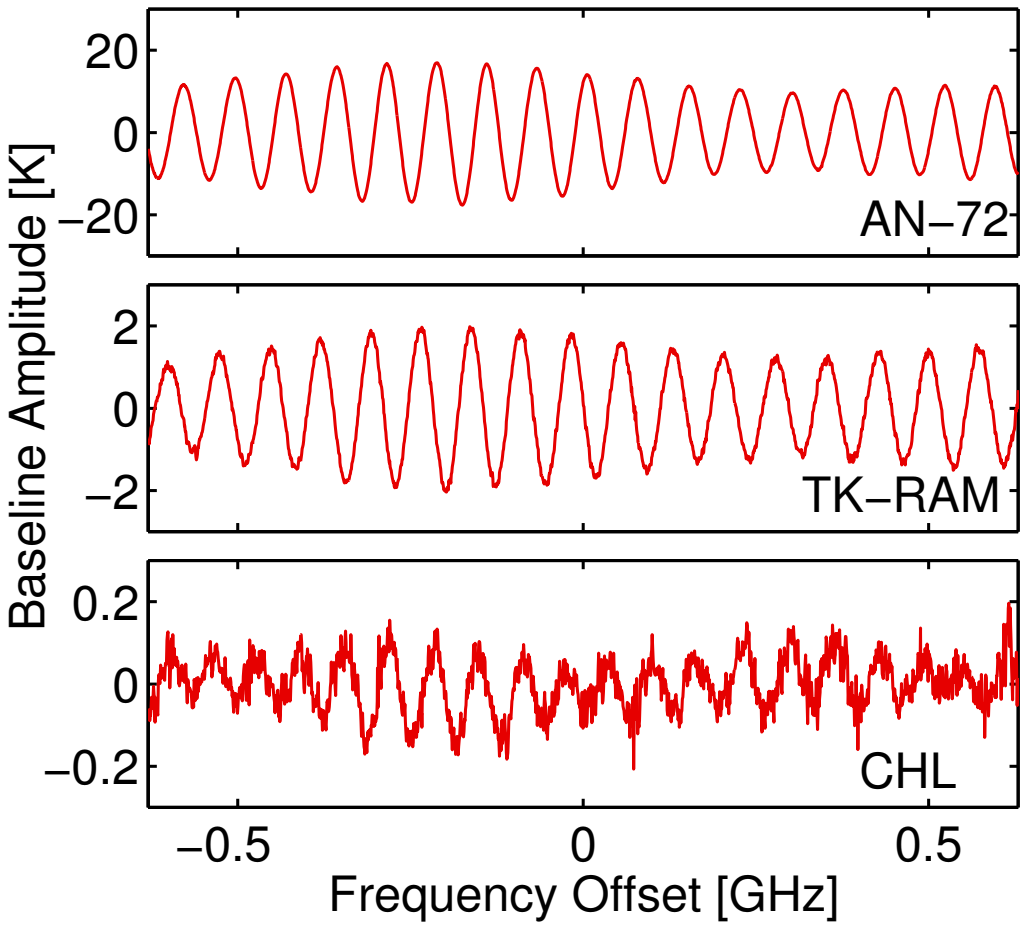

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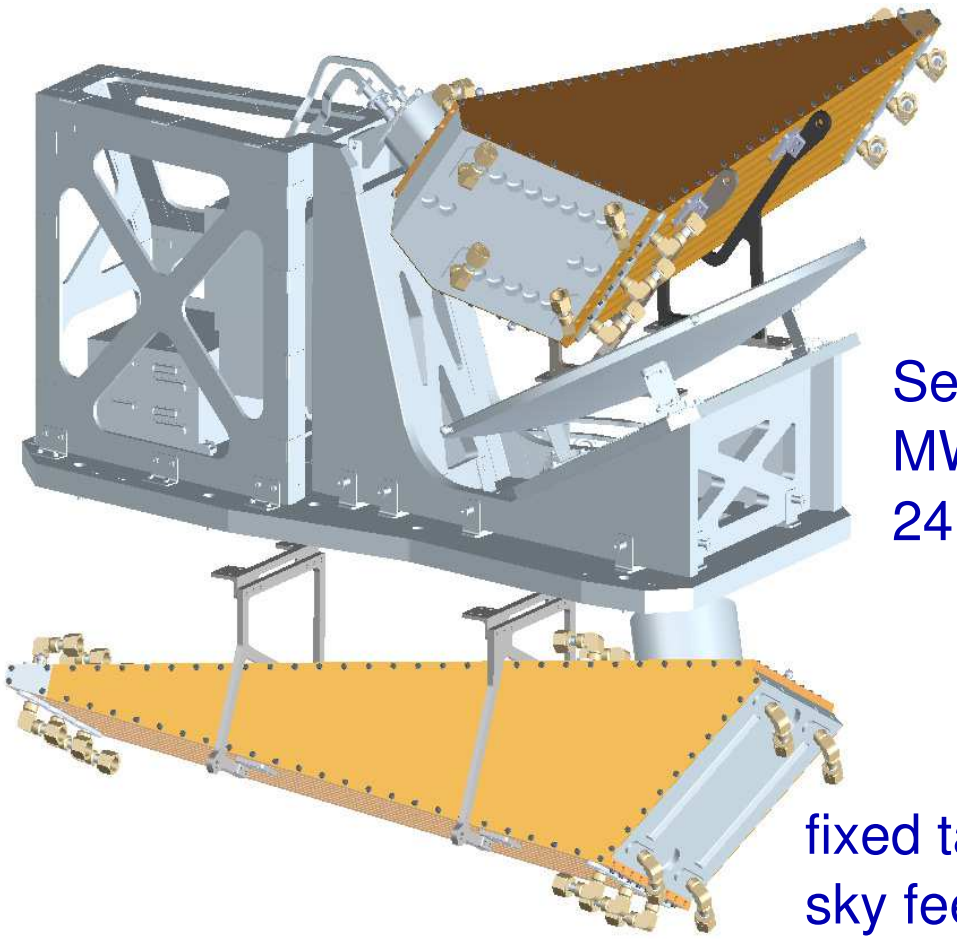
Low S11 is most crucial for spectroscopic observations !

Ground Calibration Targets for SENTINEL-3 MWR

- Fixed and variable cryogenic target for 24 and 36 GHz
- Wedged blackbody for single TM polarization
- Temperature stabilized shaped reflector minimizes IR loading



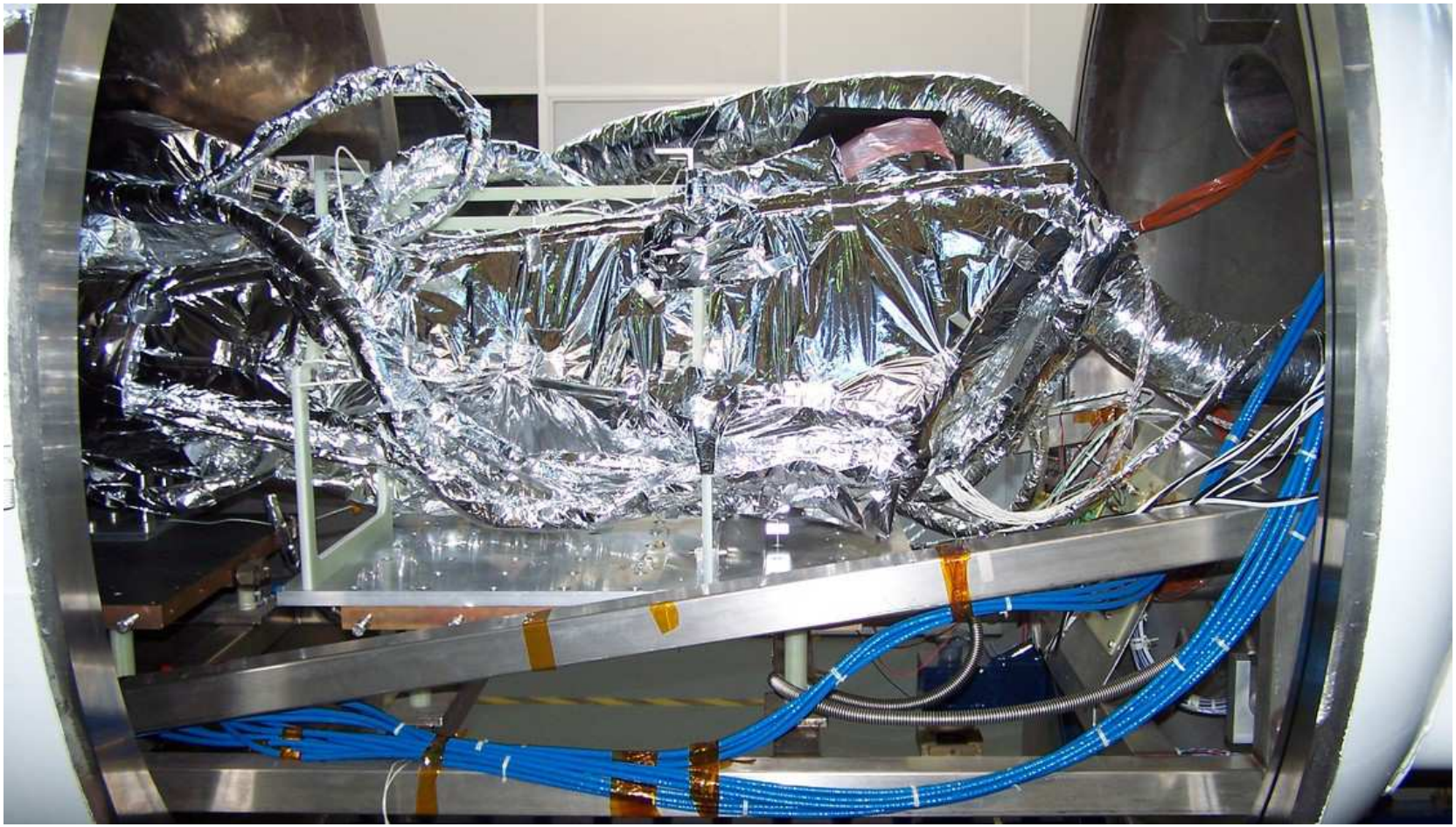
variable target for
two antenna feeds
80–300 K

Sentinel–3
MWR Instrument
24 + 36 GHz

fixed target for
sky feed 80K

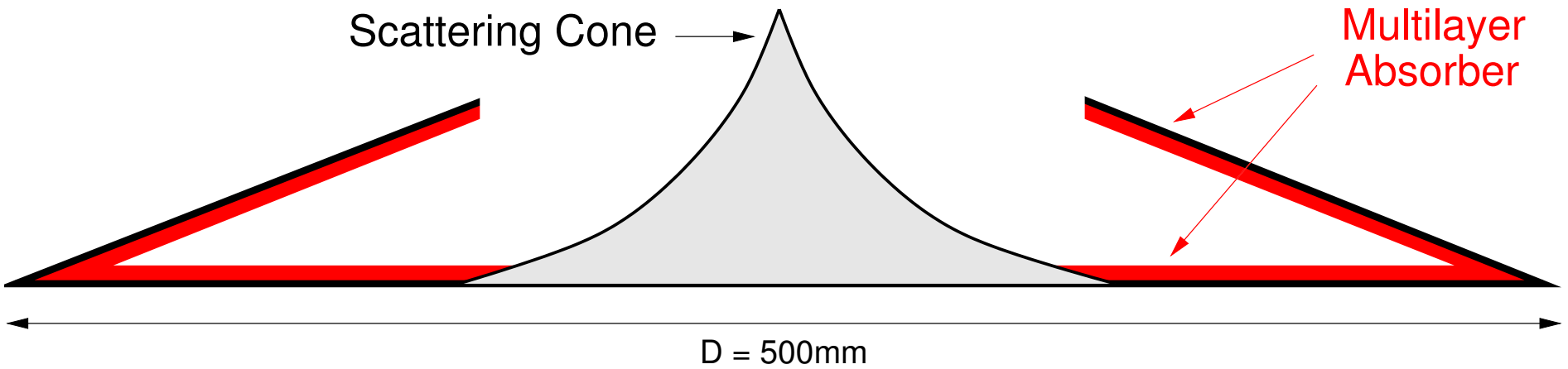
Ground Calibration Targets for SENTINEL-3 MWR

- RF testing showed S11 $\leq$ -60dB and emissivity $\geq$99.99%
- Thermal simulations and initial thermal tests showed very good results.
- Final thermal tests currently ongoing in the ABSL TV Chamber:



Low Mass Calibration Load (LMCL)

- ESA TRP project in preparation for Metop-SG (18-300 GHz)
- Design goals: low profile, low mass, low temperature gradients
- Profiled scattering cone reduces radiative heat exchange
- Annular cavity with multilayer absorber coating



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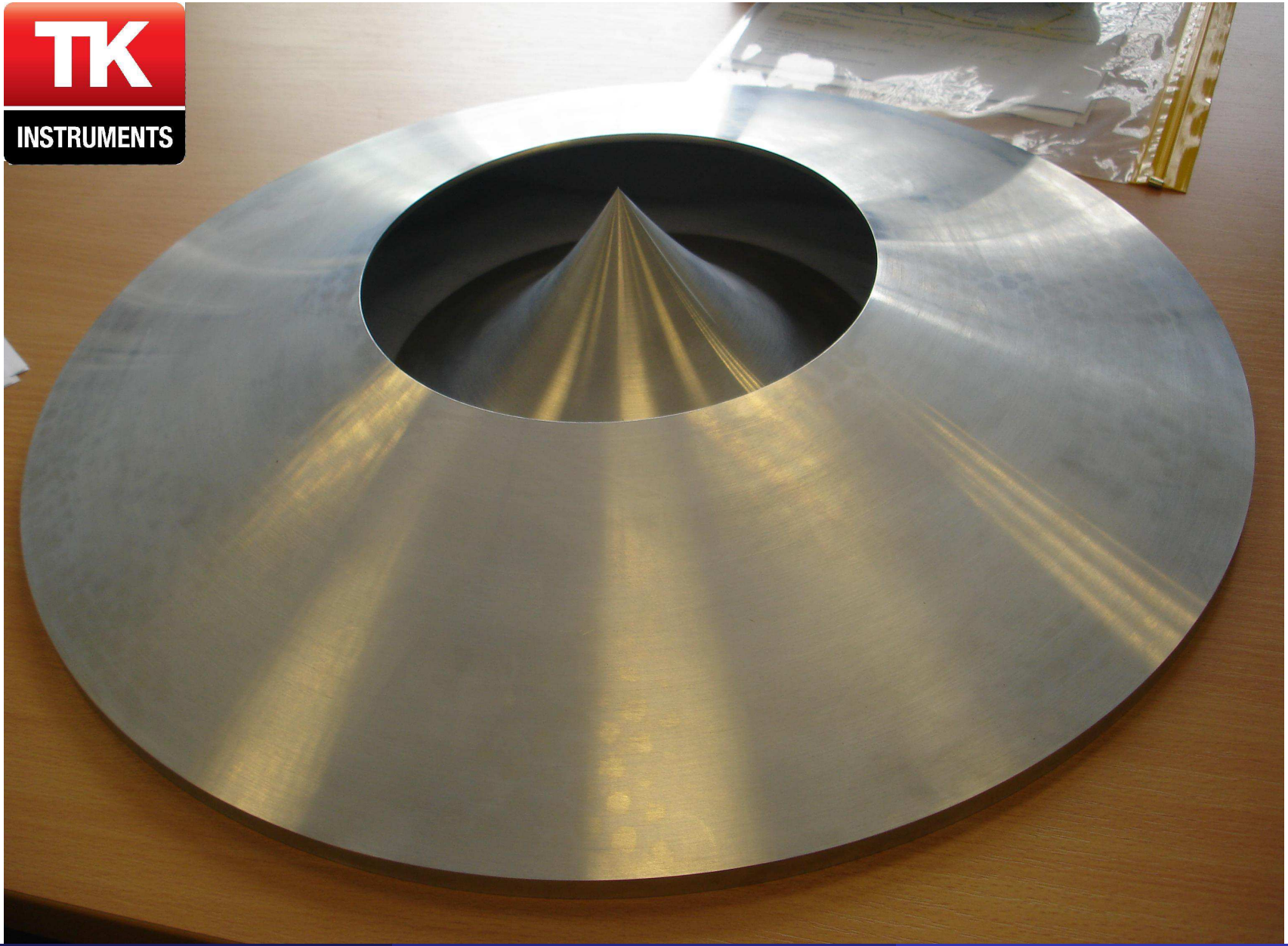
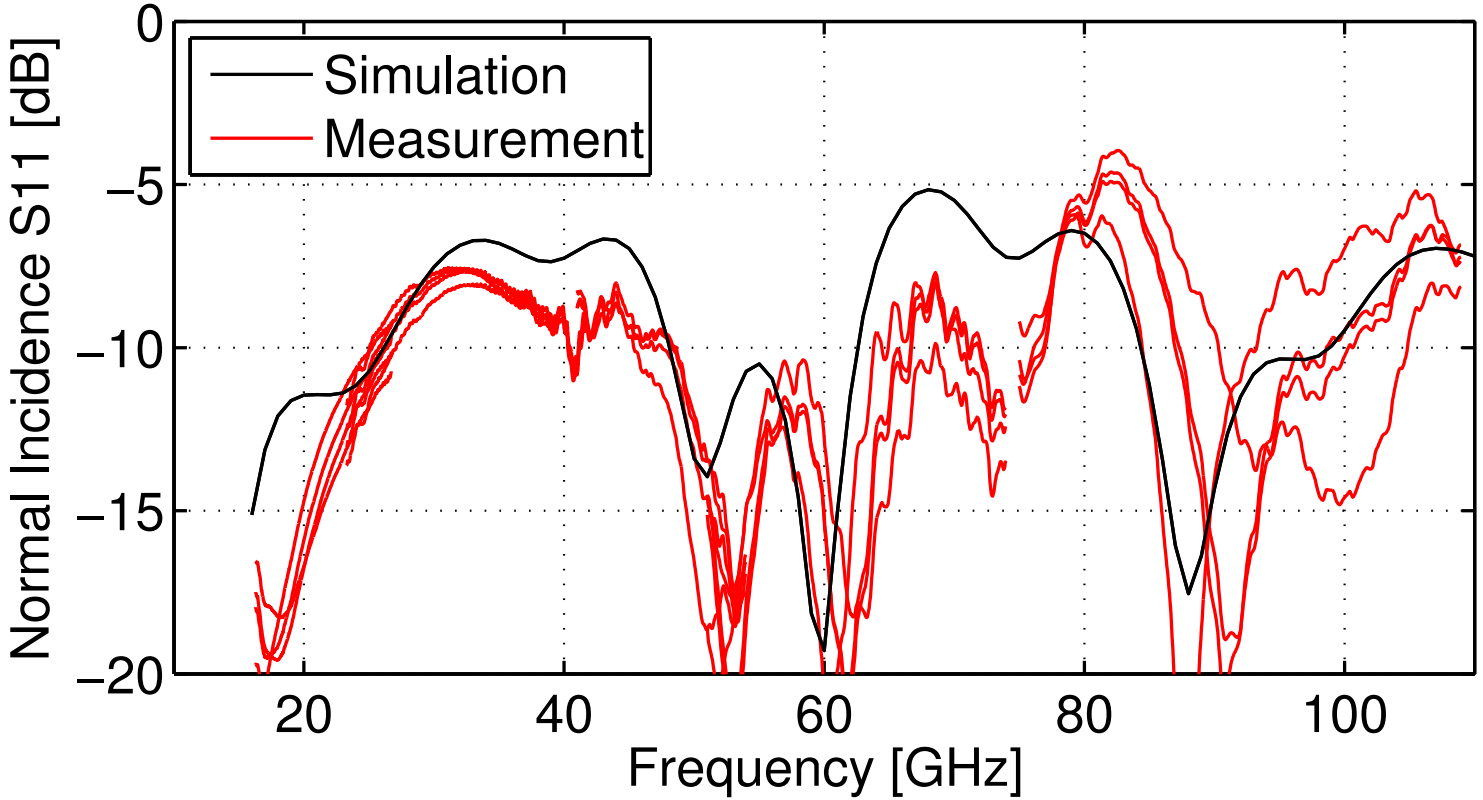


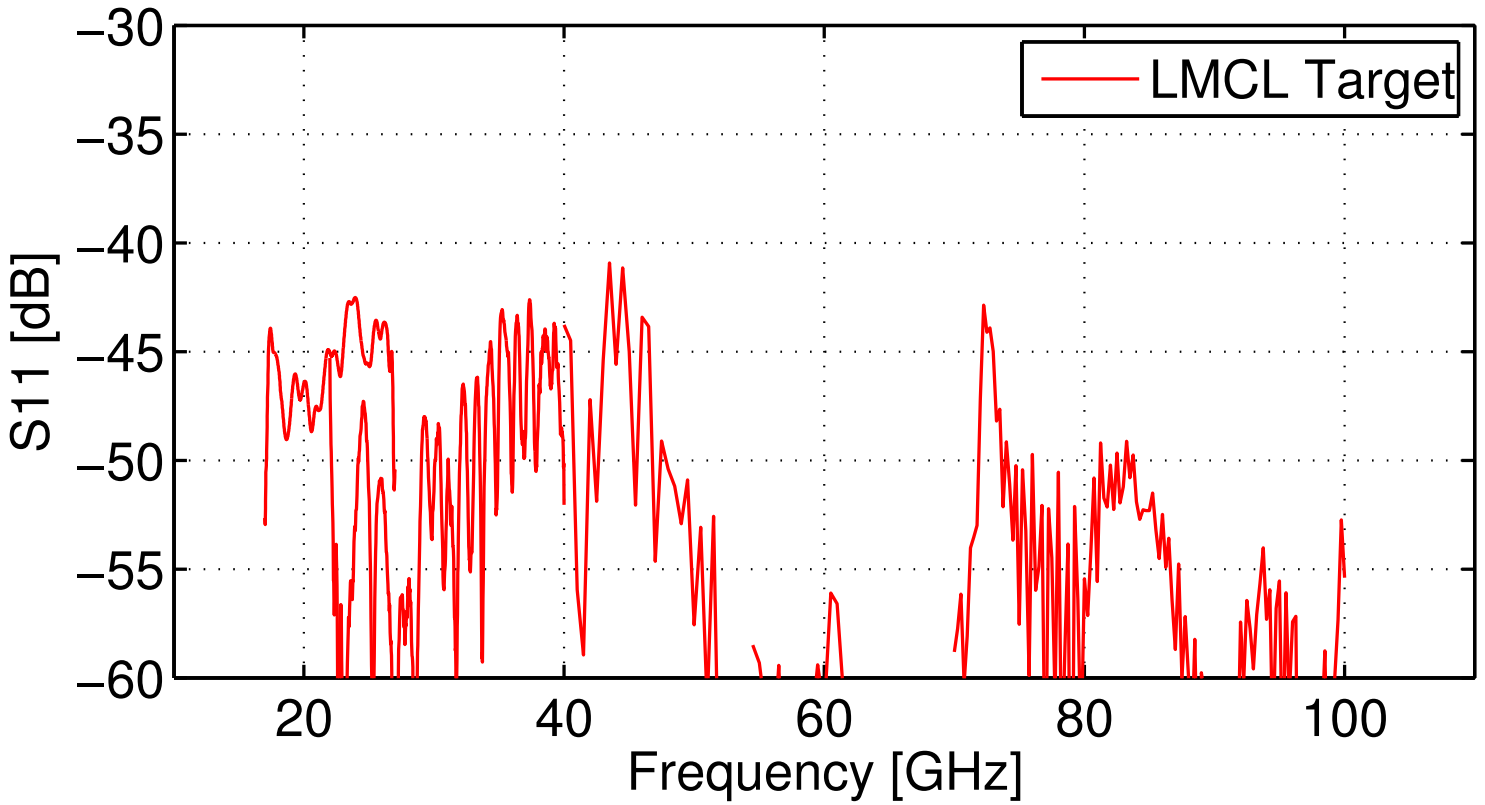
LMCL Multilayer Absorber

- Three absorber layers with different grades of magnetic loading.
- Improves broadband matching to free space for given thickness.
- Can be tuned for optimum performance in specified frequency bands.
- Tuning requires detailed knowledge of frequency dependent ϵ^*, μ^*.



LMCL Measured S11

- Multilayer is tuned for METOP-SG MWS bands:
  18 to 30GHz , 50 to 60GHz and 90GHz.
- Origin of the S11 inside of LMCL can be identified by FFT analysis
  $\Rightarrow$ Tip of scattering cone has significant contribution.



Outlook on Future Missions

- **ESA PREMIER Mission – STEAMR**
  - Frequencies between 320–360 GHz
  - Conical calibration target based on CHL
- **ESA JUICE Mission to Jupiter - SWI**
  - Frequencies around 600 GHz and 1.2 THz
  - Small conical calibration target based on CHL
- **METOP Second Generation – MWS, MWI, ICI**
  - Frequencies 18–600 GHz
  - Space and mass constraints do not allow conical or wedged target
  - Pyramidal target with optimized shape and multilayer absorber?

Conclusions

- Calibration targets are crucial for accurate microwave radiometry.
- Temperature gradients are a common source for calibration errors (e.g. SSMI calibration anomalies).
- Low S11 is a key requirement for spectroscopic observations.
- Conical and wedged targets can provide lower S11 and temperature gradients than standard pyramidal targets.
- Performance can be optimized with multilayer designs, but this requires detailed knowledge of the absorber properties.

Acknowledgements

- **ALMA Calibration Targets**
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  European Space Agency
  Peter de Maagt