STEAM-R
a multi-beam limb sounder

Matthias Renker, A. Murk, H. Kim, M. Whale

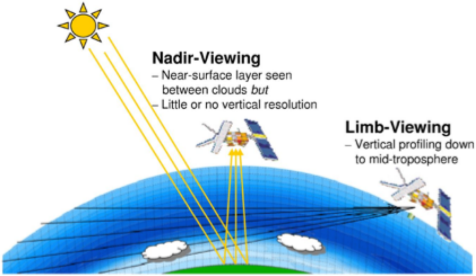
NDACC Workshop 2013

UNIVERSITÄT
BERN

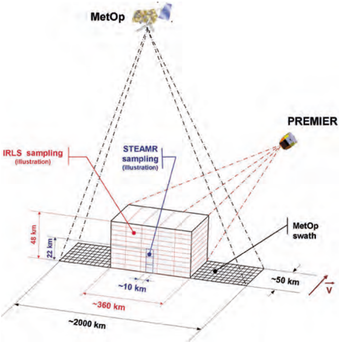
Agenda

Introduction ESA PREMIER mission

- PREMIER: one of three candidate missions for the next ESA Earth Explorer Mission



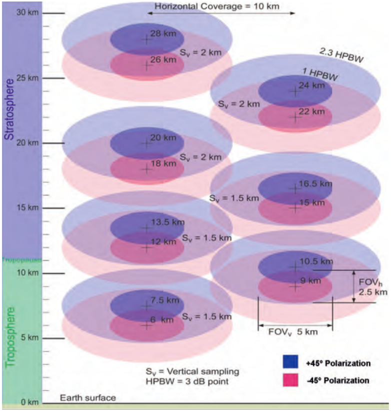
Nadir- and Limb-sounding synergy



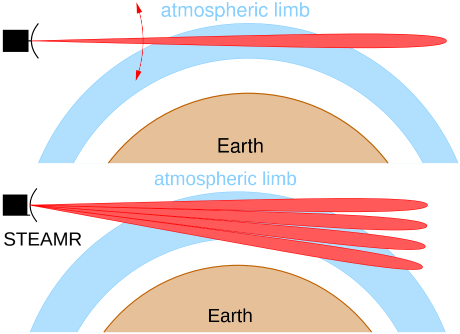
PREMIER observation principle showing IRLS and STEAMR limb-viewing arrays in conjunction with MetOp nadir-sounders.

STEAMR Instrument on PREMIER

- Multi beam limb sounder for atmospheric research
- Measures in 2 frequencies bands from 323-355 GHz
- Utilizes staring concept with 14 beams
- Provides improved spatial and temporal resolution
- Two sets of seven beams with ±45° polarisation



STEAMR field of view geometry



Scanning limb- and STEAMR limb-view

Main Antenna Optics

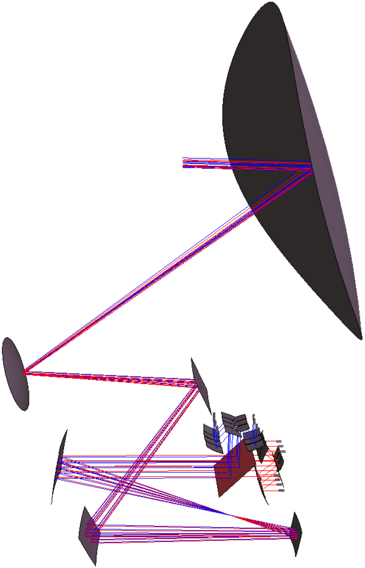
Requirements

- Beams amplitude profiles have to be made circular
- Match Guoy phase shifts for azimuth and elevation
- Ensure $(n + 1/2)\pi$ phase shift from sky to feed horns
- Frequency independent design
- Minimise FPA dimensions
- Ensure $n\pi$ phase shift from sky to FPA for best beam separation
  - However, must allow for minimum 20mm separation between feed horns for mixers

Antenna Optics Design

We use GRASP antenna software with PO/PTD algorithms and MoM solver

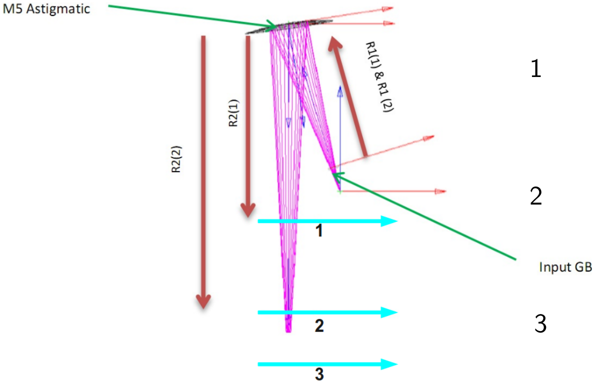
- Require definition of astigmatic reflectors in GRASP
- Allow both PO&PTD calculations and ray-tracing
- Matlab generated tabulated surfaces for GRASP



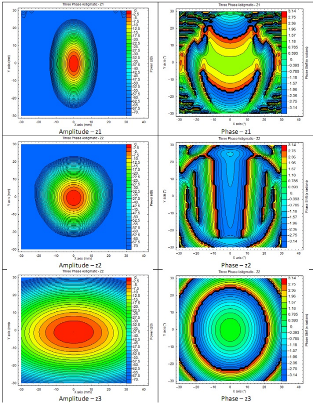
'Astigmatic' Reflectors

- Two types of astigmatic reflectors:
  - Three phase - images circular to elliptical amplitude profiles
  - Four phase (or full astigmatic) - images elliptical to elliptical

Example

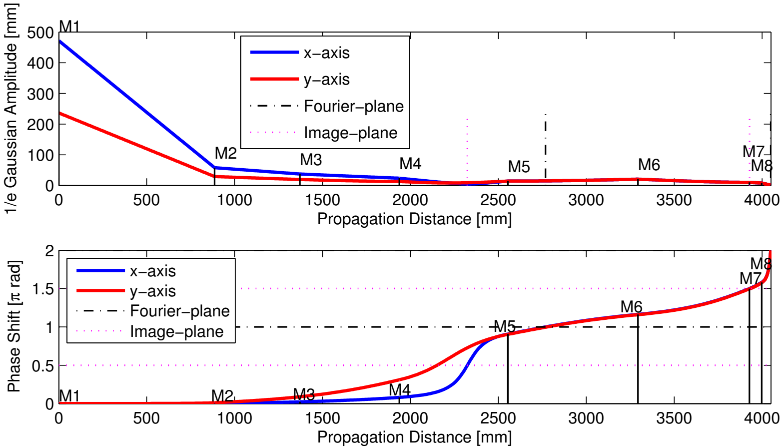


3-phase astigmatic reflector geometry



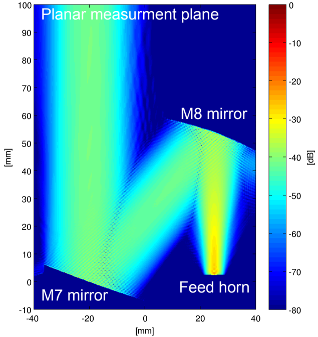
amplitude/phase patterns at key locations

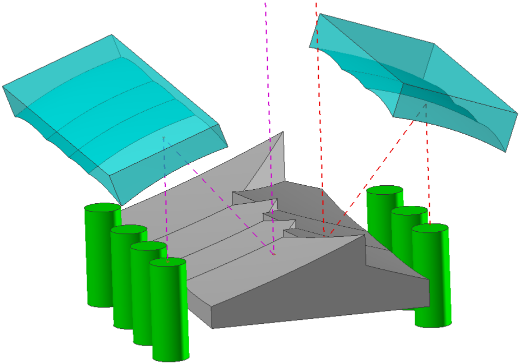
Antenna Optics Design & Optimisation



Top: GB Amplitude radii for STEAMR optics - Az & El
Bottom: GB Guoy phase shift for STEAMR optics - Az & El

Focal Plane Array - Baseline





Goals for a Focal Plane Array (FPA):

- Monolithic facet reflector design → high accuracy & exact pointing
- Reflector rim optimization for minimal diffraction
- Separate beams in image plane
- Ensure $1/2\pi$ phase shift between M7 and feed for frequency independents

PO/PTD and Method of Moments

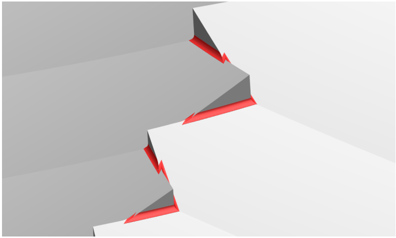
- Requires difficult procedure of surface meshing
- Model minimal milling radius of 1.3mm $\equiv 1.45\lambda$

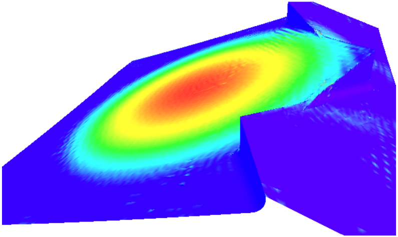
Advantages over PO/PTD are:

- Possible to analyze complex surfaces
- Scatterers in a cluster are modeled as being connected
- Includes all physical effects such as shadowing and mutual coupling

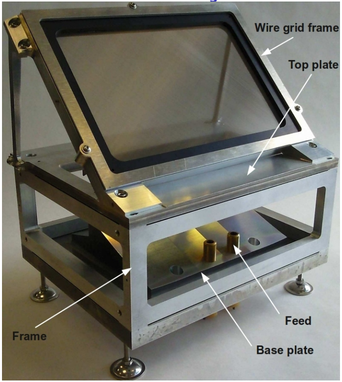
Disadvantages over PO/PTD are:

- Needs excessive memory

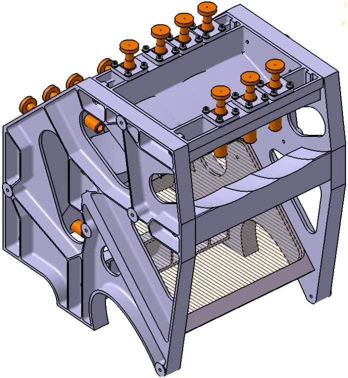




Focal Plane Array - Breadboard



Breadboard FPA with WG & 7 beams



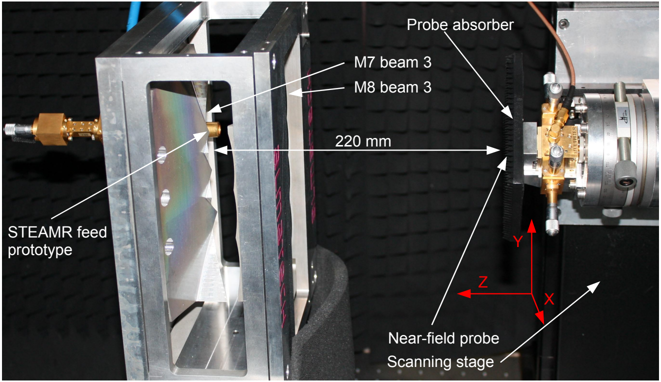
Flight-hardware FPA study with WG & 7 beams in transmission & 7 beams in reflexion

For maximal accuracy:

- Breadboard - four principal elements
  - Base plate - first facet reflectors (M7) and feed horn mounting
  - Connecting frame
  - Top plate - second facet reflectors (M8)
  - Wire grid frame - Wire grid (WG) polariser

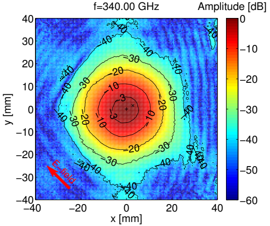
FPA near field antenna measurements

- submillimetre optical test bench with Vector Network Analyzer
- planar x-y and rotation scanning stages

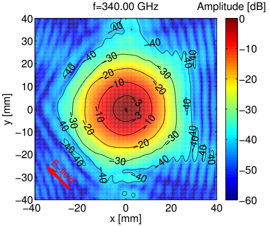


Simulation and measurement comparison

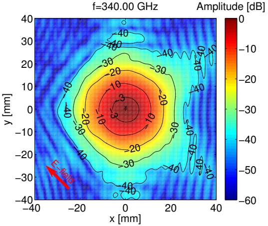
Planar measurement plane in the near field (z=220mm)



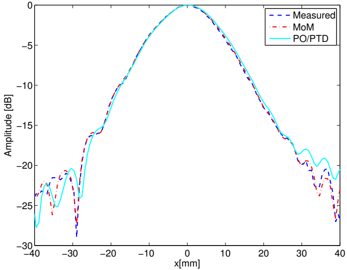
Near-field measurements



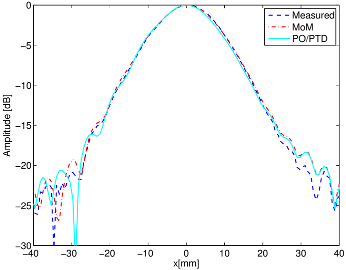
MoM simulation



PO/PTD simulation



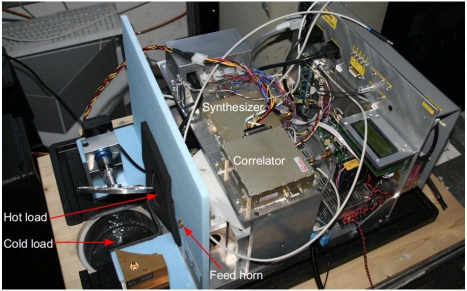
E-plane cut



H-plane cut

Test-bed on JFJ and receiver architecture

Top view of the receiver test-bed

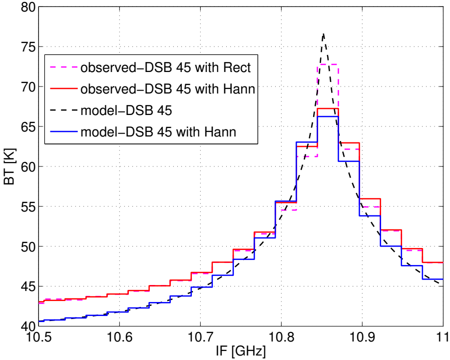


- DSB from Omnisys with 2000K system noise temperature (new version coming)
- SSB Sub-Harmonic Image-Rejection Mixer (SHIRM) from RAL version 1
- SSB Sub-Harmonic Image-Rejection Mixer (SHIRM) from RAL version 3
- Auto-correlator spectrometer with tunable internal LO and resolution
- Tunable LO synthesizer

Modelled spectra data reduction for comparison with observation

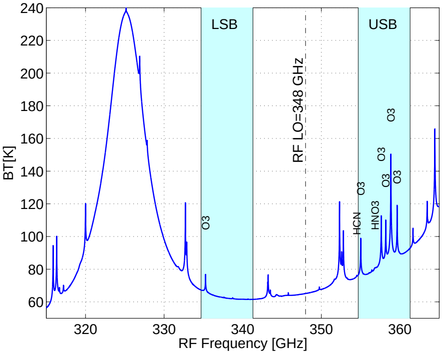
Accurate comparison of modelled and observe spectra needs convolution of modelled spectra with:

- channel response of each spectrometer channel $sin(x)/x$
- filter characteristic (Rectangular, Hanning..)

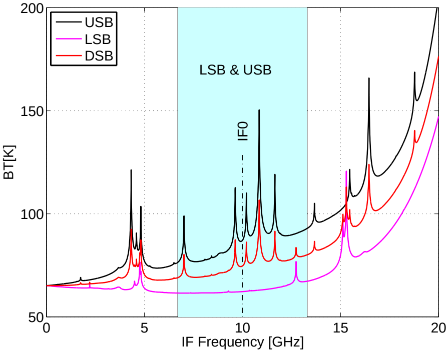


Modeled/observed DSB O_3 spectral line at 358.85 GHz (view angle 45°) with stairstep graphs with 256 channels spectra with rectangular and Hanning windowing

First-light observation with DSB receiver

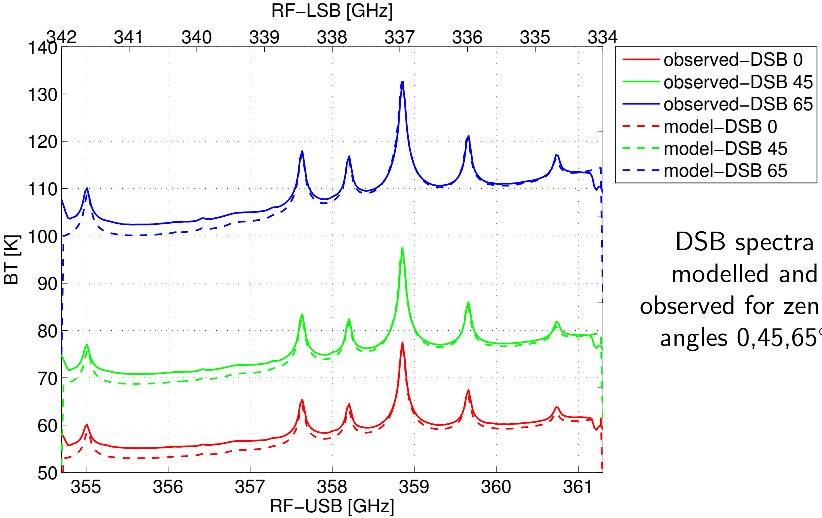


Modelled spectra over the observable bandwidth



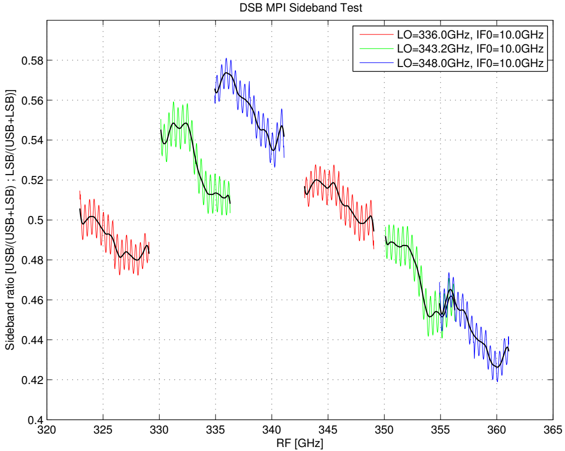
Down-converted spectra

First-light observation with DSB receiver



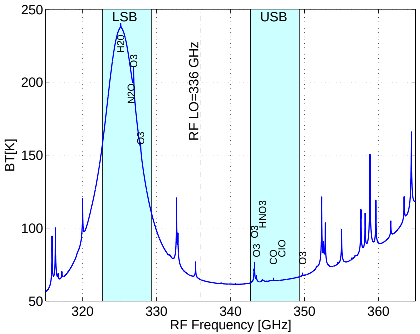
DSB spectra modelled and observed for zenith angles 0,45,65°

DSB sideband ratio

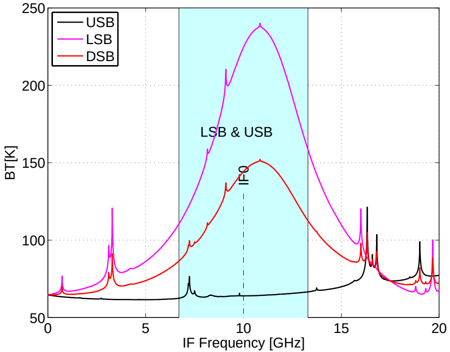


DSB sideband ratio measurement for LO set to: 336, 343.2, 348 GHz
(black line: lowpass filtered)

First-light observation with SSB receiver

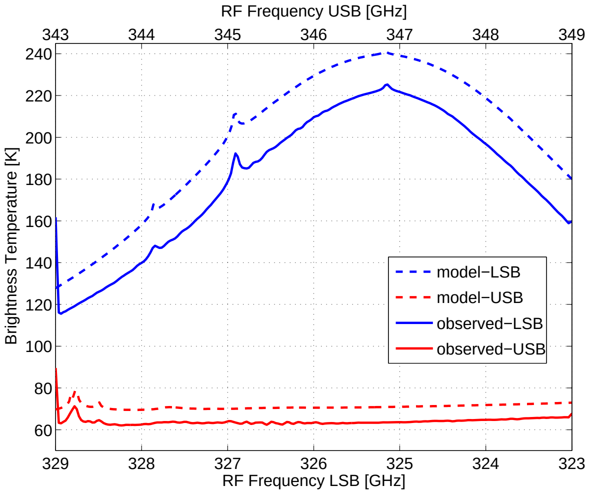


Modelled spectra over the observable bandwidth



Down-converted spectra

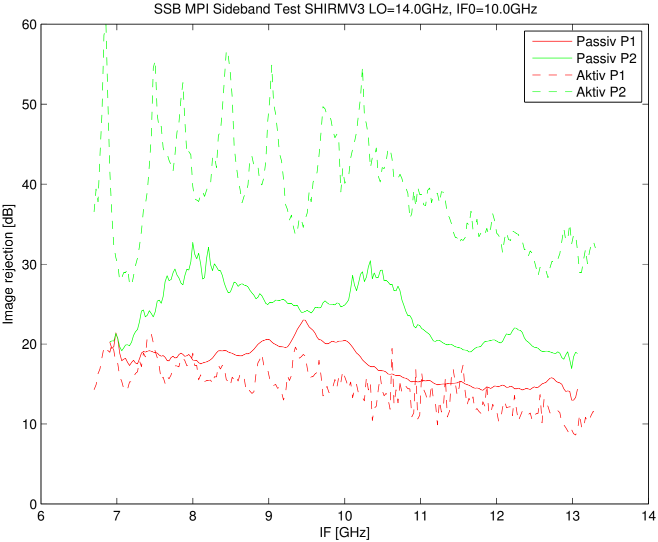
First-light observation with SSB receiver



SSB SHIRM V3 receiver model for zenith angles 45°

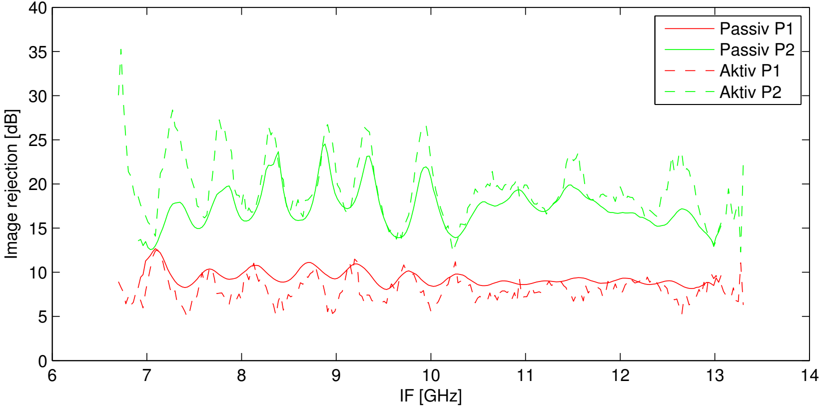
H20 line dominating LSB and no H20 breakthrough in USB
Evidence of ripple in spectrum

Sideband rejection measurements with SSB receiver



SHIRM V3 active and passive image rejection measurements
(LO: 14.0 GHz, IF0:10 GHz)

Sideband rejection measurements with SSB receiver



SHIRM V1 active and passive image rejection measurements
(LO: 14.3 GHz, IF0:10 GHz)

Future work

Mission selection: Spring 2013

- **Biomass** (forest biomass to assess terrestrial carbon stocks and fluxes)
- **CoReH2O** (snow, glaciers and surface water)
- **PREMIER** (processes that link trace gases, radiation and chemistry in the UTLS)

Ongoing work at IAP:

- New atmospheric campaign with improved DSB receivers and two auto-correlators to cover 11.6 GHz of bandwidth
- Ongoing analysis of nonlinearities in receivers by comparing lab- and atmospheric measurements
- Sideband-ratio dependencies on temperature
- Sideband-ratio dependencies on LO-power

Thank you for your attention

Questions