Millimetre Wave Technologies for STEAM-R

Simon Rea[1]*, B. Alderman[1], B. Moyna[1], G. Maxwell-Cox[2], R. Hammett[2], A. Dawkins[2], Y. Munro[2]

[1]Millimetre Technology Group, STFC RAL Space, Didcot, UK, OX11 0QX
[2]Astrium Ltd, Anchorage Road, Portsmouth, PO3 5PU

PREMIER & STEAM-R (1)

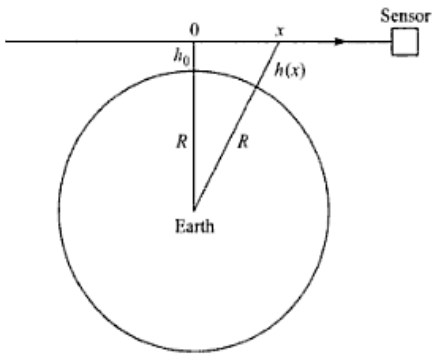
- PREMIER is a candidate Earth Explorer 7 mission
  - *PRocess Exploration through Measurements of Infra-red and millimetre wave Emitted Radiation*
  - *Focussing on Upper Troposphere / Lower Stratosphere region*

- Synergistic deployment of Infra-red and Millimetre wave instruments on same satellite platform

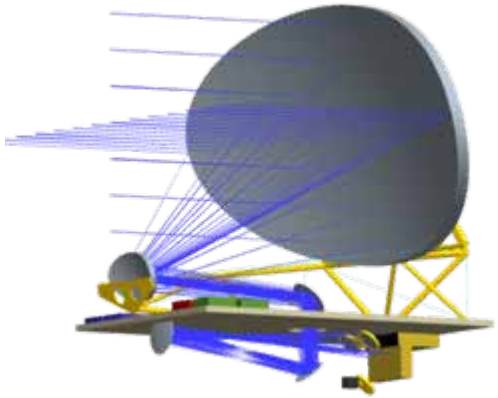
- Millimetre wave instrument is STEAM-R
  - *Stratospheric Tropospheric Exchange And Monitor Radiometer*
  - *Swedish led instrument based on ODIN*
  - *Provides trace gas measurements in the presence of cirrus cloud & deep into the upper troposphere (H_2O, CO, O_3, N_2O, ….)*

PREMIER & STEAM-R (2)

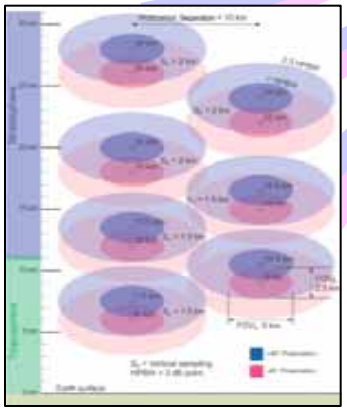
- Characteristics of STEAM-R
  - *Spectral range 310-360 GHz*
  - *Limb-sounding geometry for high vertical resolution*
  - *Large reflector (1.6m × 0.8m) for narrow FOV*
  - *Fixed receiver array for 14 simultaneous views through the UTLS region*
  - *Use of image-rejection mixers to improve measurements of trace gases in the upper troposphere*



Limb-sounding Geometry



STEAM-R



STEAM-R viewing geometry

Overview of CEOI STEAM-R Activities

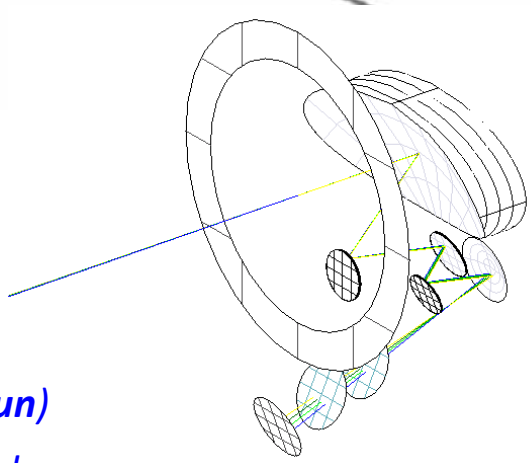
- Science support
  - *Consolidation of science case for PREMIER / STEAM-R*
  - *STEAM-R optimisation for upper tropospheric observations*
  - *Refinement of STEAM-R frequency plan*

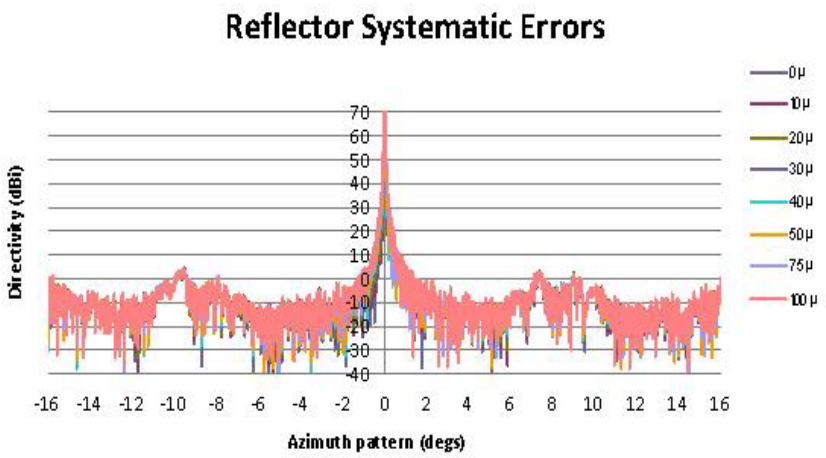
- Critical hardware analysis and development
  - *Fore-Optics analysis*
    - *Design & error analysis of dual-reflector antenna sub-system*
    - *Definition and breadboarding of optics concepts for close stacking of multiple beams*
  - *Sub-Harmonic Image-Rejection Mixer (SHIRM) development*
    - *First demonstration of 340 GHz image-rejection mixer using Schottky diodes*

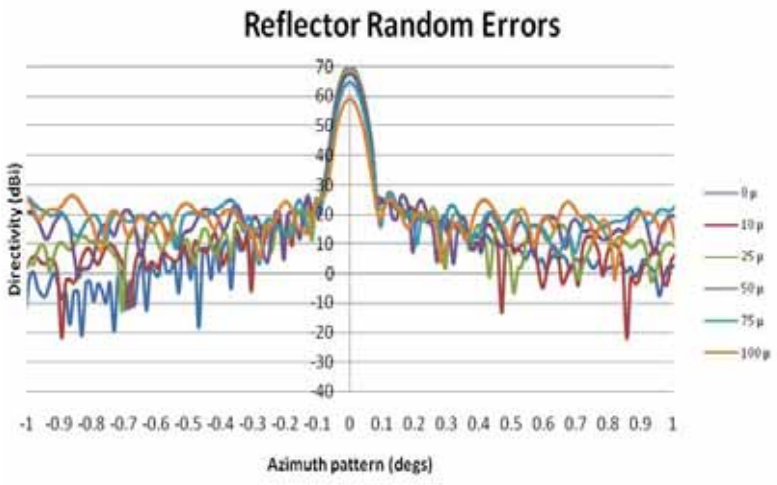
Fore-Optics Analysis (1)

Advanced error analysis on STEAM-R primary reflector

- *Systematic distortions (simulating thermal errors) 15 -100 micron*
- *Random Surface errors (simulating manufacturing errors) 15-100 micron*
- *Physical Optics analysis ±20 deg in patterns (extended SAPIENS software)*
- *Typical scanned off-axis beam patterns analysed (**2hr to 8hr per run**)*
- *Detailed pattern data supplied to RAL for support to Data Retrieval Analysis – PREMIER Study*



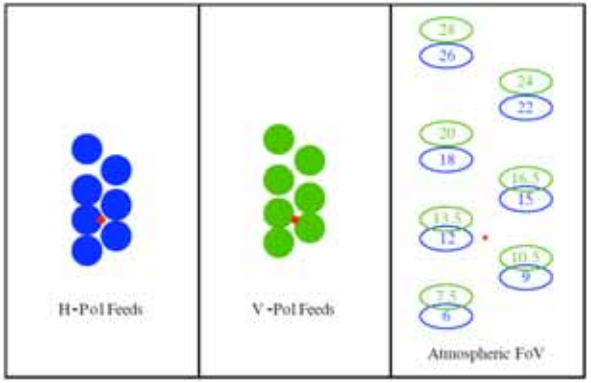




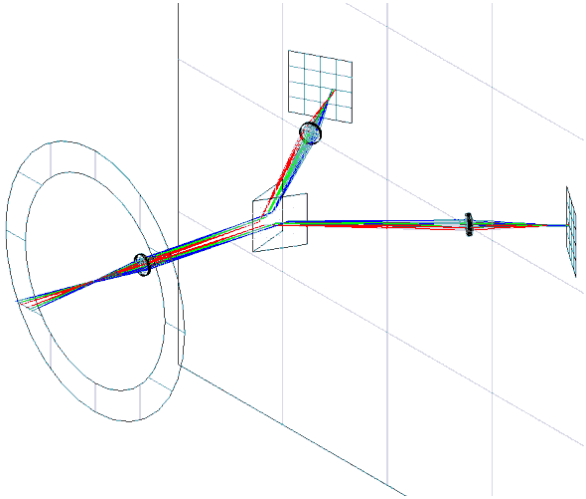
Fore-Optics Analysis (2)

Concepts for close stacking of multiple beams

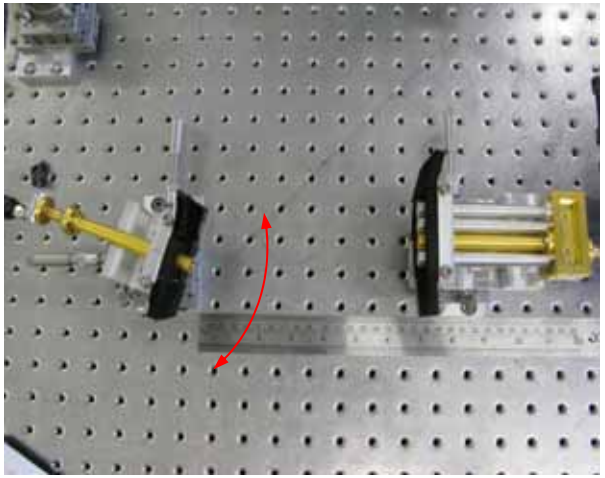
- *Feedhorn cluster*
- *Spatial beam-splitting*
- *Modelled using Beam-Propagation Synthesis (Code-V) & Ray Tracing (Zemax)*
- *Breadboard developed to corroborate modelled results*



Feed cluster



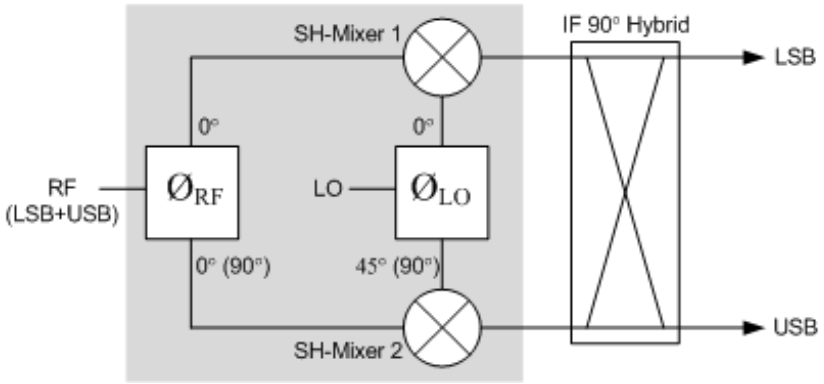
Spatial beam splitting



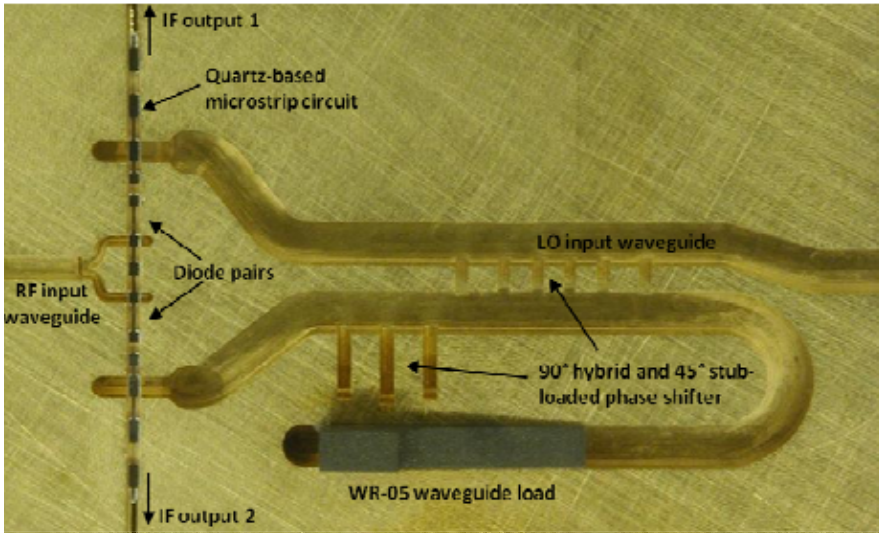
Optics breadboarding

SHIRM Development (1)

- *Development & comparison of two SHIRM topologies*
- *Development of highly-integrated IQ mixer blocks for each topology (shaded)*
- *SHIRM completed by commercial IF hybrid (connectorised)*
- *Requirements: high level of sideband rejection, low SSB receiver noise temperature*



SHIRM Architecture

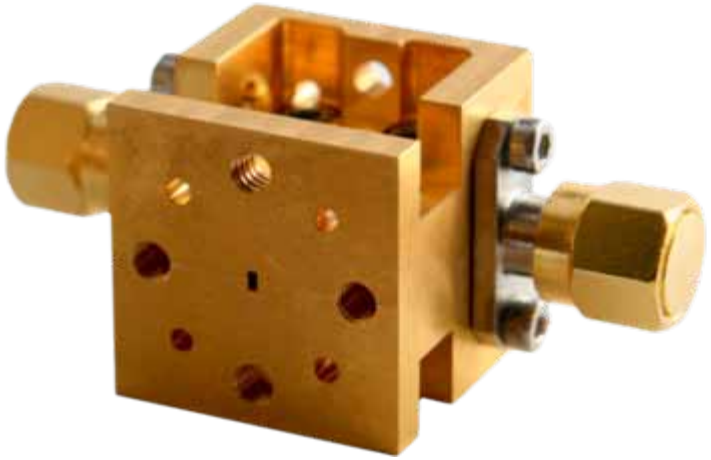


SHIRM A: Internal Detail

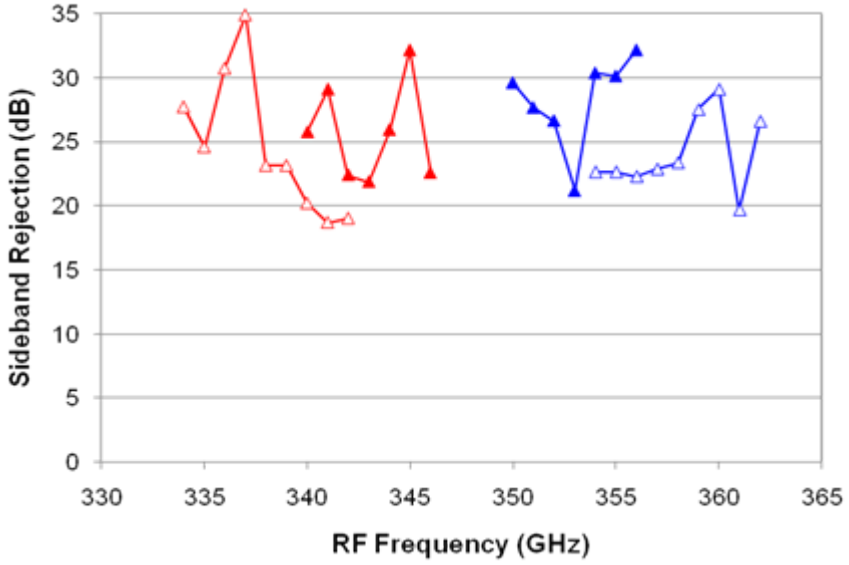
SHIRM Development (2)

Demonstrated Performance

- *Sideband Rejection*
  - *SHIRM A: >20 dB (IF bandwidth 2-14 GHz)*
  - *SHIRM B: >15 dB (IF bandwidth 2-14 GHz)*
- *SSB Receiver noise temperature*
  - *3000 K (T_{IF}=70 K)*



SHIRM Block



SHIRM A: Measured Sideband Rejection

Current Work

- SHIRM development continues in CEOI 4th Open Call
- SHIRM qualification to TRL-5
  - *Must be demonstrated by end of PREMIER Phase A study (ESA)*
  - *New SHIRM design to pass environmental testing*
  - *Environmental testing (vibration/shock, thermal vac, humidity)*
    - *Exact test specifications TBC*
- First spectral measurements
  - *Lab gas cell tests or atmospheric tests at Jungfraujoch observatory*
    - *Development of SHIRM-based radiometer*
    - *Confirmation of SHIRM performance through spectral measurements*
    - *DSB v SSB spectral measurements*