INSTRUMENT ARCHITECTURE:

MARSCHALS
MILLIMETRE WAVE LIMB SOUNDER

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Millimetre Technology Group, RAL Space
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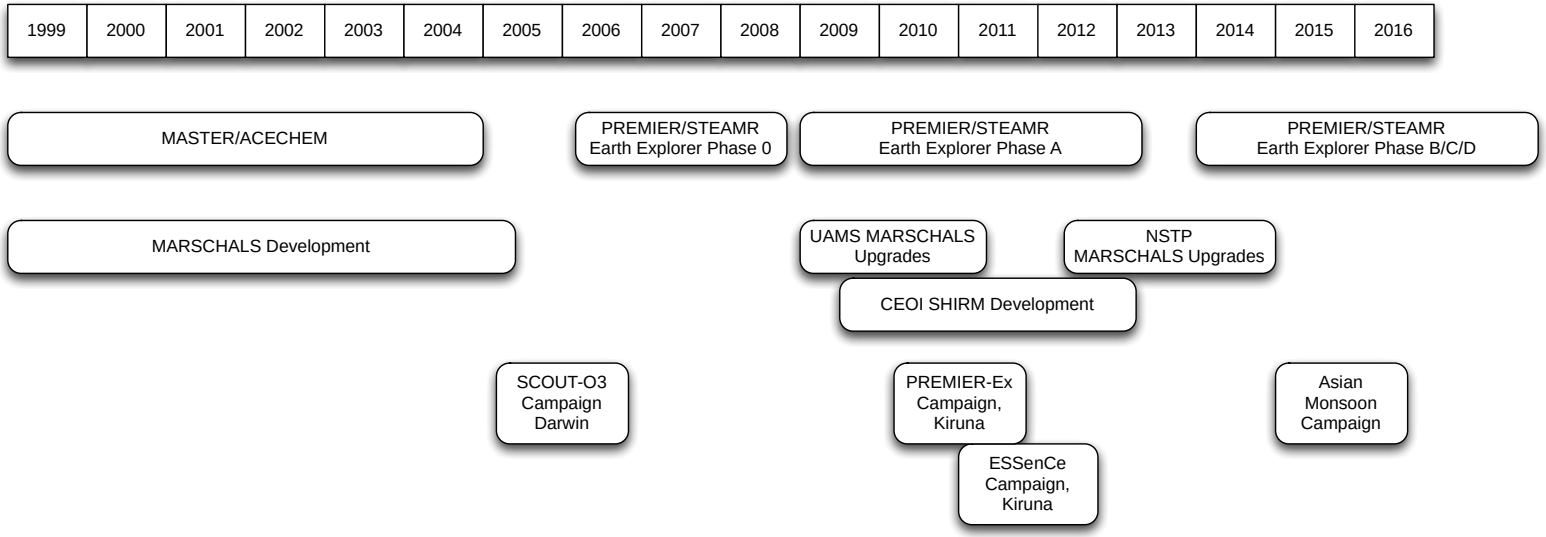
Outline

- Definition
- History
- Original instrument
- SCOUT-O3
- UAMS
- PREMIER-Ex, ESSenCe
- Future: NSTP, SHIRM, Spectrometer, Pointing, Future campaigns

MARSCHALS

- Millimetre-wave Airborne Receiver for Spectroscopic CHaracterisation of Atmospheric Limb-Sounding
  - Conceived as an airborne simulator of the MASTER[1] instrument, onboard the proposed ACECHEM[2] Earth Explorer Core mission. Funded by ESA
  - Now deployed as a demonstrator for STEAMR onboard PREMIER, an Earth Explorer 7 candidate mission



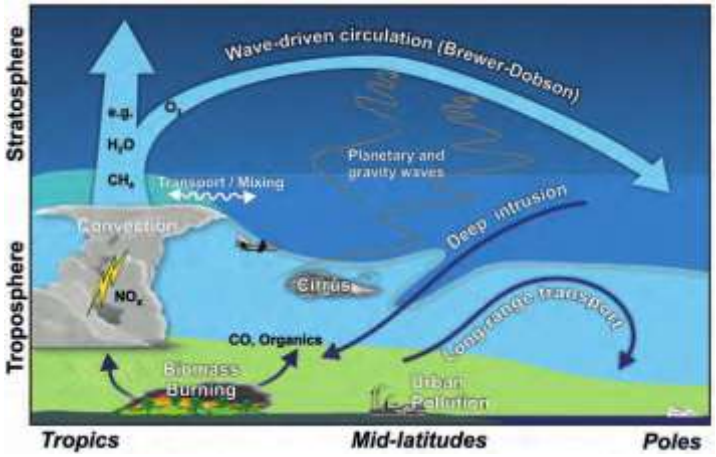
[1] Millimetre- wave Acquisitions for Stratosphere Troposphere Exchange Research

[2] Atmospheric Composition Explorer for CHEMistry and climate interactions

Key Performance Specifications

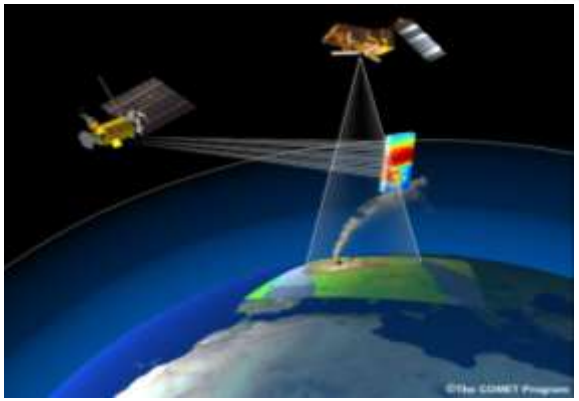
- Instrument Type Total Power Single Sideband Radiometer
- RF target bands
  - Band B 294 – 305.5 GHz (O_3)
  - Band C 316.5 – 325.5 GHz (H_2O)
  - Band D 342.2 – 348.8 GHz (CO)
- Instantaneous bandwidth 12 GHz @ 200 MHz resolution
- NET (250ms)
  - Target 1K
- Sideband Rejection > 30dB
- Beam Width 0.34˚ HPBW (2 km at 10 km tangent height)
- Beam Pointing <<0.0025 deg. rms knowledge during scan, bias excepted
- Scan range Tangent heights from –2km to platform altitude (21km on aircraft) in 1 km steps with +20˚ “space view”

PREMIER – Limb Imaging of UTLS

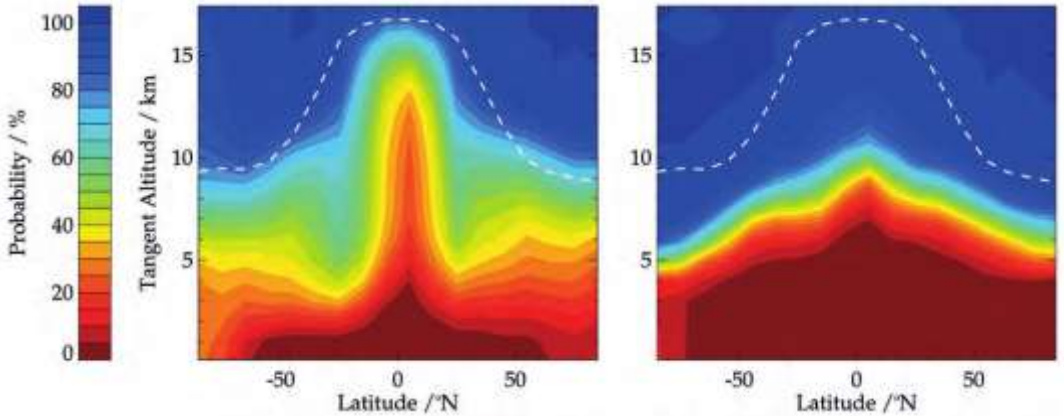


The global structure of the troposphere and lower stratosphere.

(P. Preusse)



Limb vs Nadir Sounding



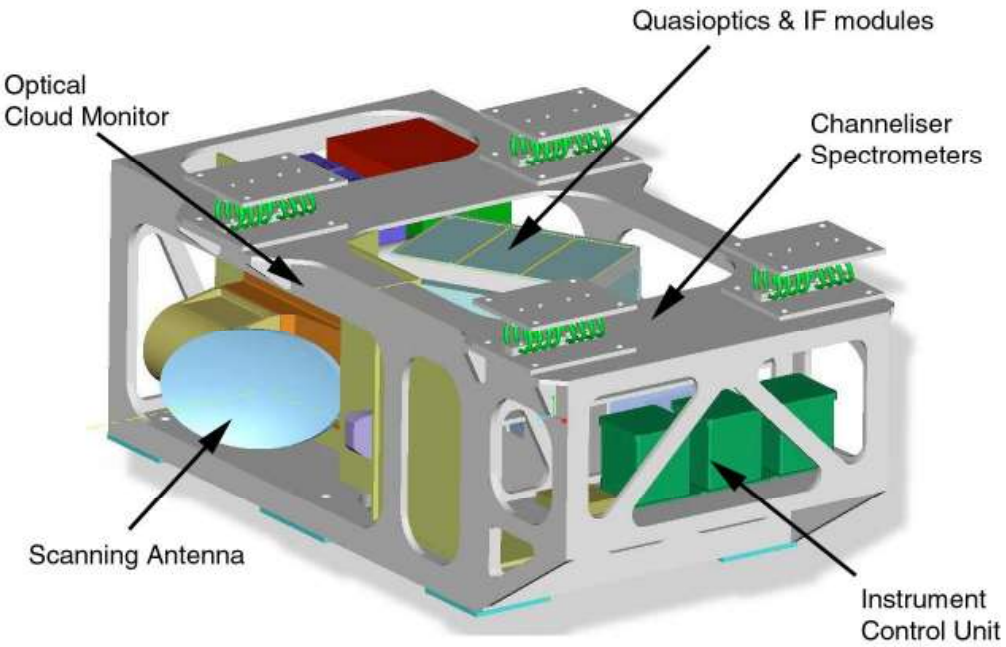
Comparison of limb transparency in PREMIER 12µm infrared (left) and 1mm mm-wave (right) atmospheric windows.

Annual-mean probabilities of transmittance >20% calculated from ECMWF analyses.

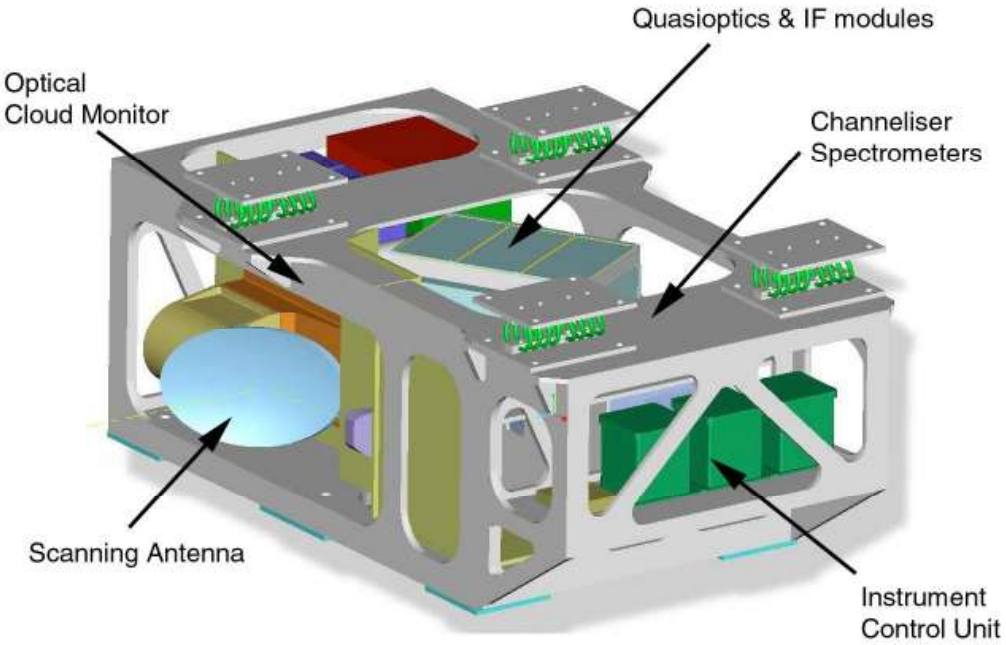
White dashed line indicates tropopause.
(R. Siddans, RAL)

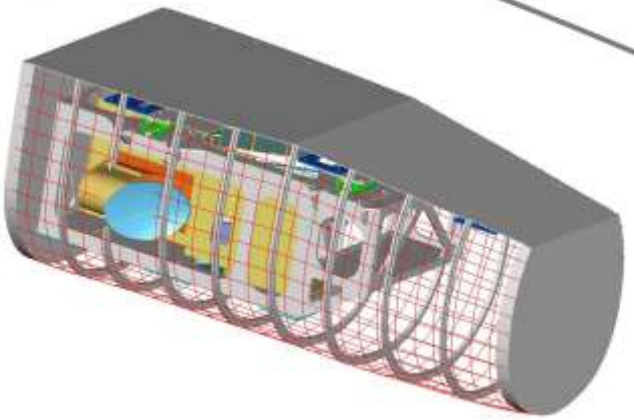
From PREMIER report for Mission Selection

Instrument Configuration

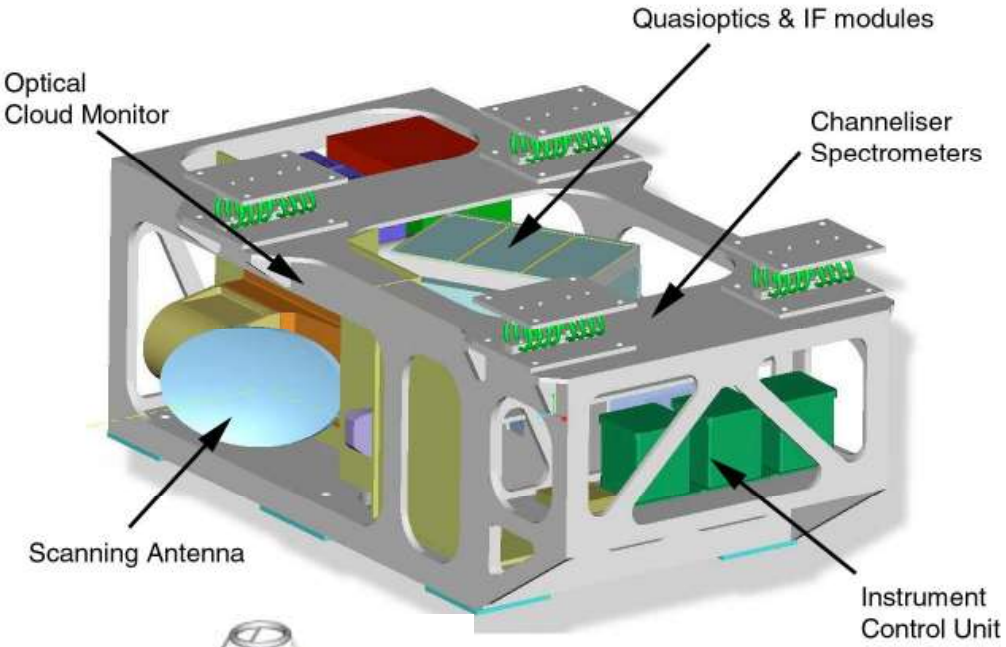


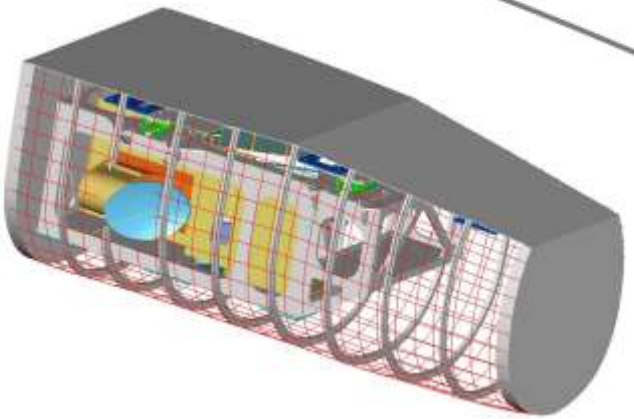
Instrument Configuration - aircraft

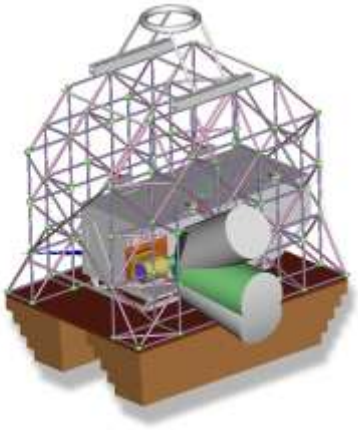




Instrument Configuration - aircraft (& balloon)







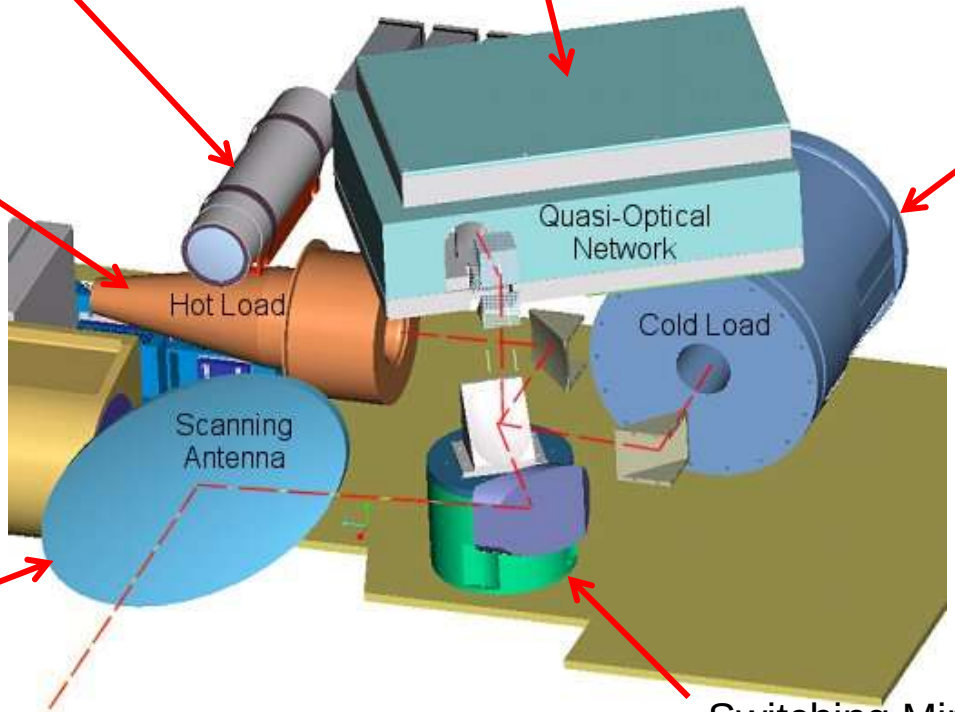
Key Elements

NIR (850nm)
Optical Cloud Monitor

Quasi-Optics Module
- SSB heterodyne receivers
- (ambient, Schottky diode)

Ambient Calibration
Load @ 300K

Cold Calibration
Load @ 86K



235mm scanning
Antenna
(LoS corrected by
Onboard IMU)
0.34˚ HPBW (2 km at 10 km tangent height)

Switching Mirror
50ms switching,
0.1˚ repeatability

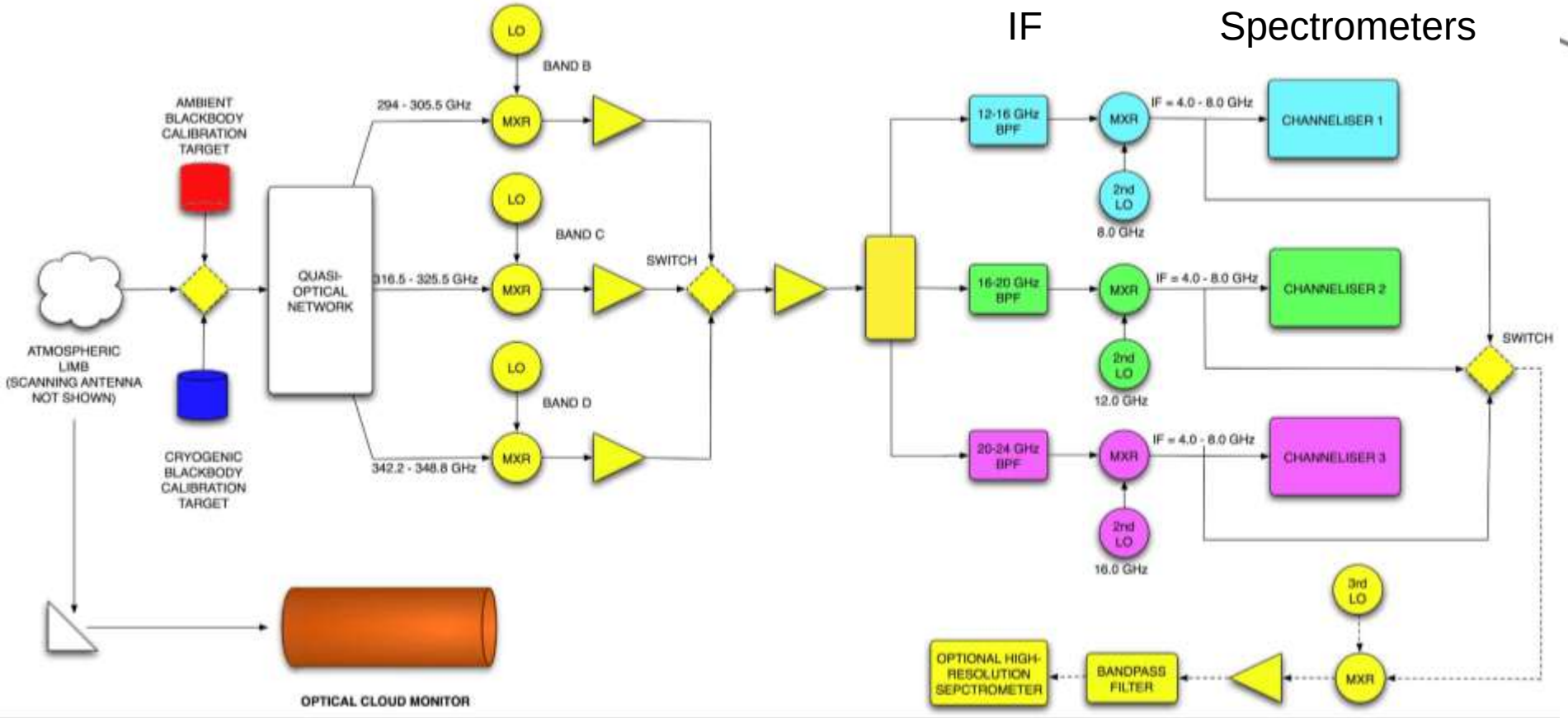
Instrument Schematic

Antenna/calibration

Mm-wave Receivers

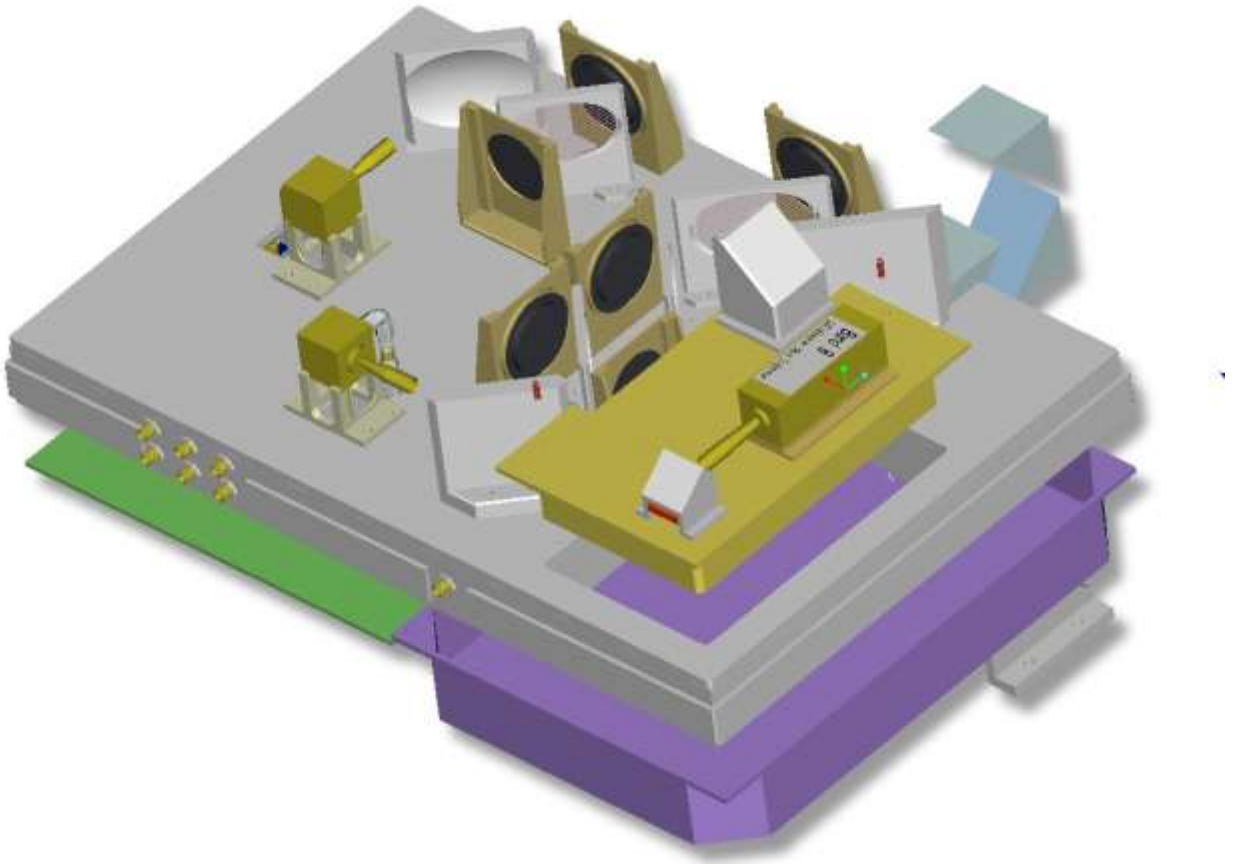
IF

Spectrometers

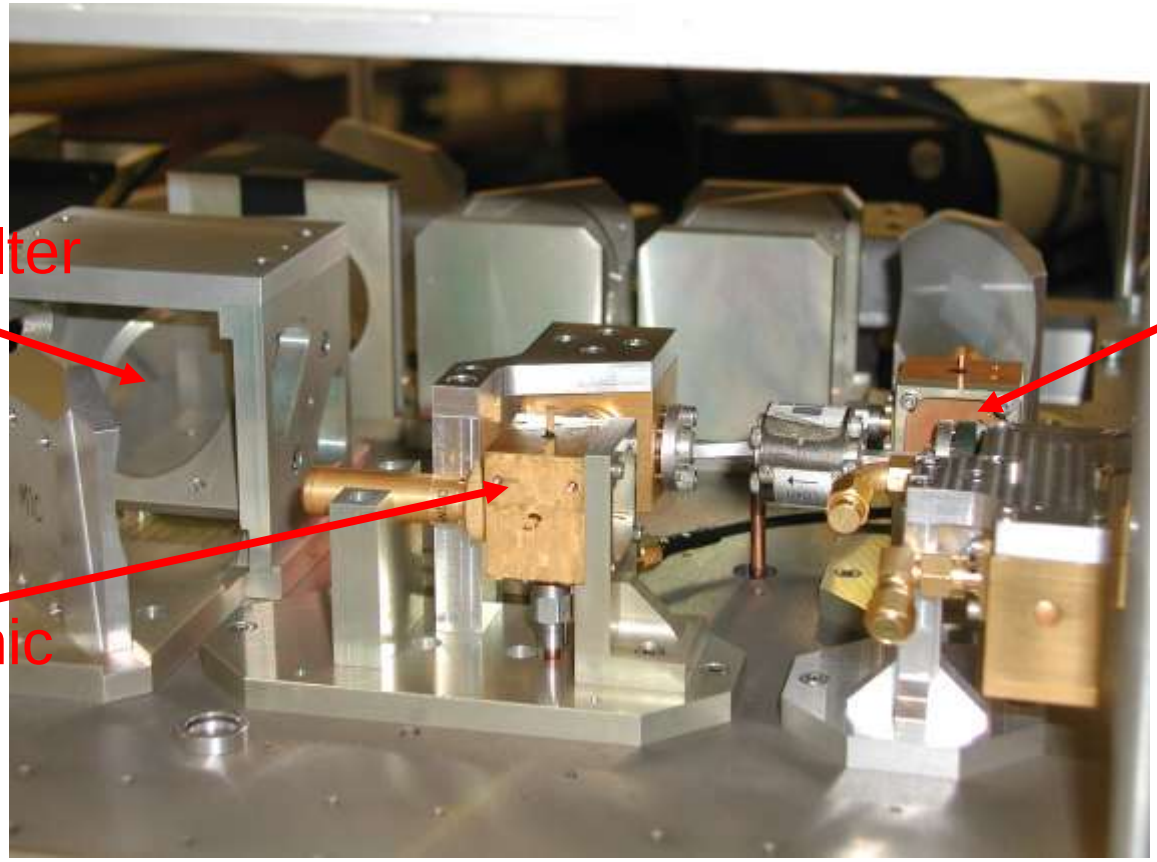


Optional High-res Spectrometer

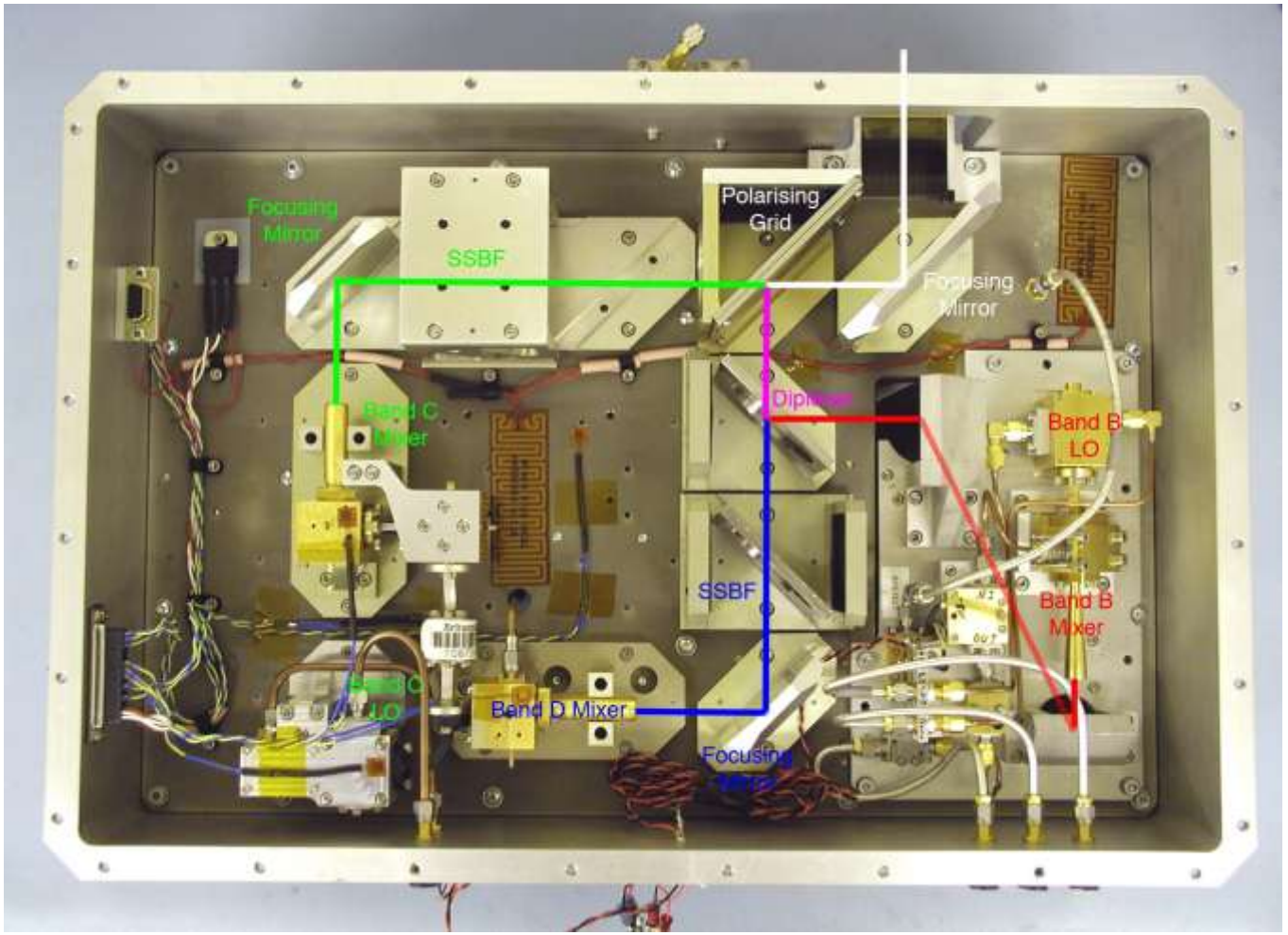
Quasioptics Module



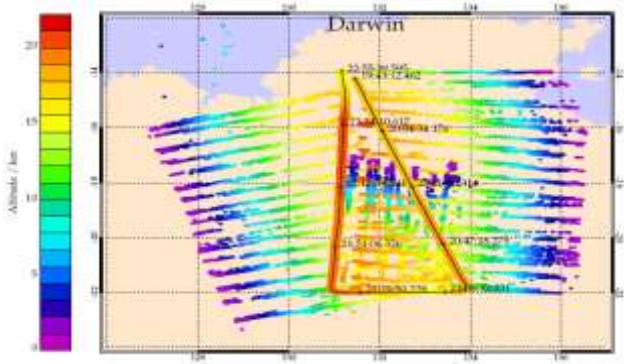
MARSCHALS Receiver Technology (Original layout c 2005)



Beam Path within QO Module

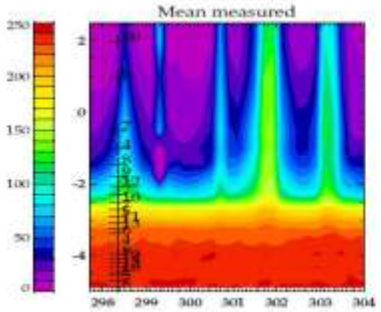


Results from 1st Science Flight SCOUT O3 Darwin Dec 5th 2005

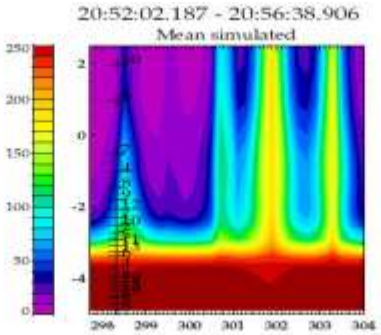


Band B

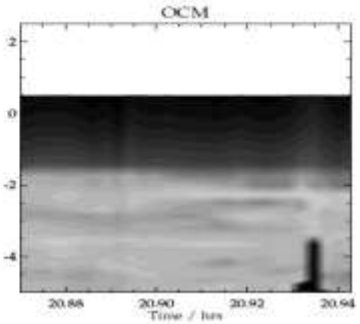
Mean Measured



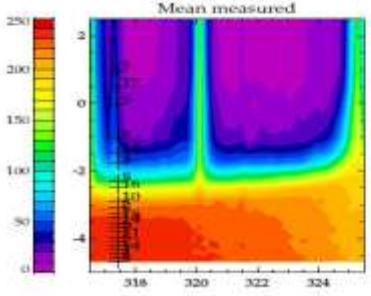
Mean Simulated

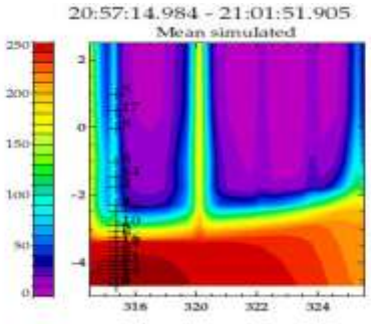


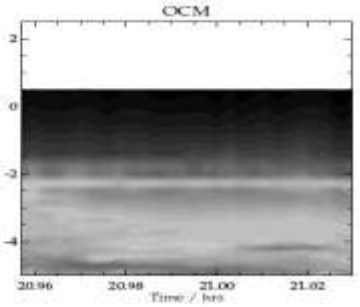
OCM



Band C







Upgrades identified post-Darwin

Analysis of spectra from Scout-O3 flights identified several high priority improvements:

Performance

- Improve receiver noise temperature – reduce NEDT
- Improve antenna pointing accuracy during dynamic flight
- Improve thermal stability
- Improve Cold load – reduce standing waves in spectra

Characterisation

- Finer resolution antenna pattern knowledge
- Finer resolution channel shape knowledge

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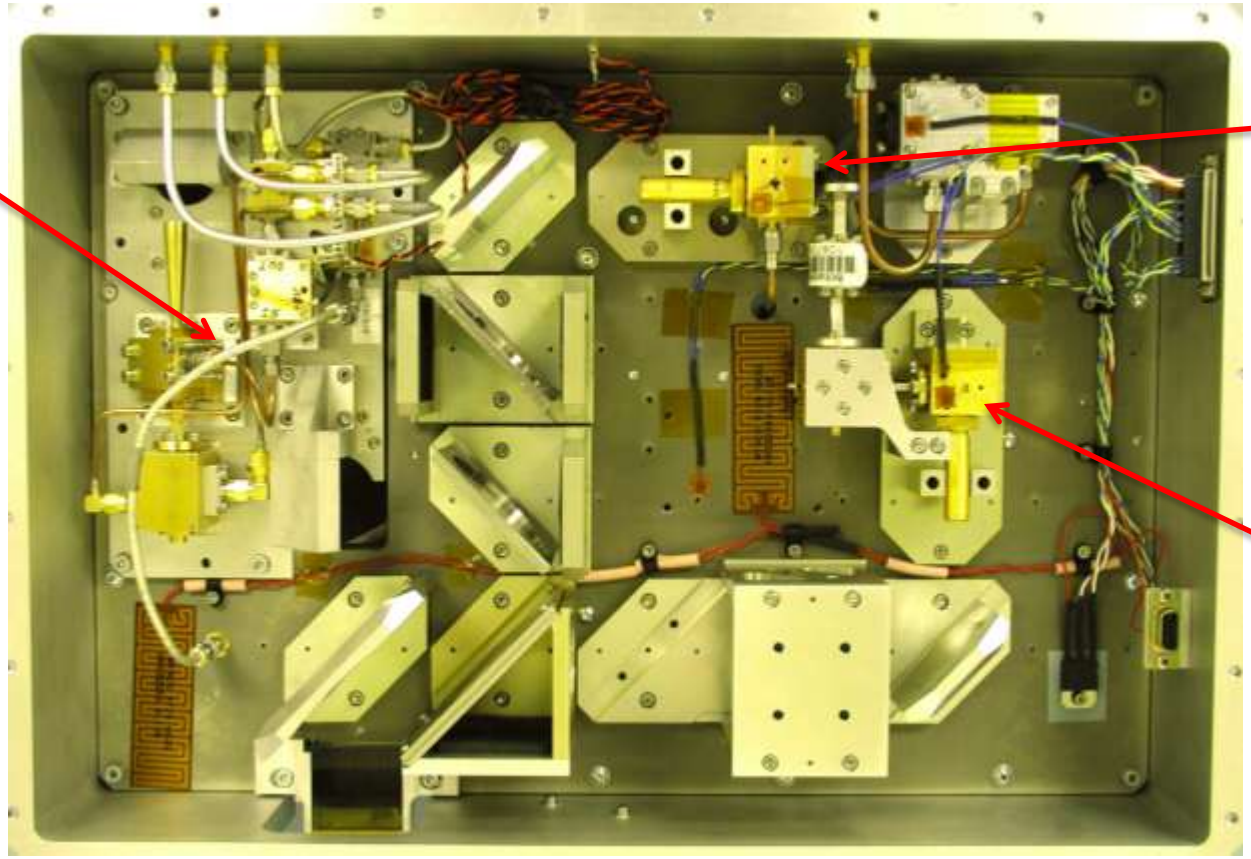
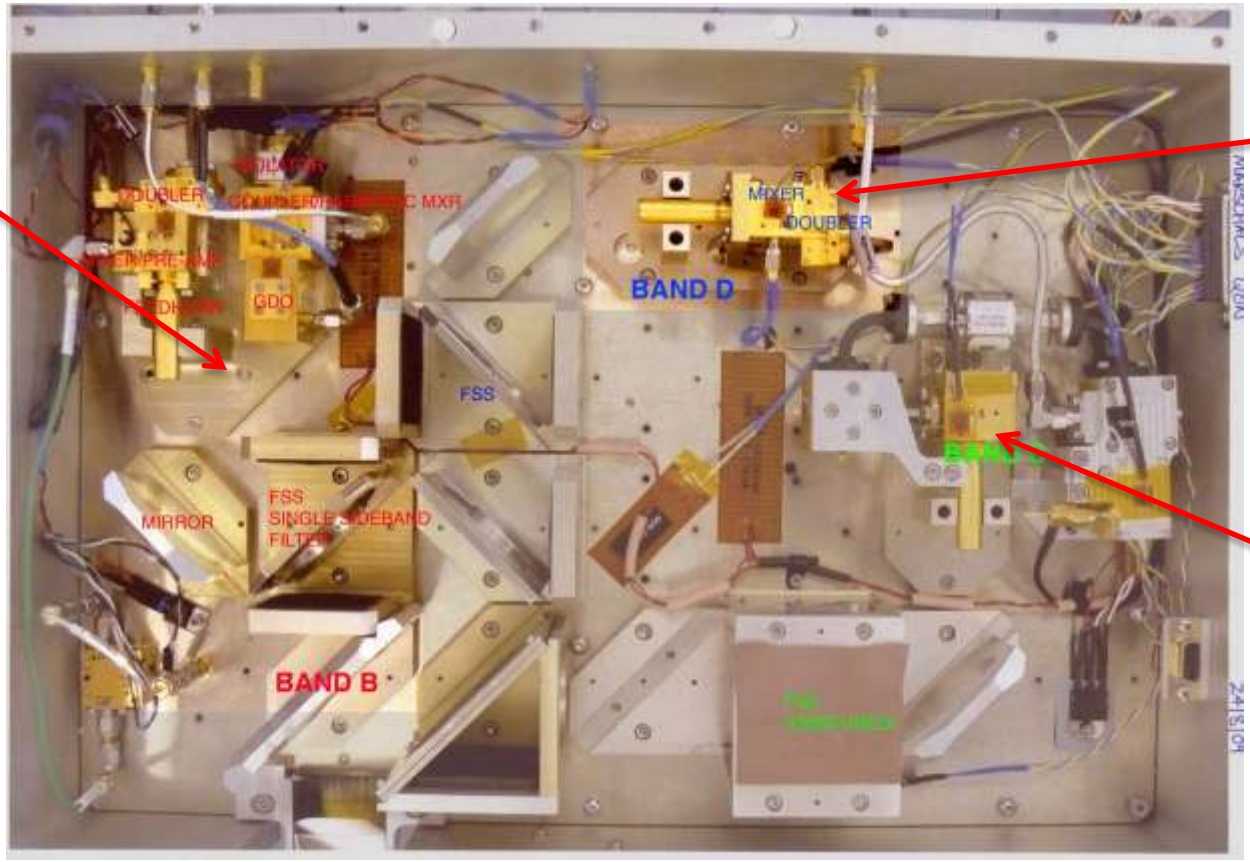
→ **UAMS** – ESA funded programme to upgrade MARSCHALS

QON Pre-Upgrade



QON following Upgrade

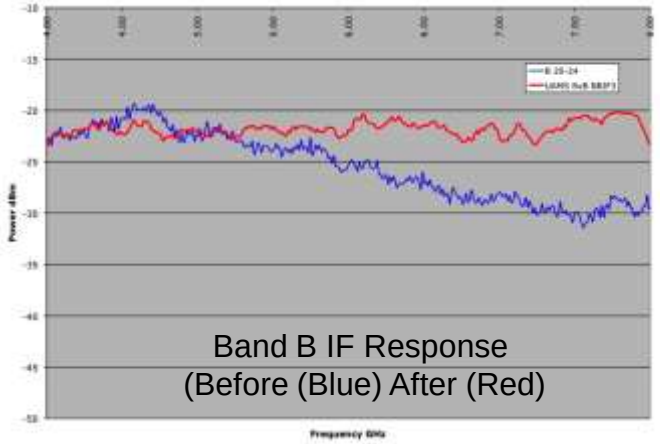
Band B Receiver
All new components



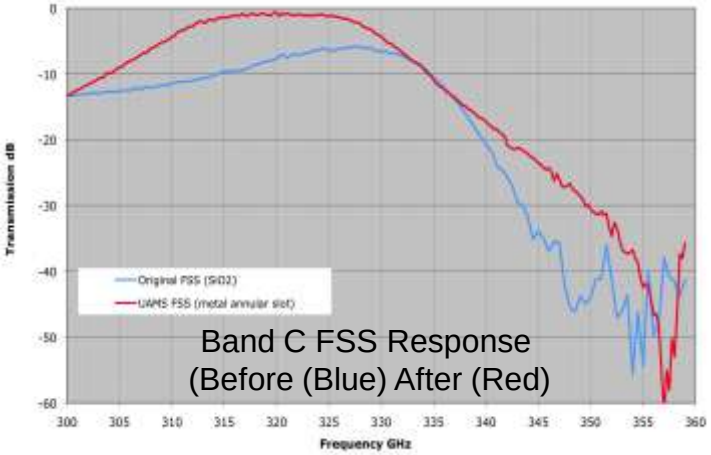
Band D
New mixer
New doubler
New SSB filter

Band C Receiver
New mixer
New doubler
New SSB filter

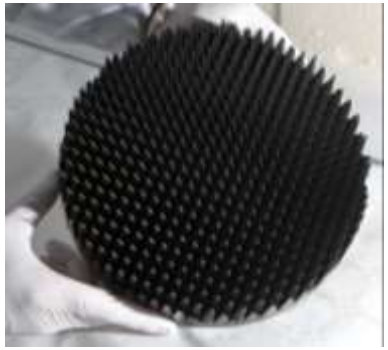
Component upgrades



Flatter IF Response in new Band B Receiver – improved dynamic range



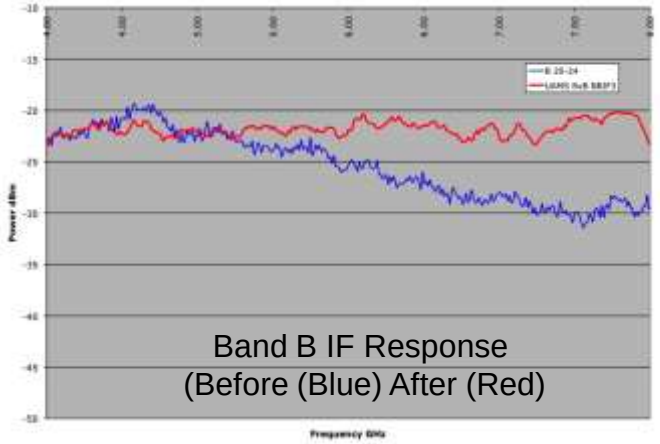
Much lower insertion Loss of Band C & D Sideband Filters – better NEDT (Queen's University, Belfast)



New blackbody target for Cold Calibration Load

- Higher return loss
- Lower standing waves
- Cleaner calibrated spectra

Component upgrades



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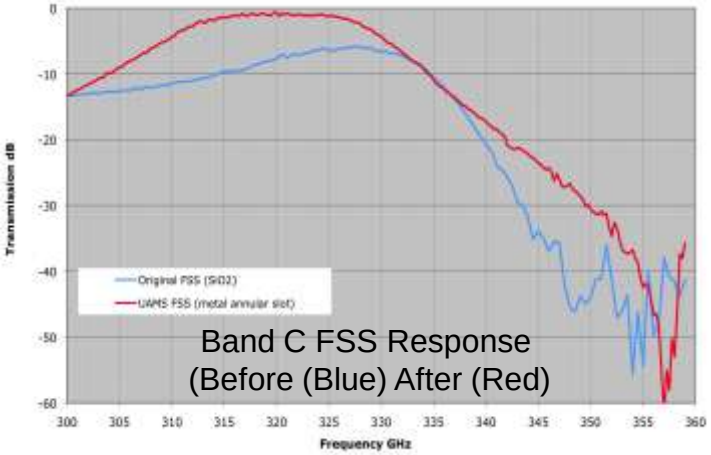

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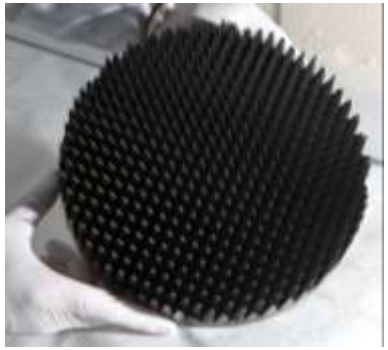

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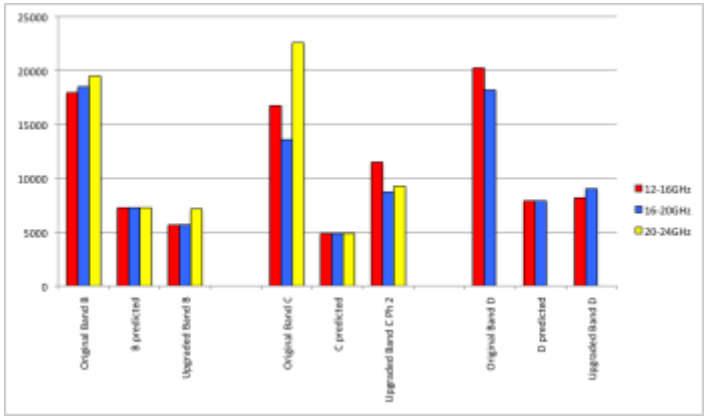
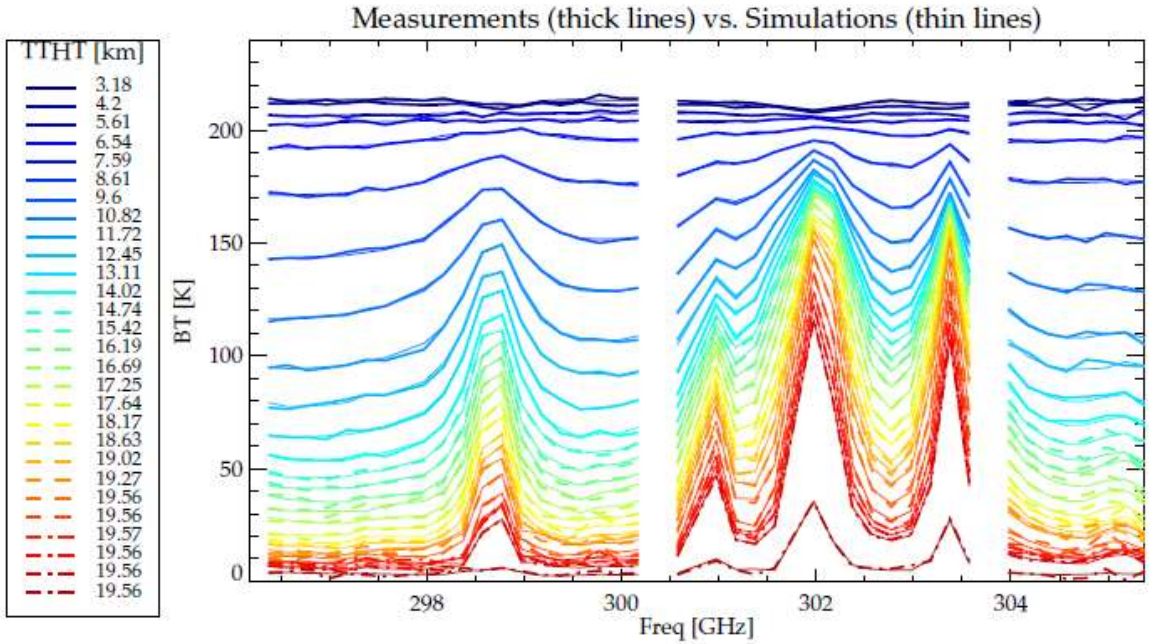
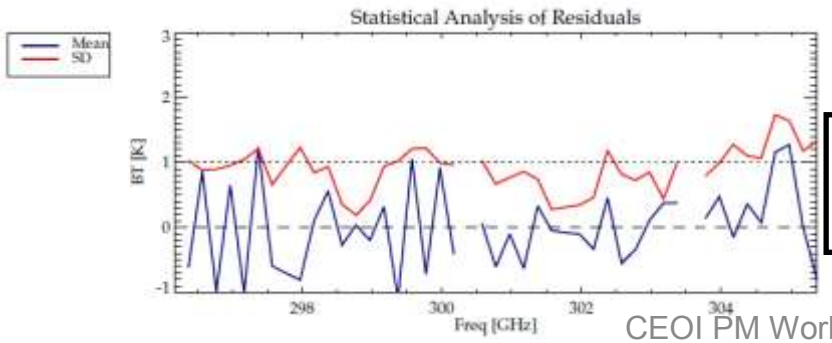


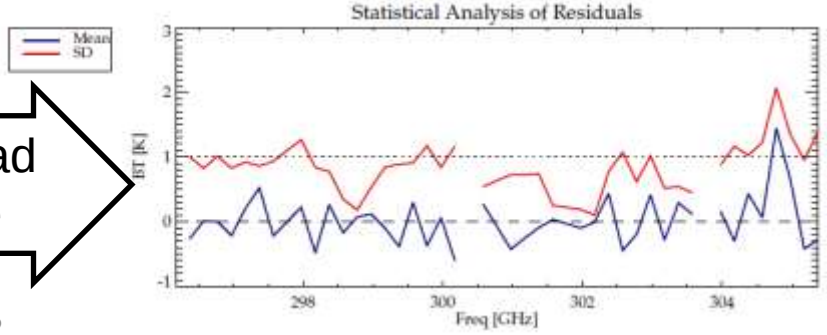
Much improved sensitivity in all bands

Reduced Standing Waves (PREMIER Ex 2010)





Cold Load Upgrade



Improvements in Measurement Performance after UAMS Upgrade

- Lower receiver noise temperatures leads to reduced ΔNEBT, and therefore lower measurement noise.
- Improved blackbody termination of the cold calibration target mitigates calibration errors and standing wave pattern in cold sky spectra.
- More frequent and more reliable pointing bias corrections mean less observation time is lost after aircraft turns (or other pointing problems).
- Upgraded computer stacks, power supplies and thermal stability improve operational reliability.

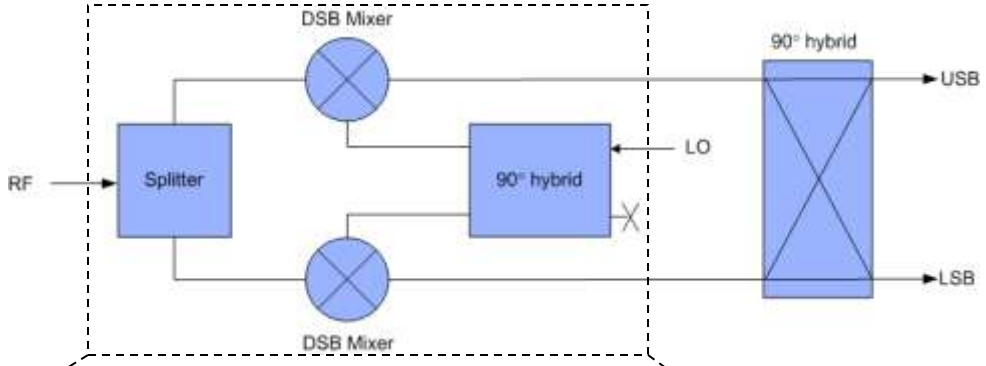
Future upgrades

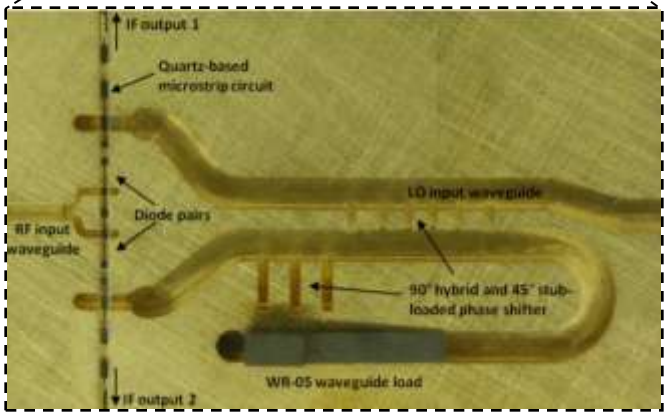
UK National funding secured for 2 year programme of major upgrades to MARSCHALS:

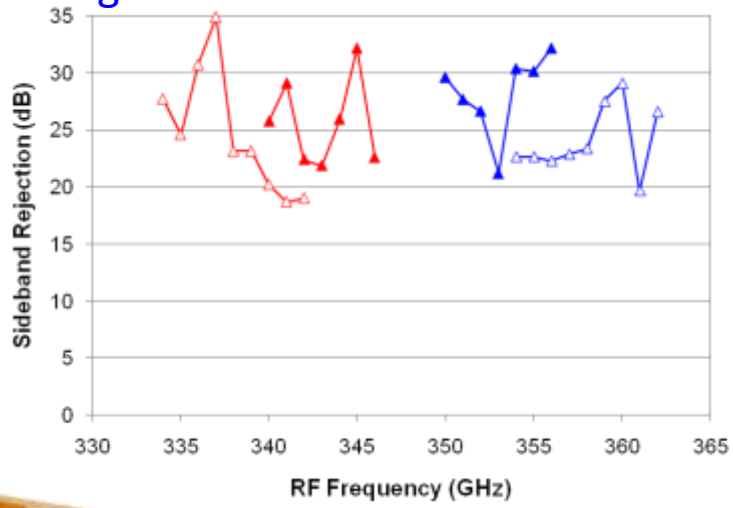
- Context : UK support for STEAMR
  - Replacement of Band D receiver with one based on sideband separating mixer (SHIRM) technology
    - (being developed with CEOI support)
  - Addition of high resolution spectrometer – digital autocorrelator or Fourier Transform type (TBC)
    - UK spectrometer development being supported by CEOI
  - Additional flights (further collaborative proposals to e.g. FP7, ESA are in preparation)

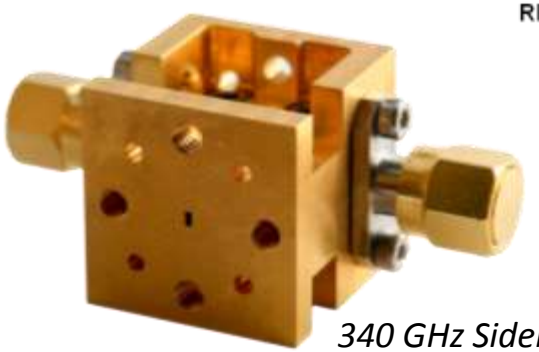
STEAMR Technology at RAL

- Sideband-separating mixers for STEAMR
  - → Incorporates 2x sub-harmonic mixers
  - → Removes need for optical sideband filtering
  - → RAL/Astrium development with CEOI funding



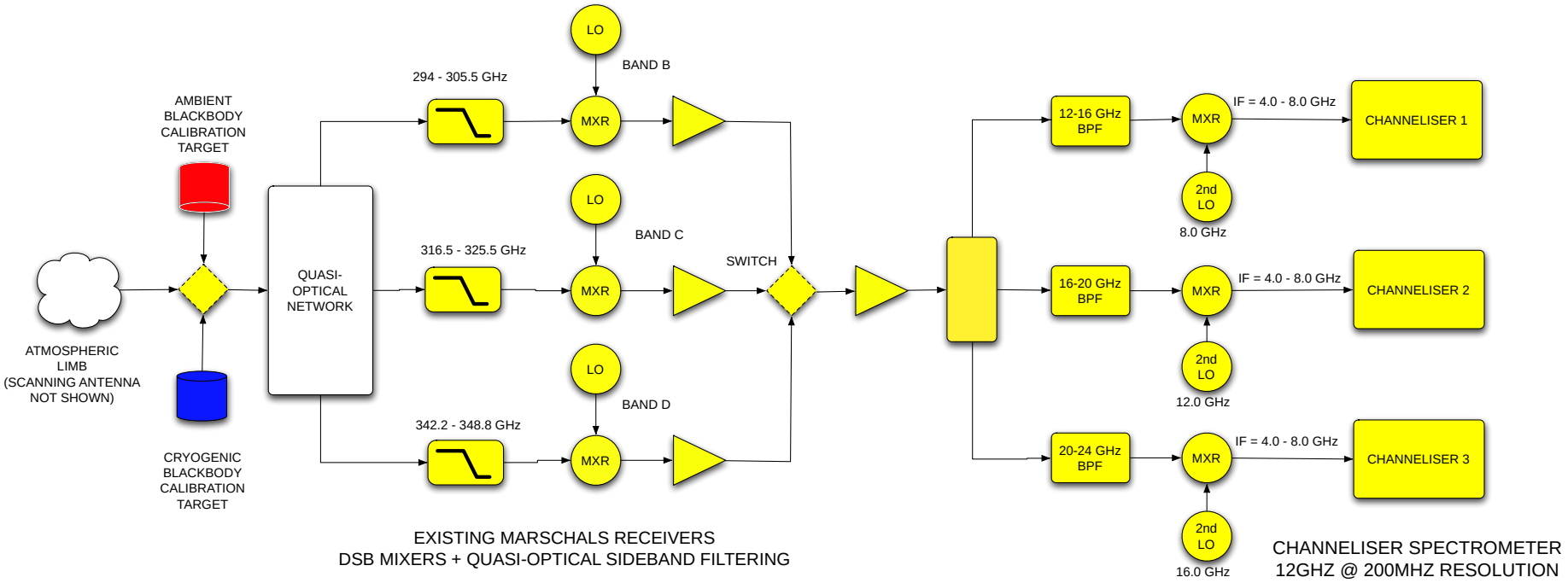






340 GHz Sideband Separating Mixer

Planned Receiver Configuration



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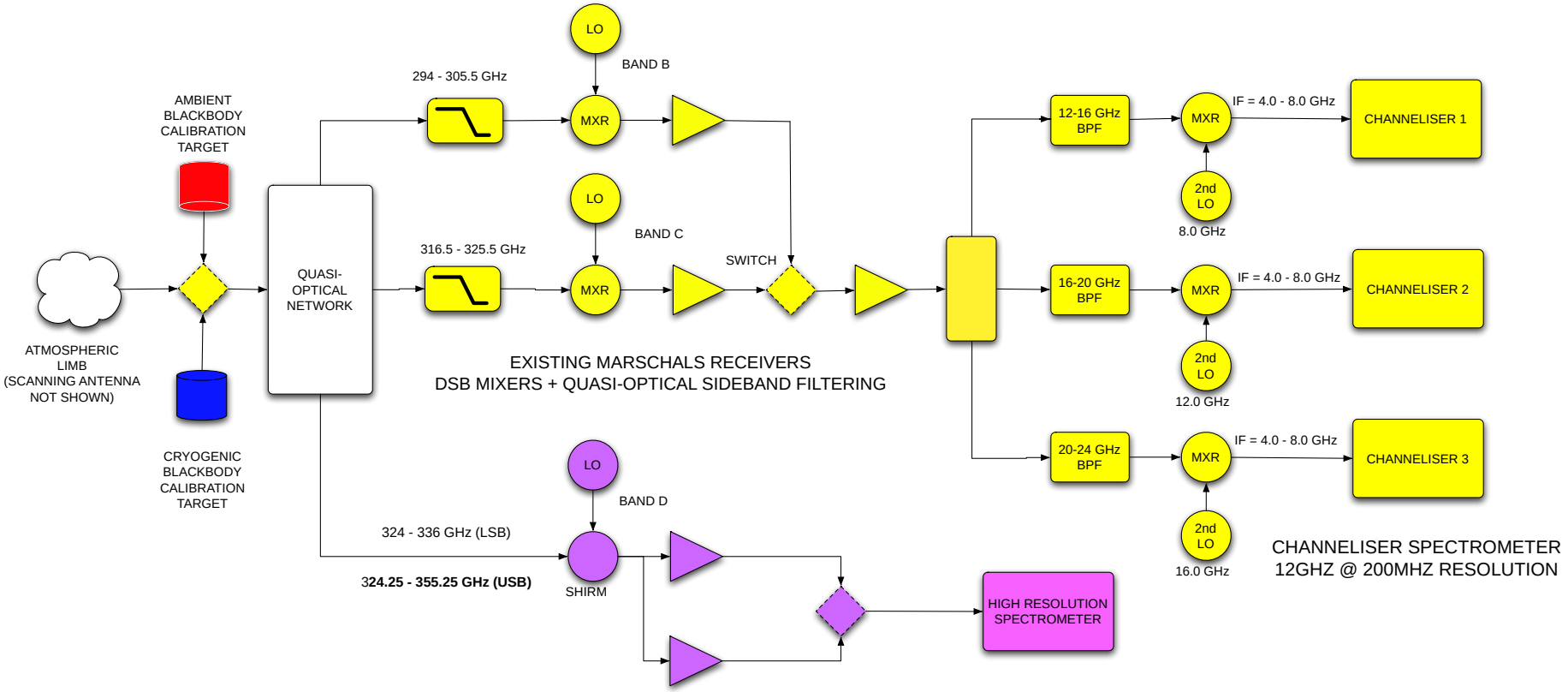

Performance Summary

Instrument Type	Total Power Single Sideband Radiometer
RF target bands	Band B 294 – 305.5 GHz Band C 316.5 – 325.5 GHz Band D 342.2 – 348.8 GHz
Instantaneous bandwidth	12 GHz
Spectral Resolution	200 MHz (with provision for addition of high resolution spectrometer with up to12 GHz bandwidth)
NEΔT (4 scans)	2K (Band B), 1K (Band C,D)
Sideband Rejection	> 30dB
Beam Width	0.34° HPBW (2 km at 10 km tangent height)
Beam Pointing	<<0.0025 deg. rms pointing knowledge during scan, bias excepted
Scan range	Tangent heights from –2km to platform altitude (21km on aircraft) in 1 km steps with +20° “space view”
Mass	330kg
Dimensions	1.55 x 0.76 x 0.56m

Summary

- MARSCHALS – into its 2nd decade
- Continuous upgrades keep it relevant as an airborne demonstrator of planned spaceborne mm-wave limb sounders
- Next upgrades will enable closest simulation yet of PREMIER, operating alongside GLORIA-AB IR Limb imaging spectrometer

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- MARSCHALS – into its 2nd decade
- Continuous upgrades keep it relevant as an airborne demonstrator of planned spaceborne mm-wave limb sounders
- Next upgrades will enable closest simulation yet of PREMIER, operating alongside GLORIA-AB IR Limb imaging spectrometer – time & place TBD!