Passive Microwave and Sub-millimetre-wave Imager Technologies

Yvonne Munro / 19 Sept 2012

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All the space you need

Overall Study Objective

The overall objective of the work undertaken by Astrium Ltd, JCR Systems Ltd, Rutherford Appleton Laboratory (RAL), and System Engineering & Assessment Ltd is to enable the UK to prepare for the next phase of the MetOp-SG mission by addressing some of the outstanding technical issues of the passive microwave instruments.

The emphasis is on the proposed precipitation/cloud imager instruments.

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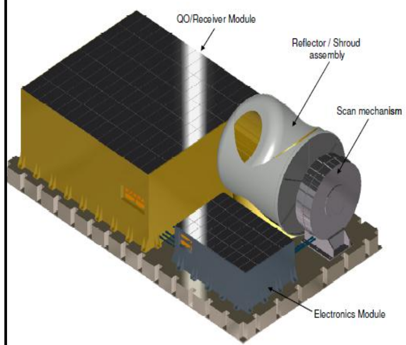
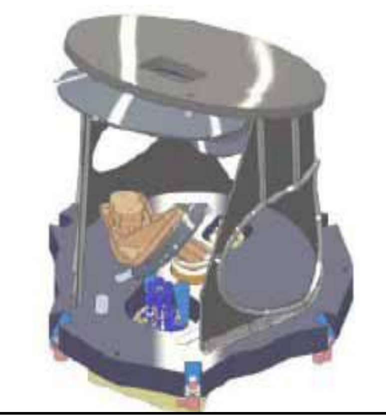
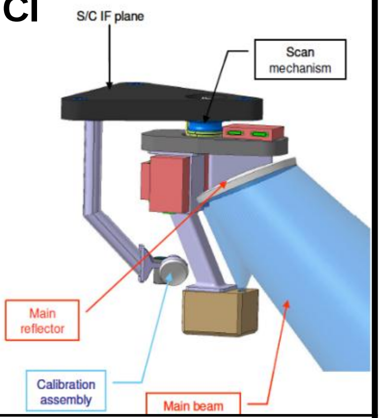
MetOp-SG Passive Microwave Missions

Mission	**MWS** 	**MWI** 	**ICI** 
Objectives	Temperature/humidity profiles in clear and cloudy air cloud liquid water total column	Cloud and precipitation products total column water vapour sea-ice, snow, sea surface wind SST, soil moisture and ocean salinity	Cloud ice products
Instrument	Across-track scanning total power radiometer	Conically scanning imaging radiometer	Conically scanning imaging radiometer
Channels	24 channels 23.8 GHz to 229 GHz	19 channels 18.7 GHz to 183 GHz	11 channels 175 GHz to 670 GHz
Priority	1	2	3

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Study Organisation

- **MetOp-SG MWI/ICI requirements**
- **Existing instrument calibration schemes**

Calibration subsystem design & analysis

Receiver subsystem design & analysis

Quasi-optics subsystem design & analysis

Active balancing subsystem design & analysis

Noise sources

183 GHz horns

183 GHz receiver breadboard test

Active balance mechanism breadboard test

Conclusions & Recommendations

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Calibration Technologies – Requirement

- Long heritage of poor in-orbit radiometric accuracy of microwave conical scanners e.g. SSMI-S, SMMR, AMSR and WindSAT.
- Literature review indicates that this has been due to combination of inadequate design of the calibration equipments and the pre launch calibration campaign.
- MWI/ICI requirements are stringent compared with previous instr: life 9 yrs (MHS 5yrs) and new definitions e.g. inter-spatial radiometric accuracy and linearity
- Operational context of MetOp-SG adds a further constraint to in-orbit options.
- Improved calibration requirement drives:
  - New technologies
  - New demands on receiver performance
  - Precision and scope of on ground calibration
  - In-orbit commissioning

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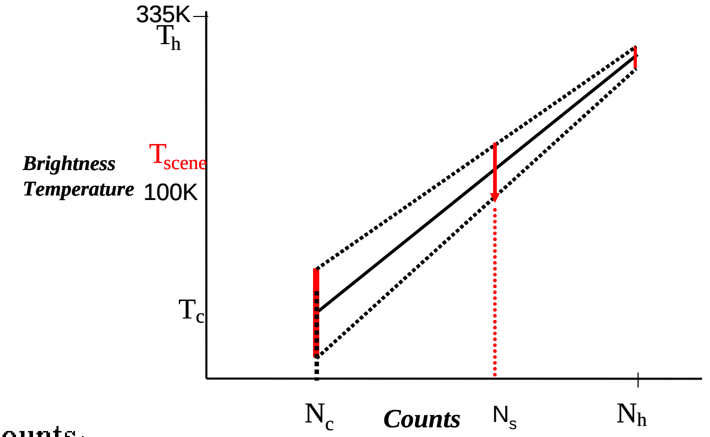
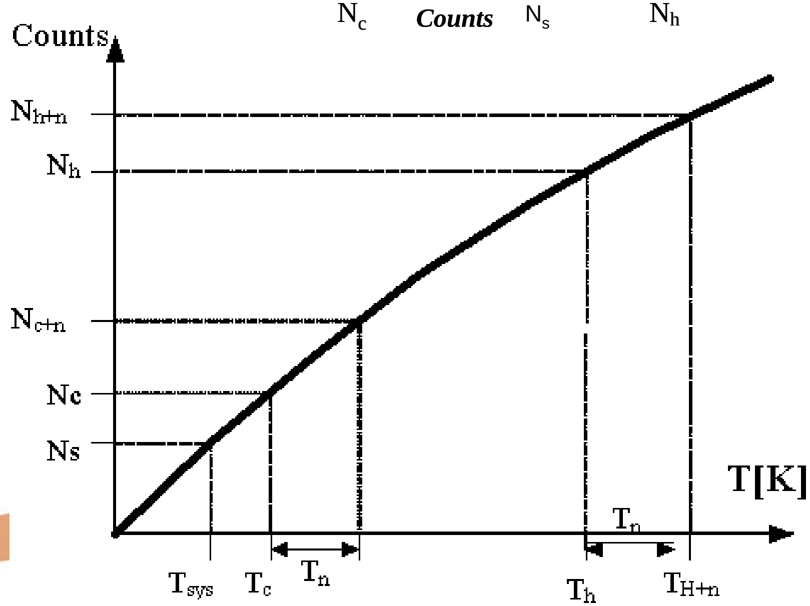
Calibration Model Enhancements

- Four-point calibration instead of conventional 2 point approach:
  - cold space view, hot load, and an additional source to provide measurements as inputs to the radiometric transfer function (RTF)
- Enables redundancy to augment the hot load measurement for short periods of time should excessive hot load gradients occur such as on SSMI & AMSR
- May allow receiver non-linearity to be tracked on-orbit to determine if any long term drifts occur.





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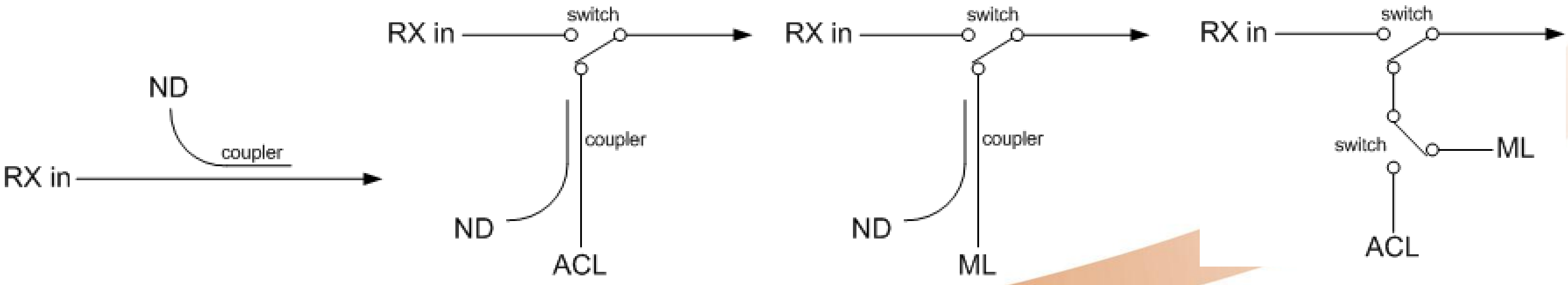
Calibration Techniques

- Wide range of combinations of “hot”, ambient and simulated “cold” sources with different switching regimes
- Switches/couplers affect overall channel reliability and performance due to additional losses
- Hence, benefits of internal calibration have to be significant to overcome these draw backs
- Most promising configurations:



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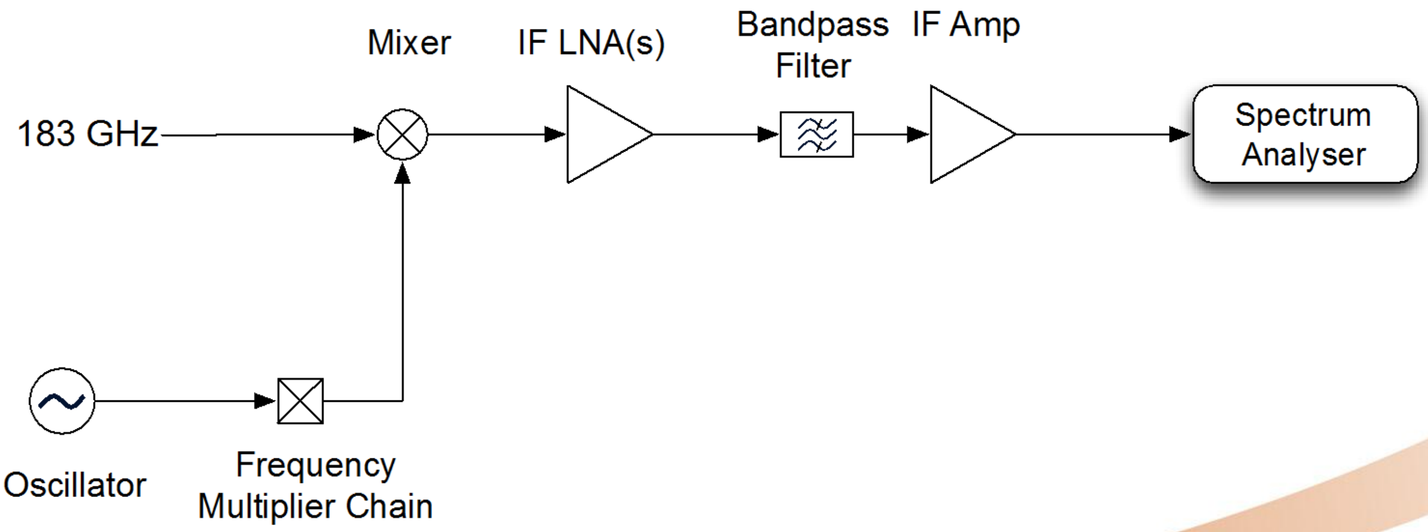
Breadboard Rx Configuration

- 183GHz heterodyne receiver
  - RAL 183GHz subharmonic mixer
  - COTS LO & IF components
  - RAL lab feedhorn available for test



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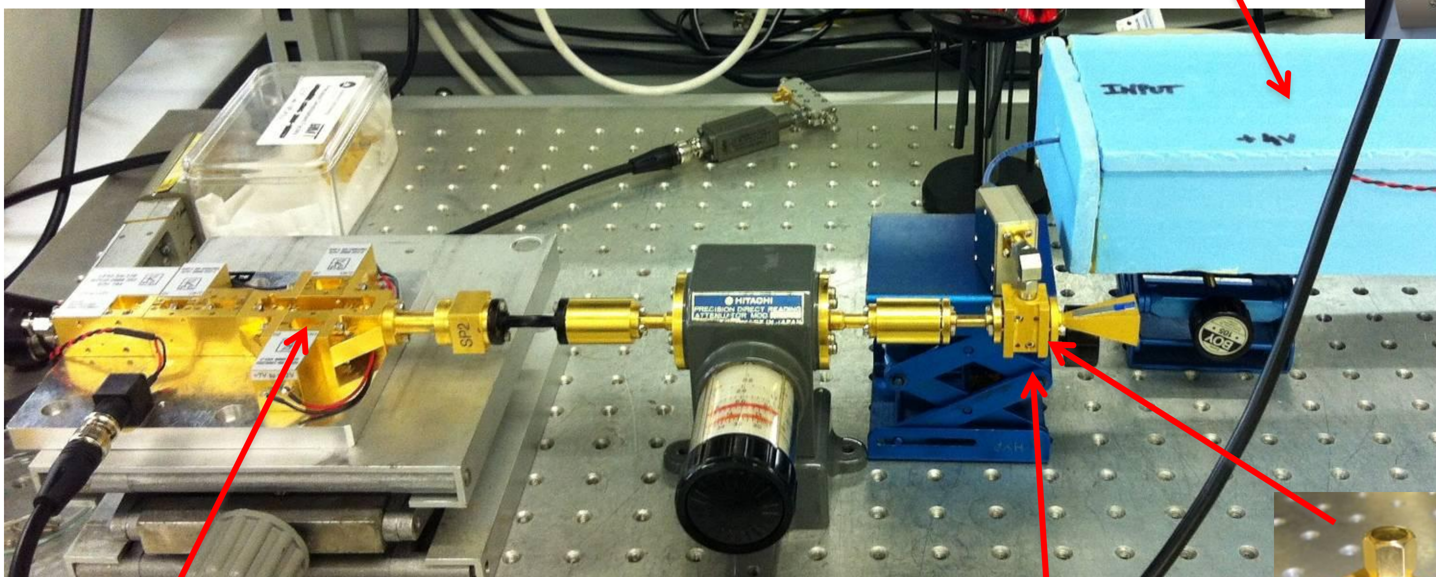
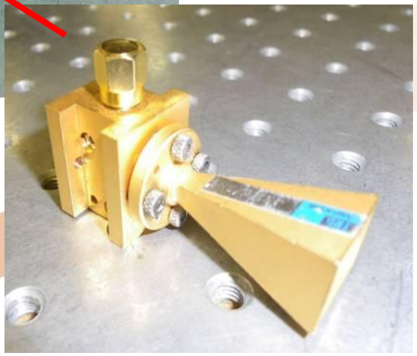
Breadboard Rx Hardware

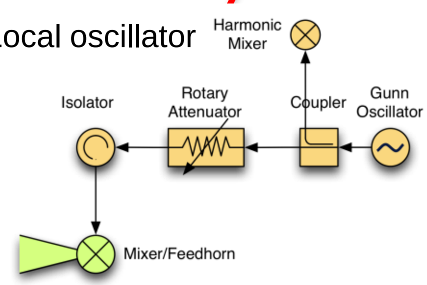
Temperature-stabilised IF



Test feedhorn



Local oscillator



183 GHz subharmonic mixer

- LO at 91.66GHz
- 173GHz to 193GHz

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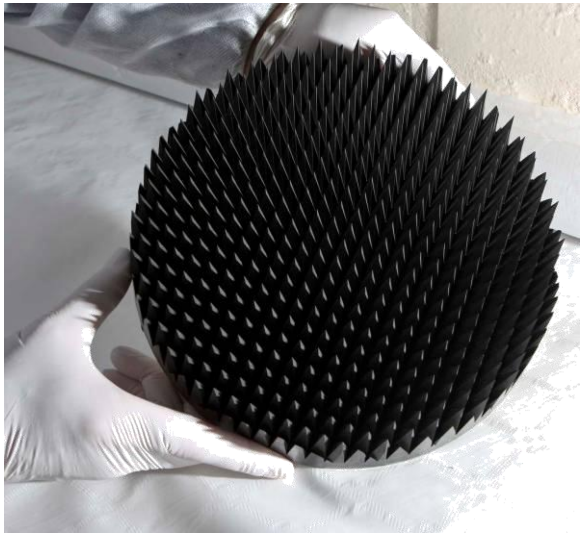
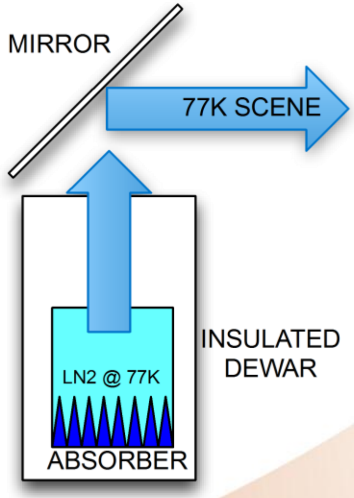
2 Point Calibration Hardware

- MetOp SG SSRD defines "…2 point calibration as a minimum. Additional calibration targets (e.g. Internal targets) may be used."



Ambient Cal Target



LN2 Bucket Load (Cold Cal)

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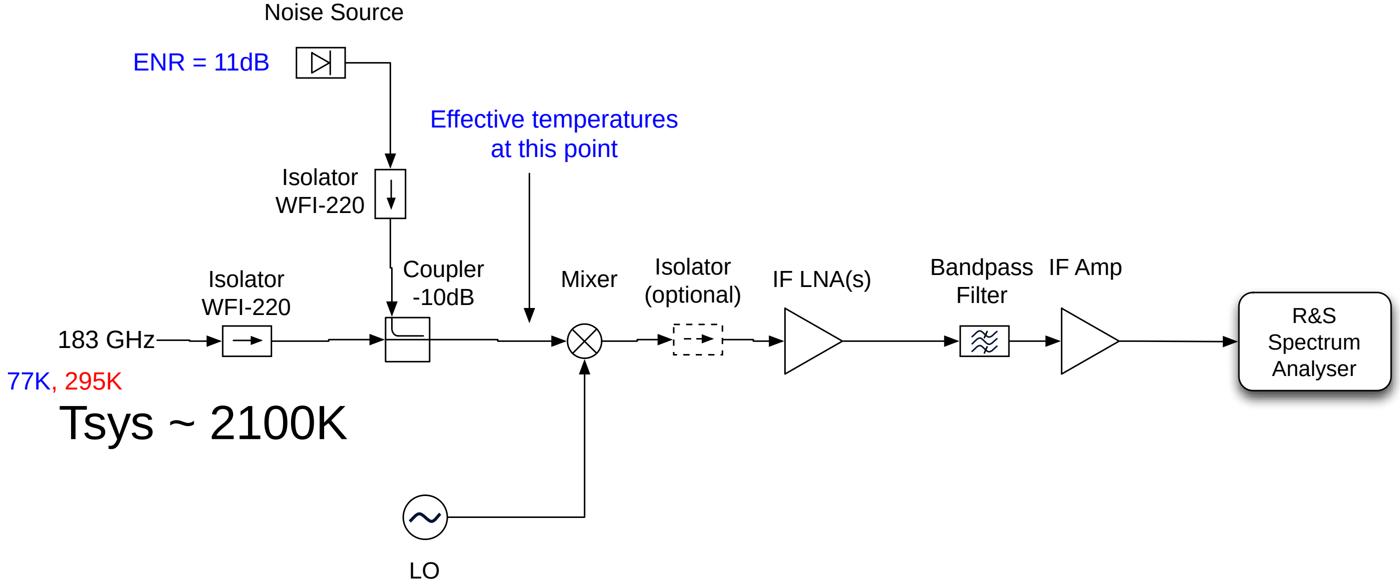
Internal Calibration



Effective Input Temperatures after Coupler for ENR=11 Diode

BB Target	Teff (K) Noise Diode ON	Teff (K) Noise Diode Off
Ambient (295K)	565	295
Cold (77K)	437	167

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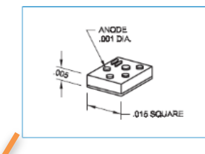
Noise Source Components

- Noise diode (COTS not available)
  - RAL development using Noise Com diodes
    - Diodes procured.
  - Several iterations built
  - Target ENR of 11dB
  - Development stalled

- RAL development using optically-pumped photomixer
  - Photomixer available (ALMA).
  - Driving a photomixer with Amplified Spontaneous Emission (ASE) from an optical fibre amplifier results in a broadband source which can be orders of magnitude brighter than a Hg-arc lamp

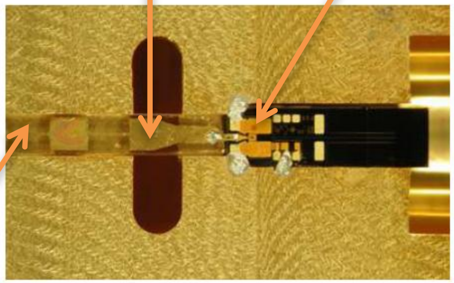
- Noise Injection
  - WR5 Faraday Isolator & Coupler (COTS)

Diode dice



Output waveguide

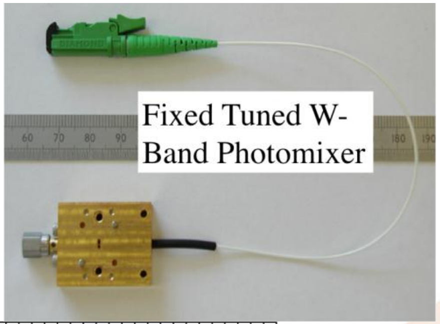
183GHz Diode Noise Source

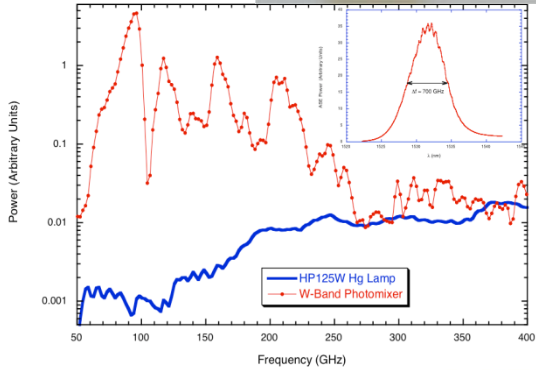


Voltage: 15V

Internal structure

Photonic noise source





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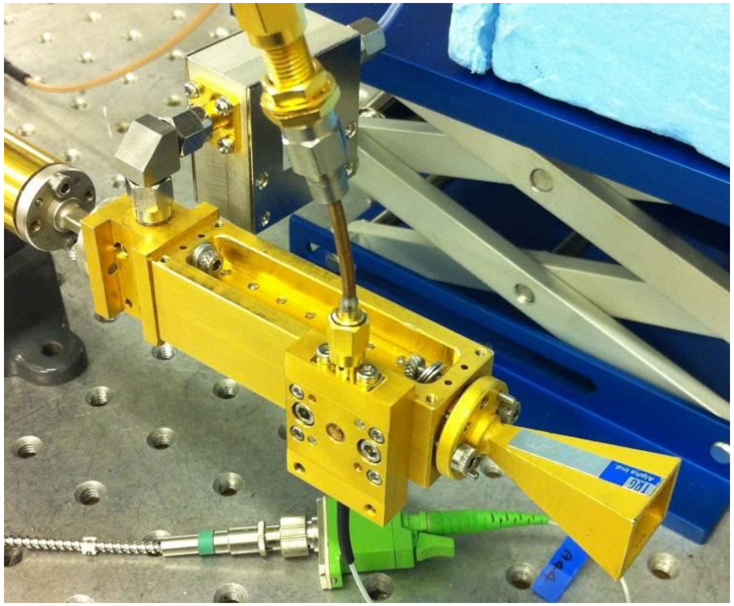
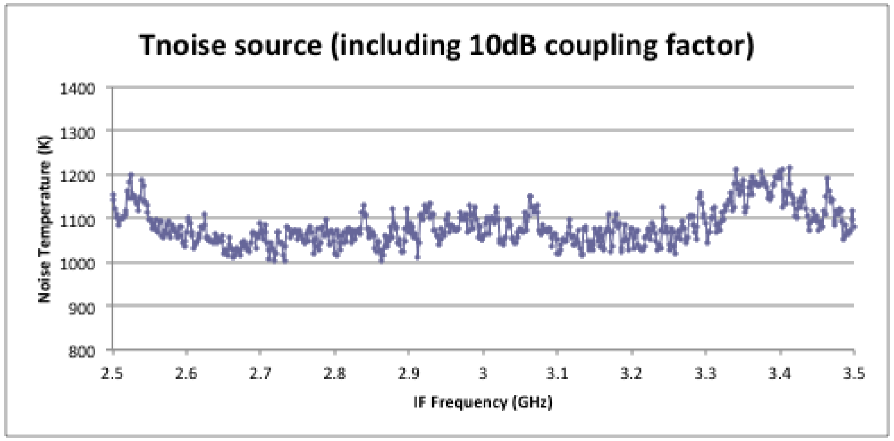
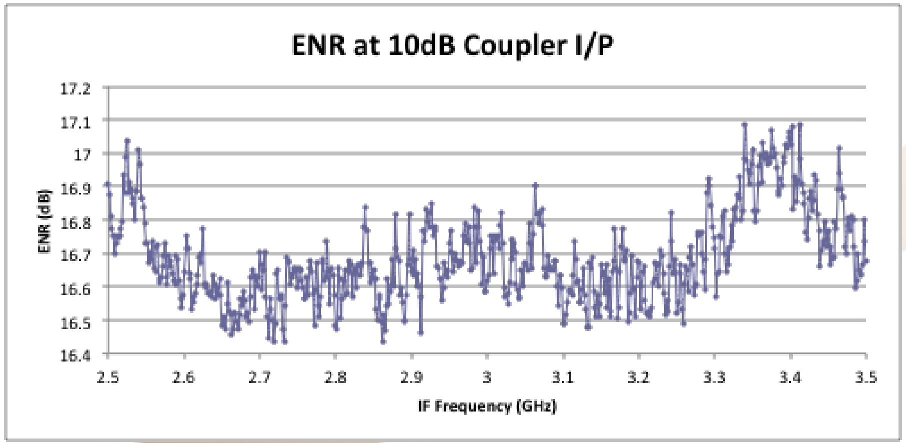
First Photonic Noise Source Results



Breadboard receiver with photomixer, 10dB coupler

- Large amounts of noise power available





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Calibration - Results

- Have established thorough understanding of the enhanced radiometric accuracy requirements for MetOp-SG
- Improved understanding of system level implications for both the MWI and ICI calibration needs and the resulting technology drivers for associated technologies
- Adapted model to incorporate new definition for linearity together with a 4 point calibration scheme
- Demonstrated relatively large non-linearities can be tolerated within definition of specification
- Demonstration of high-ENR photonic noise source
- Ongoing development of diode noise source

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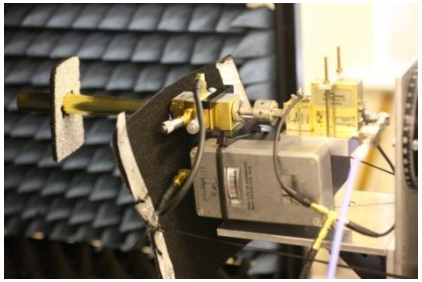
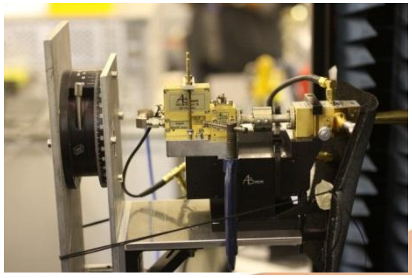
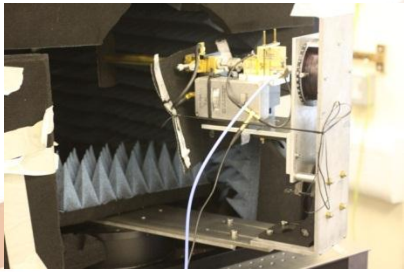
166/183 GHz Ultra Gaussian Horns

- Feedhorns designed against MWI and ICI channel requirements and antenna geometries & 183 GHz breadboard
- Horns manufactured by Thomas Keating Ltd by electroforming copper process with gold plating to the internal and external surfaces of the horn.
- Radiation patterns have been measured for the PMSIT Ultra Gaussian Horns at RAL.
- Measurements made at 160,166,172,183 and 194 GHz, with co-polar and cross-polar pattern taken in the 0 º and 90º planes

166/183 GHz Ultra Gaussian Horns







Range test setup showing rotational mount

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166/183 GHz Horns - Results

- Pattern test results follow the predicted performance from CHAMP, offering the beam HPBW at 183 GHz of 9.4º. This is compatible with the design beamwaist radius of 3.8 mm for the horn. The pattern shape is close to Gaussian with a first sidelobe of -38 dB, offering a clean pattern shape for the proposed QO system for MWS in both the 183 and 166 GHz bands.

- The return loss has been measured for one of the horns and is consistent with the CHAMP prediction, offering -37 dB at 183 GHz design frequency with the levels generally below -33 dB in the band

- Further measurements in the 166 and 183 GHz bands will be made as time permits in support of the work towards MWS (under NSTP)

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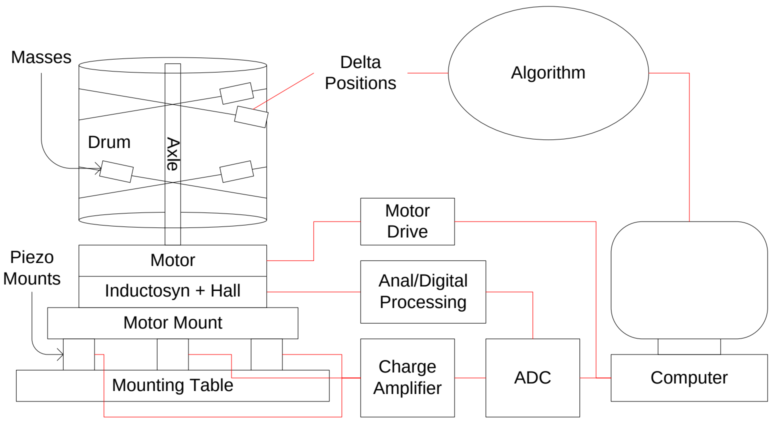
Active Balance Subsystem



- Unbalanced instruments give rise to exported forces and torques, which affect platform stability
- The aim of this work was to develop algorithms & demonstrate a concept for balancing rotating instruments, such as Metop-2G MWI and ICI

- Balancing was investigated through building a test bench based on the MIMR mechanism
- Unbalance was measured through measure forces (using piezo washers) as a function of angle (using an inductosyn)

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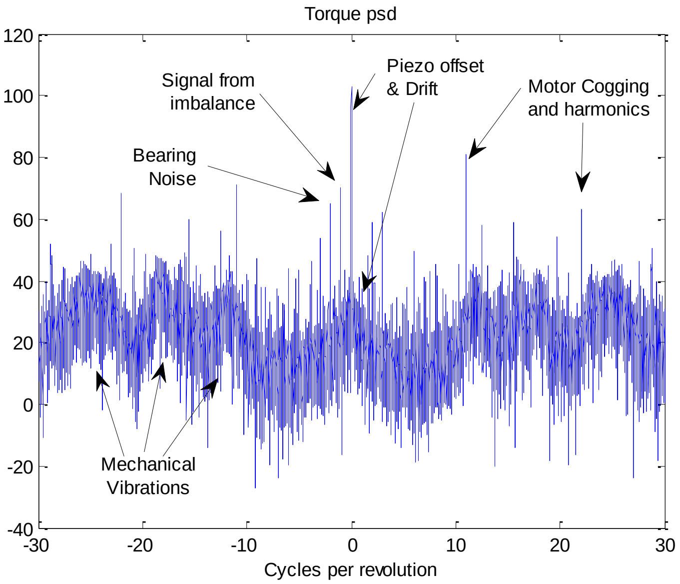
Active Balance Subsystem - Results



- Algorithms developed and balance demonstrated to 1 order of magnitude better than expected for Metop-2G Balance achieved:
  - ΔForce=500μN
  - ΔTorque=100μNm
- Imbalance measured to one order of magnitude higher

- Project has shown mechanism distortion potentially affects the balance that can be achieved in the lab
- Implications for AIT and flight need further investigation

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Conclusions

- The study has fulfilled its objective, resulting in:
  - Improved understanding of system level implications for both the MWI and ICI calibration needs and the resulting technology drivers
  - Improved understanding of the issues in active balancing of conically scanned instruments
  - Optimised 183 GHz horn design

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