UK Technology Development for Spaceborne Atmospheric Limb-Sounding Missions

Brian Moyna (RAL)
Outline

- Introduction: limb–sounding technique
- ALiSS
- MM-wave receiver technology
- SHIRM
- Complete breadboard radiometer
- WBS-II
- Deployment on JFJ
- Micro FTS
- Airborne Demonstration – StratoClim 2016
- Summary
Limb Sounding Technique

- Limb sounding gives much higher vertical resolution than nadir sounding, but its line of sight is often obstructed by clouds below the mid-troposphere.
Limb Sounding Technique

- Limb sounding gives much higher vertical resolution than nadir sounding, but its line of sight is often obstructed by clouds below the mid-troposphere.
- The atmospheric layer at the tangent point contributes most of the atmospheric signal.
- The tangent point of the line of sight moves towards the observer for higher scan angles.
ALiSS: Atmospheric Limb Sounding Small satellite

- ALiSS will provide high vertical and horizontal resolution measurements of the Upper Troposphere / Lower Stratosphere region (UT/LS) to specifically address the looming gap in limb profiling data for science and, in near real time, for operational systems

- A unique contribution of STEAMR will be to extend the ALiSS measurement range into the UT, including convective regions important to troposphere-stratosphere exchange e.g. the Asian Monsoon region, where cirrus clouds are ubiquitous
  - Clouds opaque to IR, transparent at mm-wave
  - Sideband-separating SHIRM mixers, a high priority option from the PREMIER study, will improve the accuracy of trace gas retrievals in the UT by minimizing spectral confusion and allowing the spectral dependence of continua to be determined
Mm-wave Receiver Technology

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Mm-wave Receiver Technology

- IF LNA
- POWER DIVIDER
- Spectrometer
- Spectrometer
- SCHOTTKY DOUBLER
- W BAND POWER AMP
- W BAND TRIPLER
- KA BAND OSCILLATOR

* Pin: 60-110mW
* Max efficiency: 16%
* 5mW/7dBm output: 70-104 GHz
Mm-wave Receiver Technology

T_{HOT}

T_{COLD}

IF LNA

POWER DIVIDER

SCHOTTKY DOUBLER

W BAND POWER AMP

W BAND TRIPLER

KA BAND OSCILLATOR

Spectrometer

Spectrometer

W-Band Power amplifier chip packaged at RAL

Test 103 single bias supply

Saturated Output Power
Mm-wave Receiver Technology

chalizi

IF LNA

POWER DIVIDER

SCHOTTKY DOUBLER

W BAND POWER AMP

W BAND TRIPLER

KA BAND OSCILLATOR

Spectrometer

Spectrometer

$T_{\text{HOT}}$

$T_{\text{COLD}}$

ral 160-180 Ghz Schottky Doubler

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Mm-wave Receiver Technology

- **T_{HOT}**
- **T_{COLD}**

IF LNA - POWER DIVIDER

SCHOTTKY DOUBLER
W BAND POWER AMP
W BAND TRIPLET
KA BAND OSCILLATOR

Spectrometer
Spectrometer
SHIRM: Sub-Harmonic Image-Rejection Mixer

- SHIRM Optimised performance
  - Sideband rejection: 15 dB min. (>20 dB nom.), IF BW = 2-14 GHz
  - SSB receiver noise temperature: ~3000 K

- Devices employ planar Schottky diode technology from RAL Space

SHIRM development at RAL, Astrium, supported by CEOI
Mm-wave Receiver Technology
Technology – Calibration Targets

• Metal-cored black body calibration loads for radiometer calibration:
  – Ground-based (ALMA)
  – Airborne (MARSCHALS, ISMAR)
  – Space
  – Lightweight aluminium or magnesium alloy core
  – Wide temperature range 77-370k

• Wideband performance
  – Typically better than 50dB return loss from 100GHz to at least 700GHz
  – Can be optimised for other frequency ranges

245mm diameter mg-alloy-cored calibration load for ISMAR airborne radiometer

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Breadboard Sideband-Separating High Resolution Radiometer (CEOI 5th Call)

- Development of total-power radiometer comprising
  - 340 GHz sideband-separating receiver
  - 2x WBS II units providing 4 GHz bandwidth
Wideband Spectrometer II
STAR Dundee

- Two ADCs sampling at 3 Gsamples/s
  - I & Q sampling
  - Resulting signal bandwidth > 2 GHz
- Custom Fast Fourier Transform (FFT) chip design
  - Windowing
  - 2048 point complex FFT at 3 Gsamples/s
    ~ 1.5 MHz resolution
  - Power detection and accumulation
  - Zero dead-time between data acquisitions
Signal fed into I input, Q input = 0
Averaged for 10,000 spectra
Primary signal at 600 MHz (spurs at ~200, 400 & 800)
Clock breakthrough is low (@ 100 MHz)
Instrument CAD Model
Complete Instrument

- Motor
- Mirror
- Sub-reflector
- Cal target
- IQ Down-Conversion Circuitry
- WBS II
- Electronics
- Eurotherm
- Power Supply
- Receiver
Field-Test of SHIRM Receiver at Jungfraujoch (3.5 km)
The microFTS: Miniature Fourier Transform Spectrometer.

Low mass, low power, imaging Fourier Transform Spectrometer (FTS) with no moving components.

• Spectral performance:
  - 2 to 20µm @ 16cm⁻¹ FWHM
  - 200 to 1100nm @ 0.5nm FWHM

• Low mass spectrometer: 1.56kg

• Compact: 350 x 300 x 50mm

• Low power: 0.5mW (average)

The microFTS operational principle
The microFTS is limited by the detection limits of the detector array used. The microFTS has been demonstrated in the UV, Visible, NIR, Mid and Far IR.
Technology Development: 2D Imaging Spectrometer

Imaging development work links the imaging capability with an optically encoded scan mirror.

<table>
<thead>
<tr>
<th>Detector</th>
<th>Vanadium Oxide Microbolometer</th>
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<tbody>
<tr>
<td>Spectral Bandwidth</td>
<td>2 - 14μm</td>
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<tr>
<td>Resolution</td>
<td>4cm⁻¹ @ 10μm</td>
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<tr>
<td>FOV</td>
<td>0.24rad</td>
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<tr>
<td>iFOV</td>
<td>9.4mrad</td>
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<tr>
<td>Mass</td>
<td>&lt;1.2kg</td>
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</table>
Airborne demonstration: StratoClim 2016

- STEAMR demonstration from M55 “Geophysica”
- MARSCHALS upgrade:
  - SHIRM receiver with WBS-III spectrometer (see STAR Dundee Poster!)
  - MicroFTS?
Summary

• Mission opportunity (ALiSS) for combined IR/mm-wave limb sounders
• UK well-placed to provide mm-wave receiver hardware
• Novel Micro FTS would be of interest as a complete UK instrument contribution
• Airborne demonstration of sideband-separating receiver, Wideband FFT spectrometer (and optionally Micro FTS) in StratoClim 2016
Thank You!

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