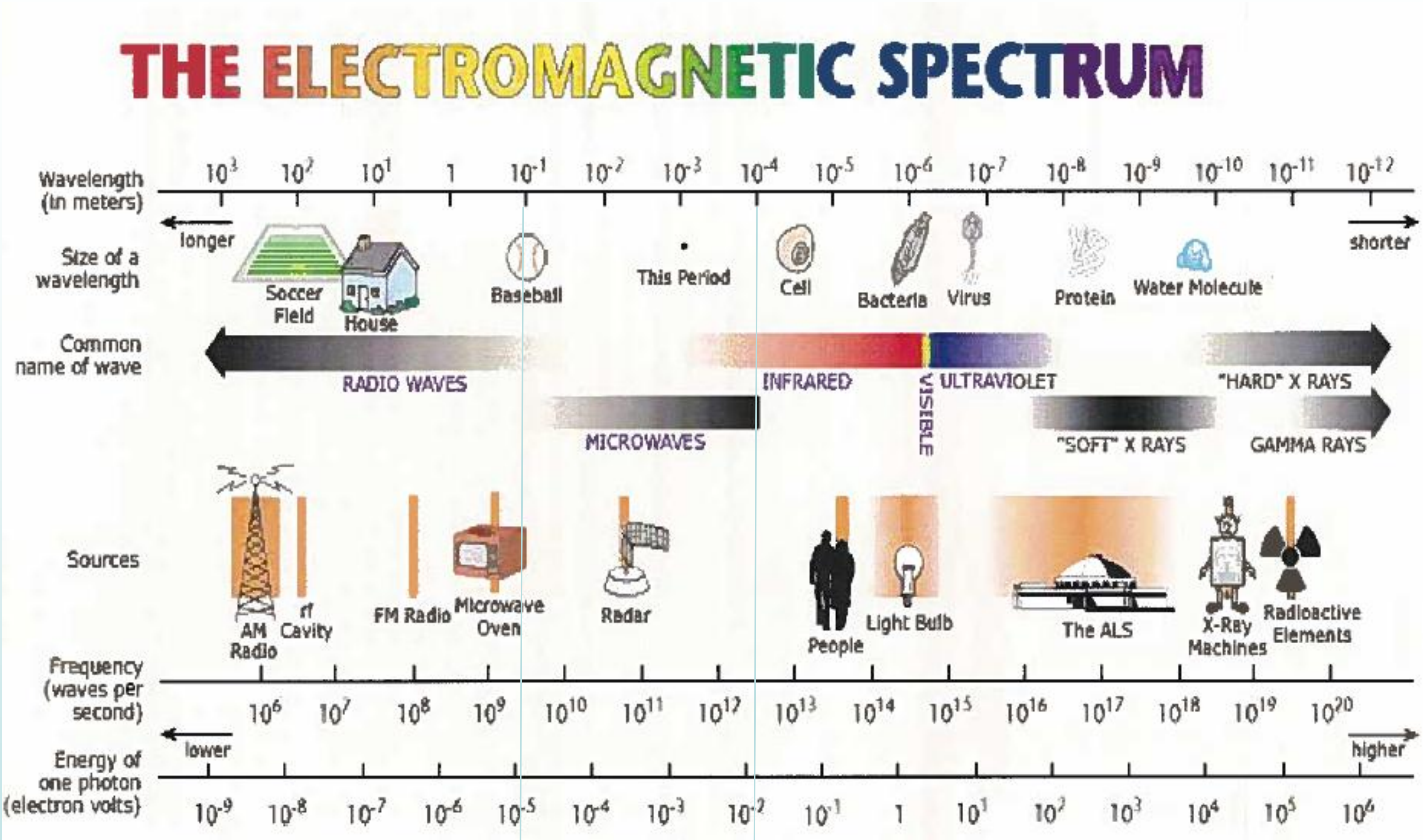
Passive Microwave Training Workshop

Introduction to Passive Microwave Radiometry

&

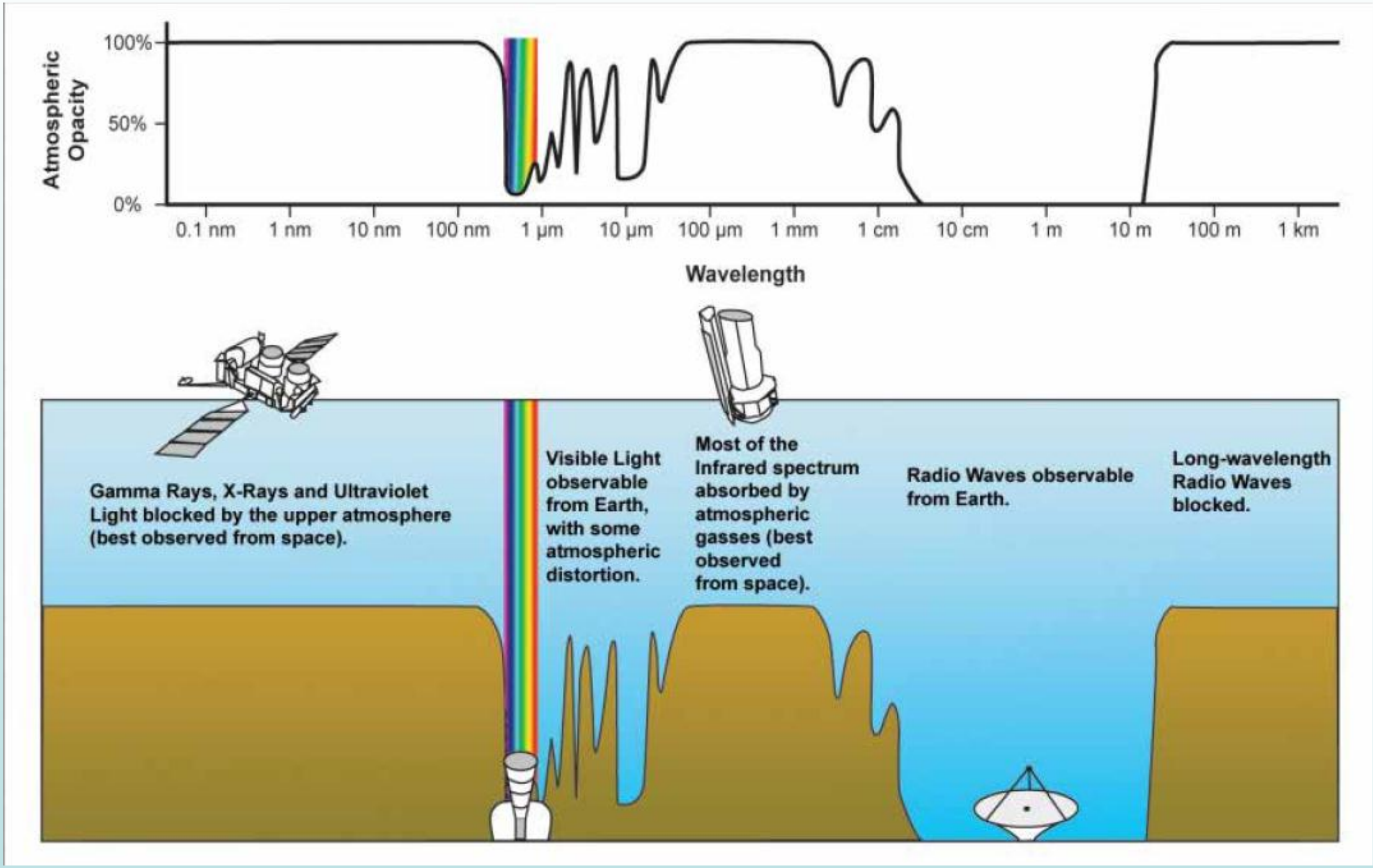
Passive Microwave Technologies in Development

Mick Johnson, CEOI Director

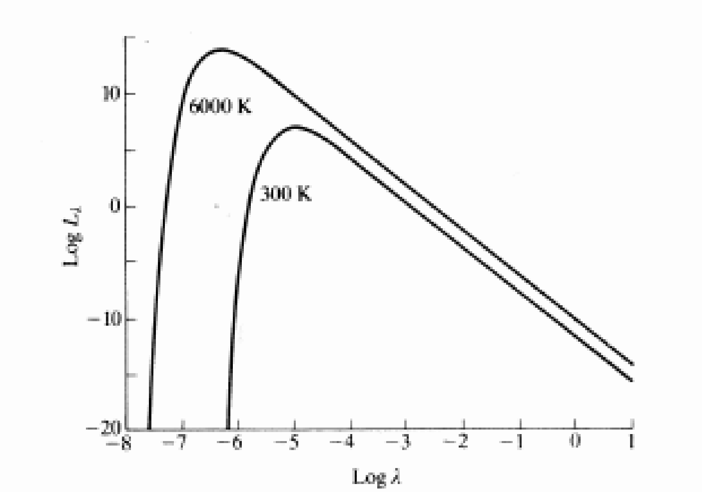


	Microwave	**Sub-mm/THz**	**Far IR**
Wavelength range:	1 m – 1 mm	1 mm - 0.1 mm	100 µm – 15 µm
Frequency range:	300 MHz – 300 GHz	0.3 THz - 3 THz	3 THz – 20 THz

Atmospheric Transparency



How much energy is there in the microwave band?



Planks Law, long wavelength approximation:

Radiance $L_f = 2kT/\lambda^2$ (λ>>50 µm with T=280K)

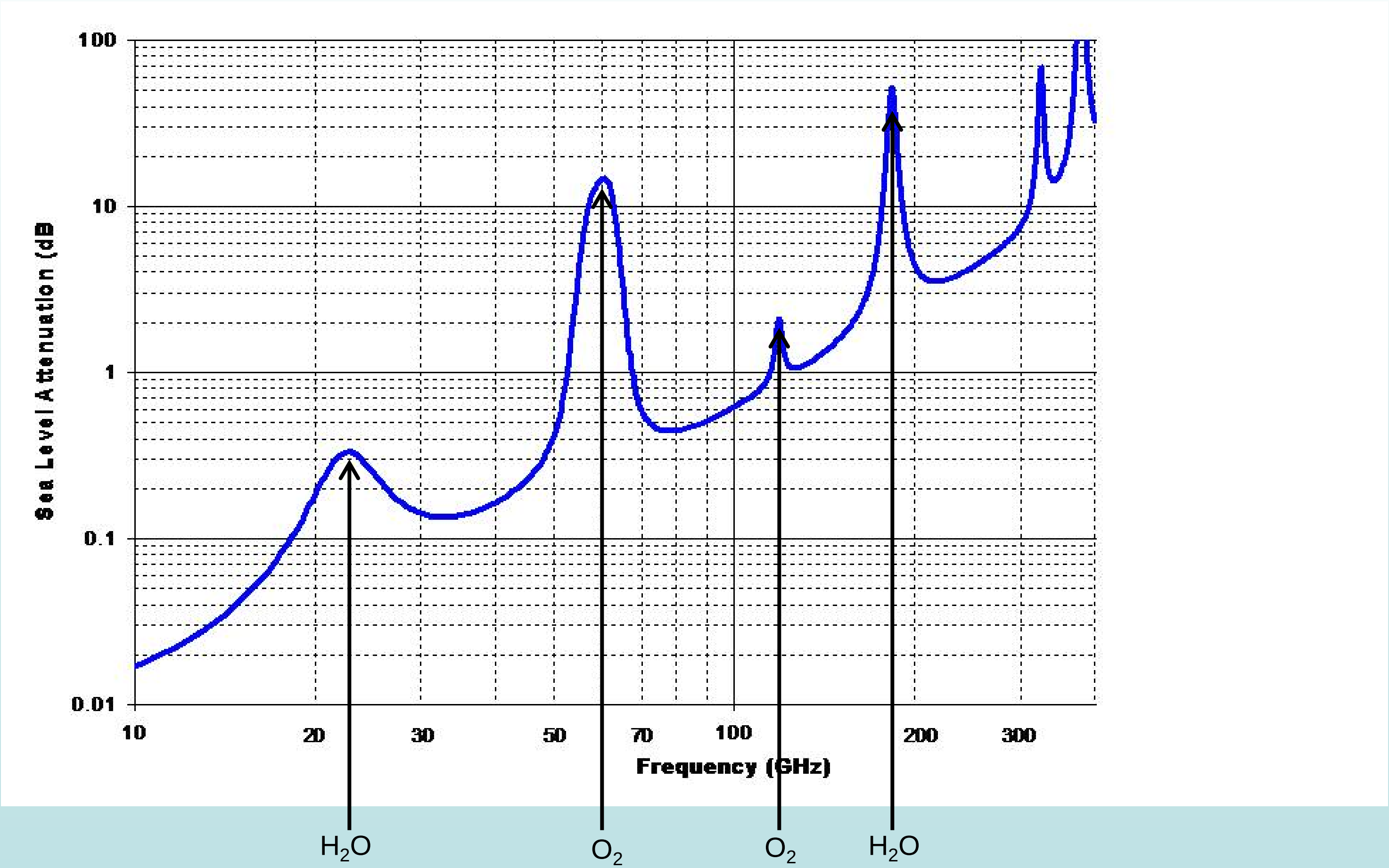
Sun @ 5800K, peak at 0.5 µm

Earth @ 280K, peak at 10.3 µm

	Band	Fraction of Total Radiation
Visible	0.5 – 0.6 µm	6×10^{-33}
Near-IR	1.55 – 1.75 µm	7×10^{-10}
Thermal IR	10.5 – 12.5 µm	0.12
Microwave	1.52 – 1.56 cm	1×10^{-10}

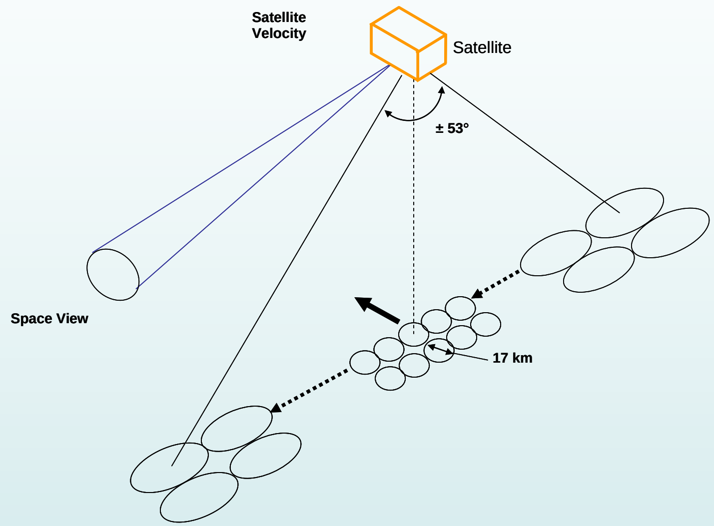
Conclusion: small but measurable amounts of radiation are emitted in the microwave region

Main microwave absorption lines

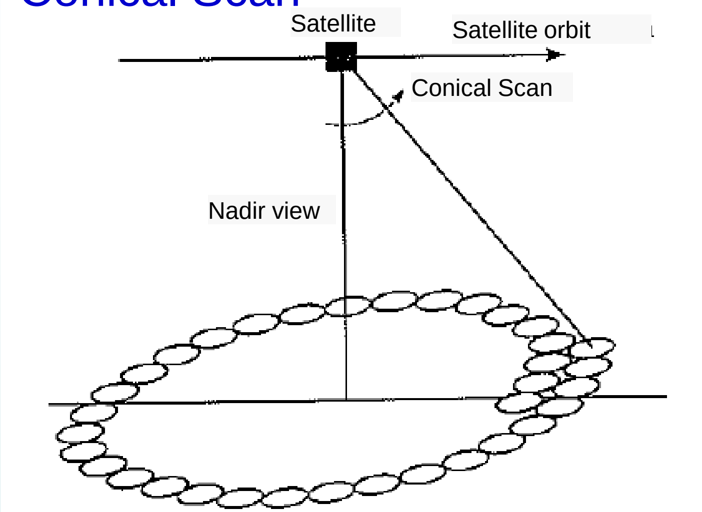


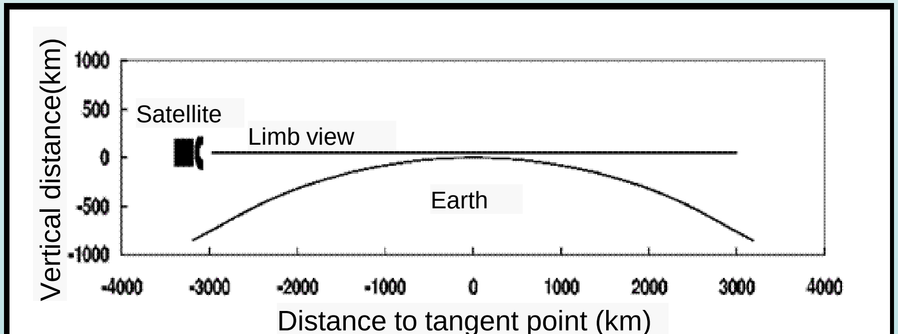
Scanning options

Cross Scan

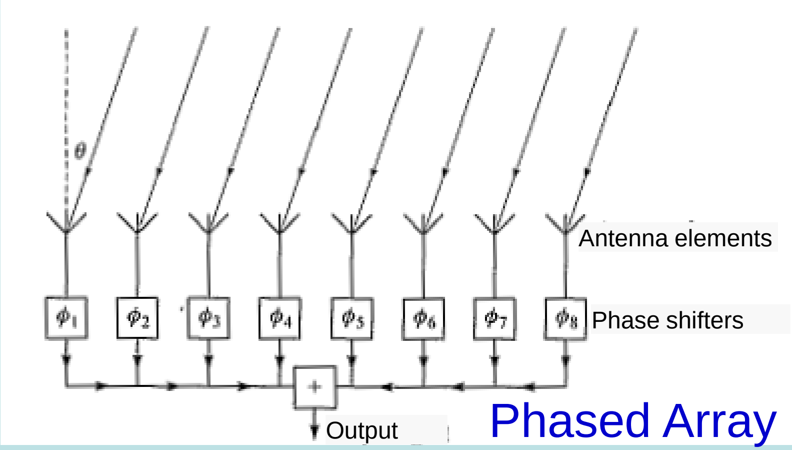


Conical Scan





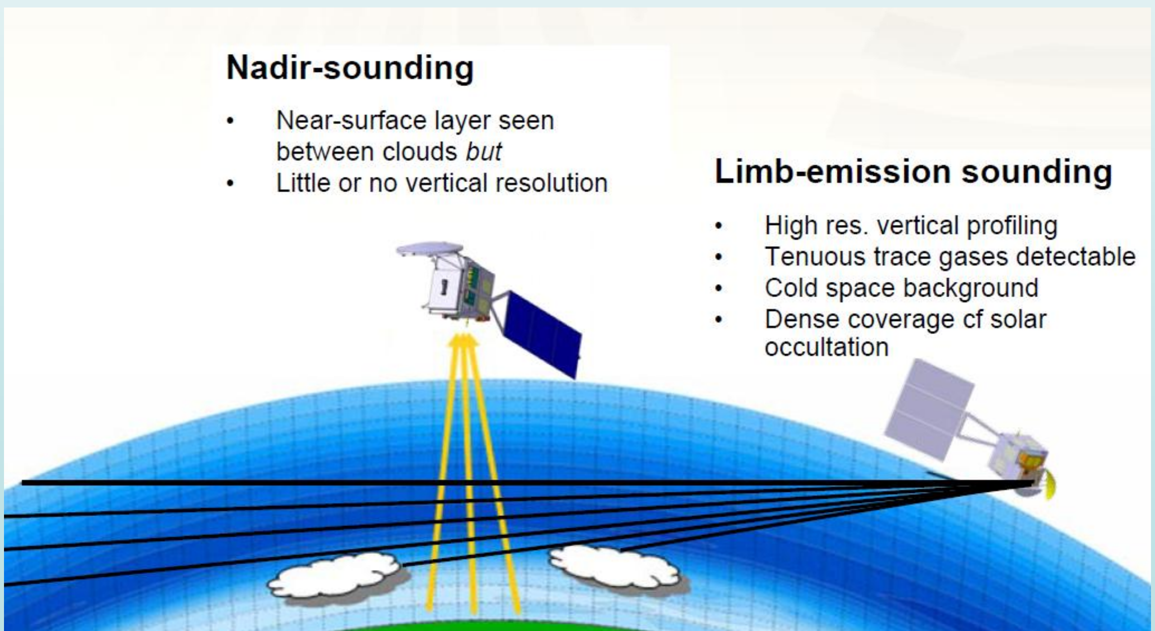
Limb Sounding

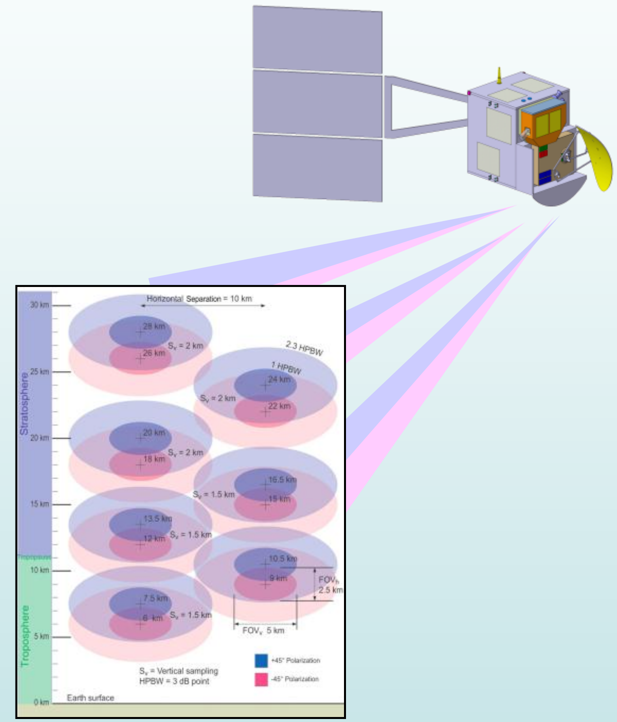


Phased Array

Limb-Nadir Combination

- PREMIER is ESA mission candidate to observe atmospheric composition
- Important climate observations, combined observations with MetOp
- IR and microwave limb sounders
- Single-sideband (SSB) observations in upper troposphere are a key feature in STEAM-R

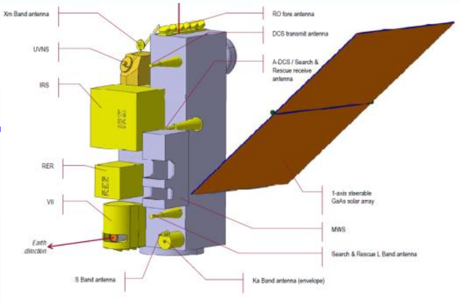


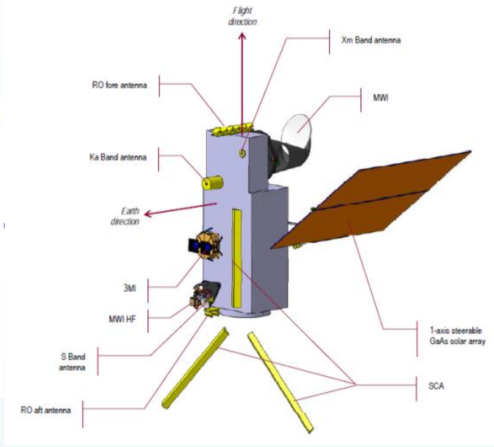


STEAM-R viewing geometry: 14 simultaneous views in UTLS region. Receivers split into two 7-element arrays observing in orthogonal polarisations

MetOp SG mission

- Main application: numerical weather prediction (NWP), and climate monitoring
- Follow on to current MetOp satellite series
- MetOp-SG will consist of pairs of satellites
- >20 year overall mission lifetime





MetOp Second Generation concept		
	MetOp-SG-A	**MetOp-SG-B**
Launch	~2019	~2020/2021
Orbit	LEO, polar, Sun-synchronous	LEO, polar, Sun-synchronous
Altitude	817 km	817 km
Mass	~3000 kg	~2400
Lifetime	8.5 years	8.5 years
Intstruments	8	7
	Visible Infrared Imager (DLR)	Microwave Imager (ESA)
	Microwave Sounder **(ESA)**	Ice Cloud Imager (ESA)
	Infrared Sounder (CNES)	Scatterometer (ESA)
	Radio Occultation (ESA)	Radio Occultation (ESA)
	Multi-view Multi-channel Multi-polarization imager (ESA)	Argos Data Collection Service (NOAA/CNES)
	Radiation Energy Radiometer (NOAA)	Search and Rescue (COSPAS-SARSAT)
	Sentinel-5 (ESA/GMES)	Space Environment Monitor (NOAA)
	Low Light Imager (NOAA)	

The Microwave sounder

MWS

Microwave Sounding

Objectives

- Temperature/humidity profiles in clear and cloudy air
- Cloud liquid water total column
- Imagery: precipitation

Heritage

AMSU-A, MHS

Baseline performance

- as AMSU/A, MHS
- horizontal resolution as ATMS

Implementation

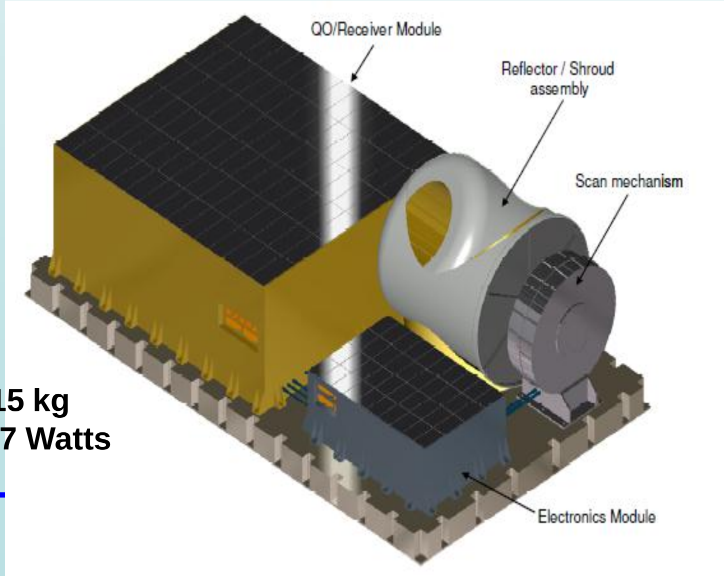
- NOAA ATMS as baseline
- ESA development in Phase A as option

Evolution

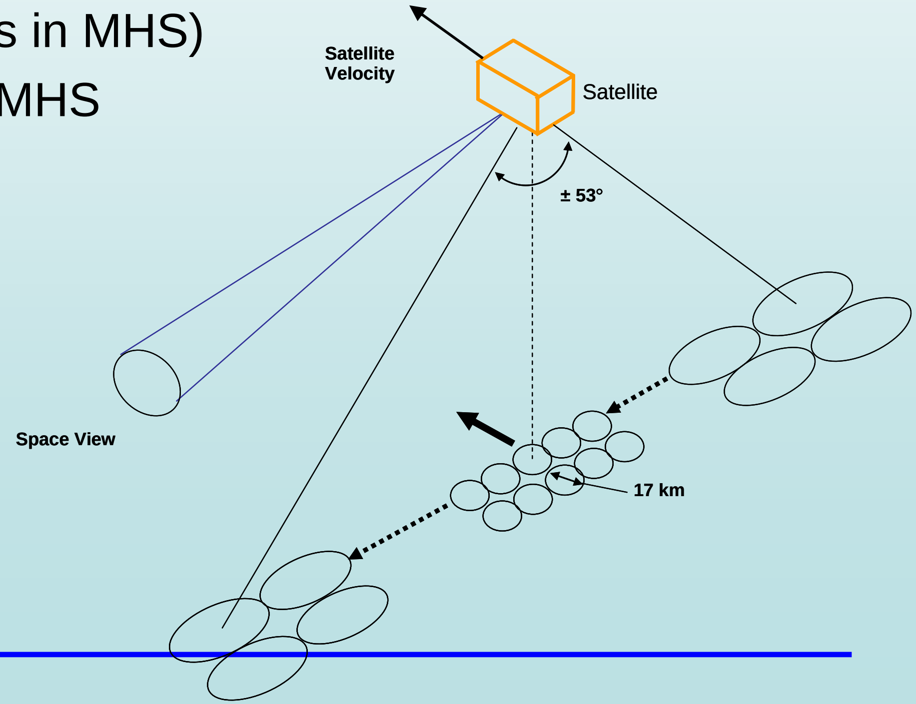
- **Addition of a quasi-window channel at 229 GHz**
  - Cirrus cloud information
- **Higher spatial oversampling compared to AMSU-A and MHS: noise reduction**
  - More information on temperature and water vapour profiles

What does the MWS do?

- Measures global temperature and water vapour profiles for Numerical Weather Prediction (NWP).
- Scans the Earth across track, with 93 pixel over a scan of ± 53°.
- Scan duration determined by 17 km footprint for the higher frequency channels.
- Instrument self-calibrates each scan rotation with a view to cold space and to an on-board (hot) calibration target (OBCT).
- Increase to 24 channels (cf 5 channels in MHS)
- Mode of operation almost identical to MHS



115 kg
177 Watts



MWI
Microwave Imaging

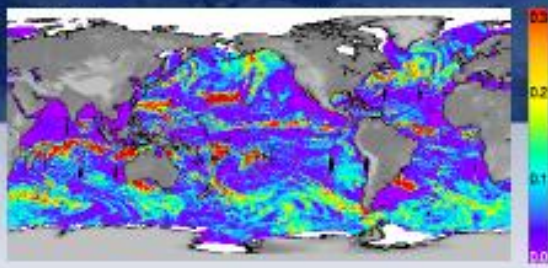
Objectives of a new mission
- precipitation and cloud products
- water vapour profiles and imagery
- sea-ice, snow, sea surface wind

Heritage
SSM/I(S), AMSR-E

Baseline performance
4 spectral channels as SSM/I (18.7 – 89 GHz)

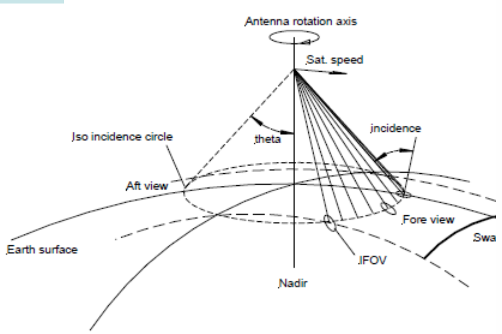
Implementation
ESA development

RSS (2011)

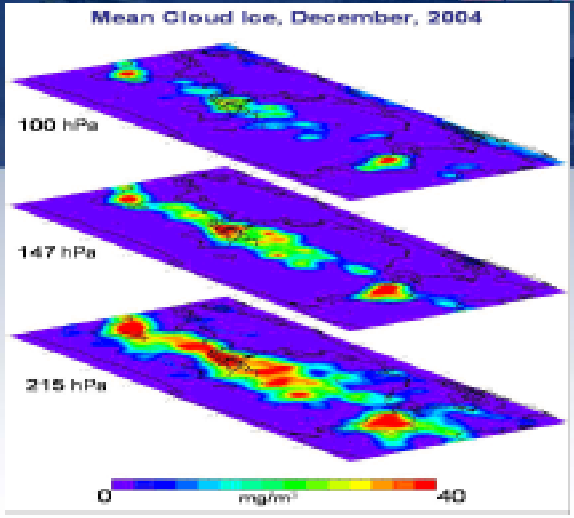


Breakthrough: 19 channels

- **Continuity of key microwave imager channels for weather forecast**
- **Inclusion of dedicated sounding channels**
  - Enhanced precipitation measurements through inclusion of dedicated sounding channels
- **Extension towards 183 GHz**
  - water-vapour and cloud profiling



ICI: Ice Cloud Imaging



NASA: Aura/MLS

Objectives of a new mission

- Cloud products, in particular ice clouds
- Snowfall detection and quantification
- Water-vapour profiles and imagery

Heritage

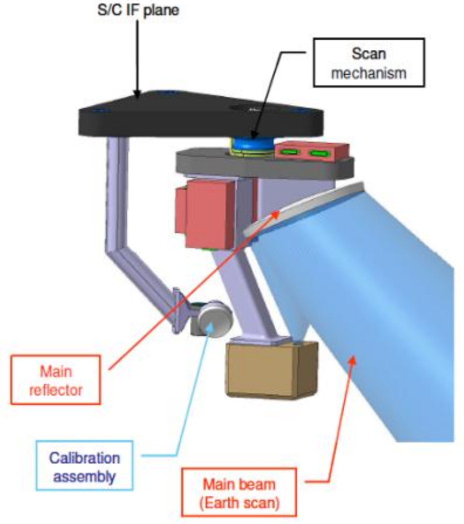
Aura-MLS, Odin-SMR (both limb viewing)

Baseline performance

- Conically scanning
- Nadir-viewing geometry
- 11 spectral channels
  - 183 – 664 GHz

Implementation

ESA development



Breakthrough: 11 channels

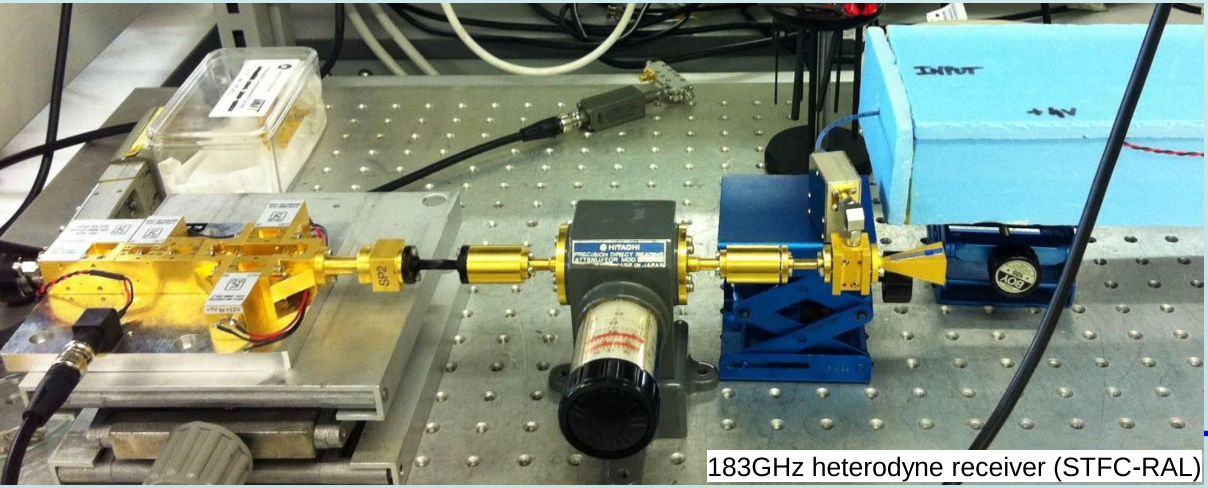
- **Establishes operational ice-cloud imaging mission**
- **Support of weather forecast, hydrology, and climate monitoring**

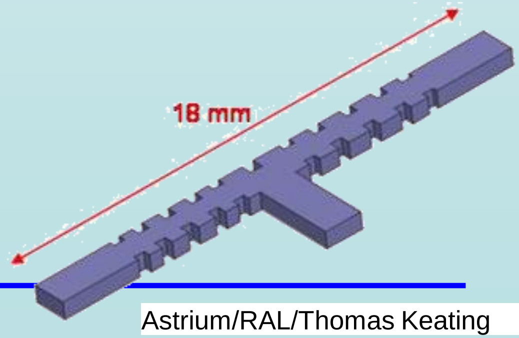
Key technologies for MetOp-SG

- Heterodyne receiver breadboard (STFC-RAL)
  - 183GHz subharmonic mixer, local oscillator, IF Electronics
- Optimised feedhorn design at 183 GHz (Astrium)
- 165/183GHz waveguide diplexer (Astrium)
- Development of a 183/229 GHz quasi-optics system (Astrium/RAL)


STFC-RAL


Astrium/Thomas Keating/RAL


183GHz heterodyne receiver (STFC-RAL)

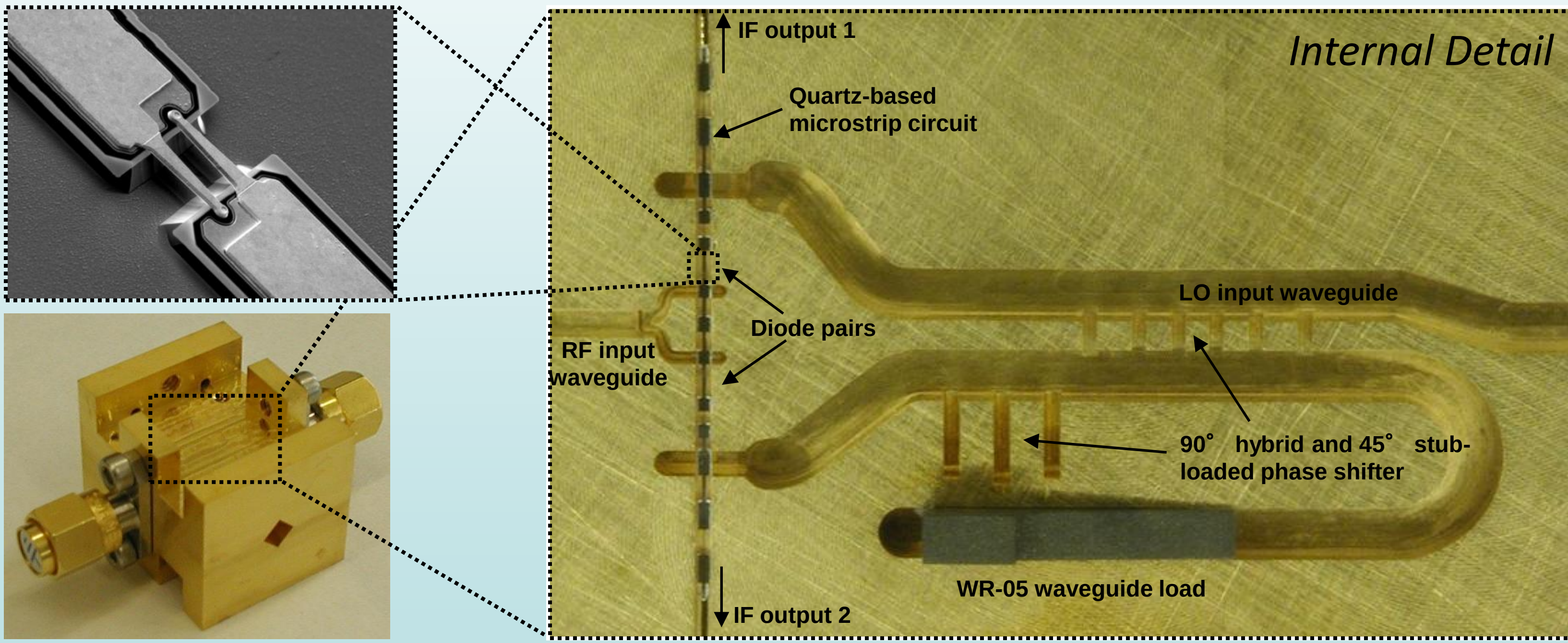


Astrium/RAL/Thomas Keating

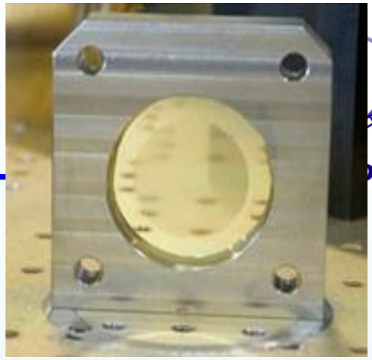
The SHIRM for STEAM-R

- The SHIRM Sub-Harmonically pumped Image-Rejection Mixer (RAL/Astrium)
- Demonstrated successfully with CEOI funding

RAL Schottky Diodes



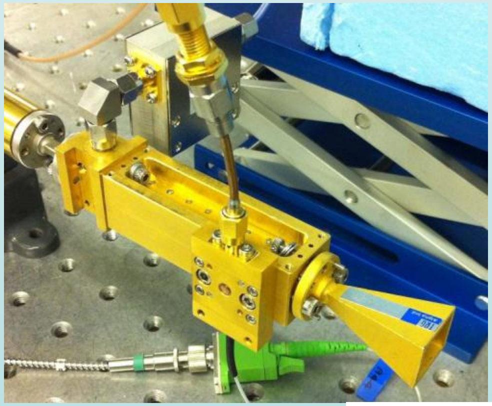
Other UK Developments in Passive Microwave/ Millimetre Wave



Queens University Belfast

- Frequency Selective Surface (FSS) Filters (QUB)
  - Frequency separation in quasi-optics systems
  - Ultra low insertion loss at >350GHz
- Wideband spectrometer (STAR-Dundee)
  - High spectral resolution with digital FFT
- Calibration of microwave imagers (JCR Systems)
  - Improved techniques
  - Development of switcher/coupler technologies
- Metamaterials
  - Study of artificial micro-structures to reduce stray reflections in quasi optical systems

STAR-Dundee



STFC-RAL