

Large Synthetic Aperture: The Geostationary Atmospheric Sounder Project

Peter de Maagt, TEC-EEA



GEO Sounder Project



- TRP/GSTP activity with the objective to develop a (sub) mmw sounder in Geostationary Earth Orbit
- (instigated in 2001 during the Space Technology Innovation Workshop in Copenhagen)



Study Team:

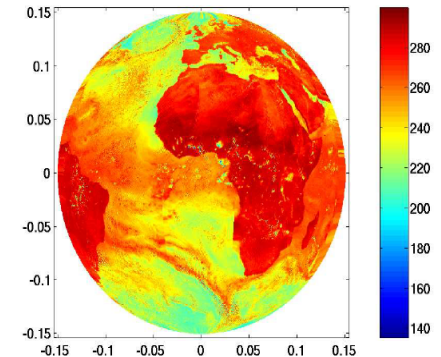
- RUAG Space
 - System design
 - Antenna design
 - Mechanical/thermal design
 - Data post-processing
- Omnisys Instruments
 - Electronics system design
 - Front-End Electronics design
 - MMIC design
 - Back-End Electronics design



The GAS instrument



- Meteorological Instrument
 - Now casting & Short range forecasting
 - Full disc coverage with 15 minute image updates
 - 2015 – 2020 NWP needs (EUMETSAT)
- Interferometric Imaging
 - Measures Brightness Temperature, Full Polarization Capability
 - T(h) : O₂ @ 53 & 118 GHz
 - WV(h) : H₂O @ 183 & 380 GHz
- Will enable full sounding capability from GEO
 - will complement IR sounders in term of: Precipitation, Cloud liquid water, Meteorologically interesting scenes (full cloud cover, Storms & Hurricanes)



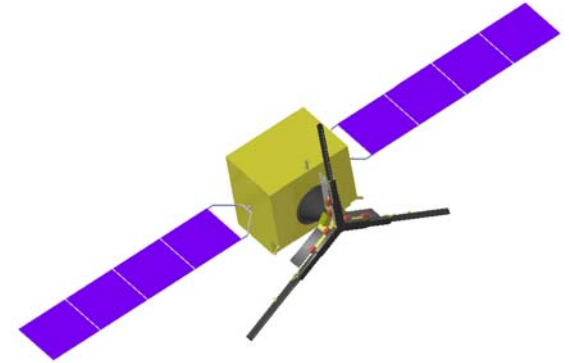
“User requirements ”

- Regional NWP requirements 2015 (EUMETSAT) :

	<i>Optimum</i>	<i>Breakthrough</i>	<i>Threshold</i>
Vertical profiles of wind, temperature and water vapour			
Horizontal resolution	3 km	30 km	200 km
Vertical resolution	100 m	1 km	2 km
Temporal resolution	0.5 h	3 h	12 h
Wind accuracy	1 m/s	-	3 m/s
Temperature accuracy	0.5 K	-	1.5 K
Water vapour accuracy	5%	-	10%
Precipitation intensity			
Horizontal resolution	3 km	10 km	50 km
Temporal resolution	-	1 h	-
Accuracy	0.1 mm/h	-	1.0 mm/h

Driving requirements

- Requirements 2015 – 2020
- 15 - 30min Revisit Time \Rightarrow GEO Orbit
- 30 km Resolution \Rightarrow 8 m Aperture
pointing acc. < 0.01 deg
- All Weather Capability \Rightarrow mmw -
submmw f

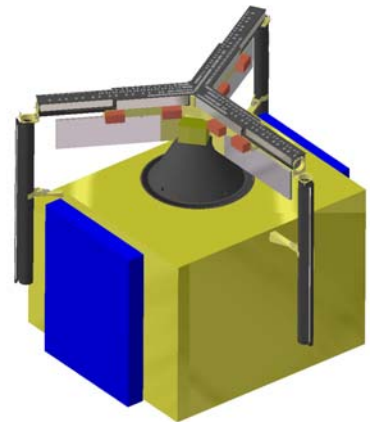


Foldable Interferometer

- Can be Launched

Rotating Interferometer

- Provides $\sim 75\%$ saving in number of receivers

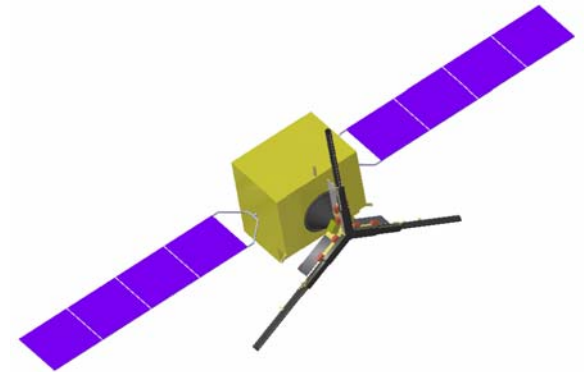
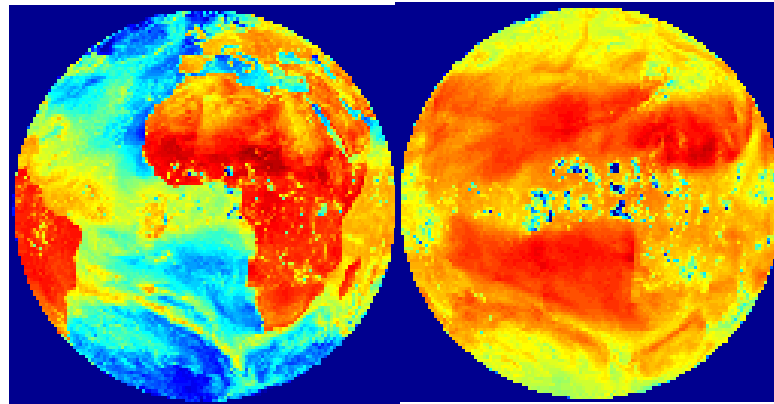
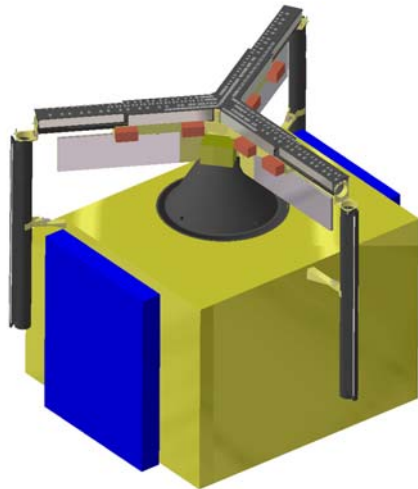


GEO Atmospheric Sounder - GAS

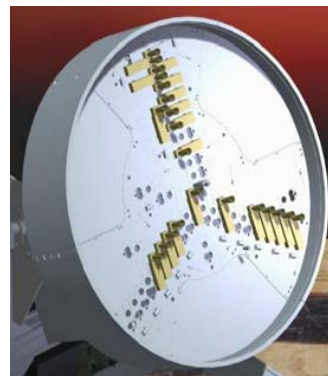
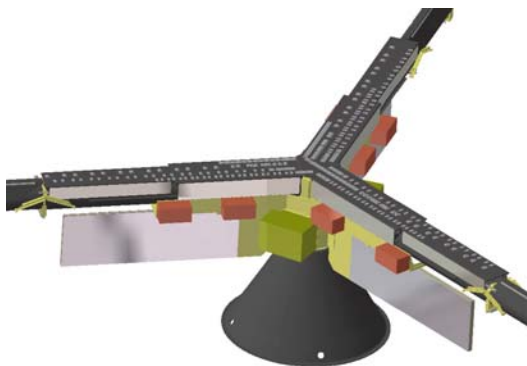


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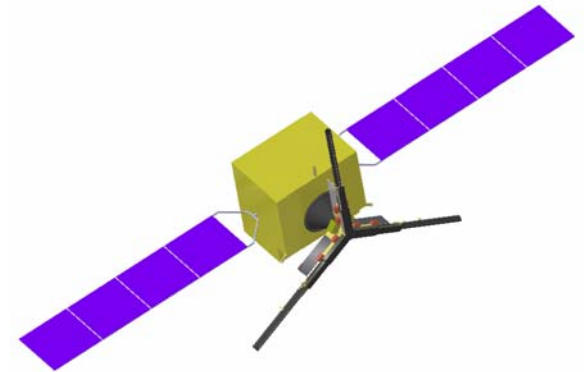
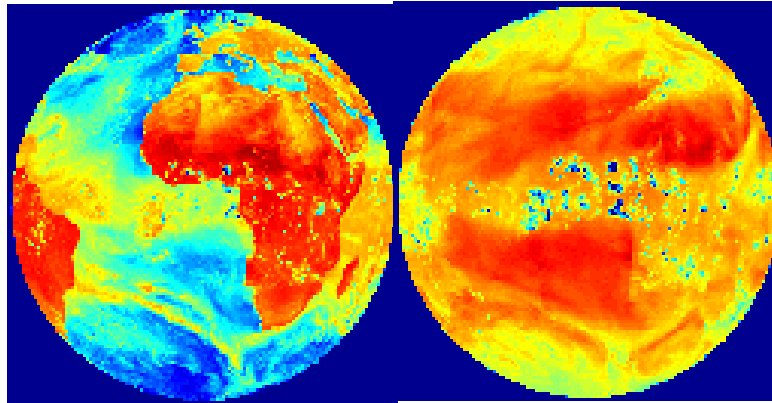
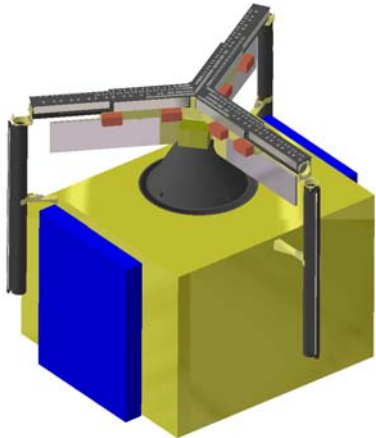
TEC-EEA



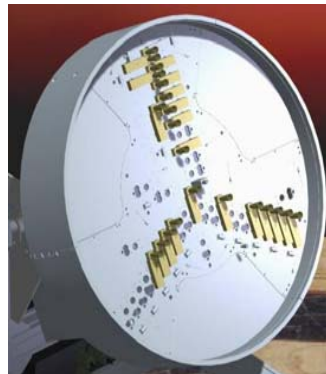
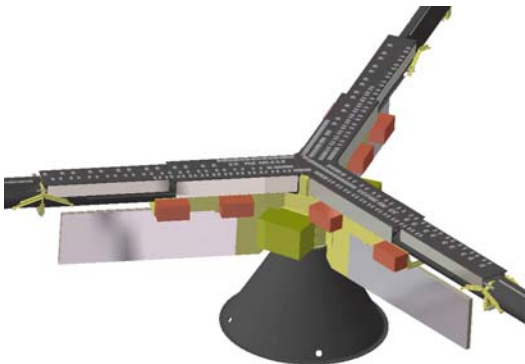
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- GSTP Ultra stable structures for GAS instrument, 650K (TEC-MCS)
- GSTP GEO-Sounder MMIC, 500K (TEC-ETM)



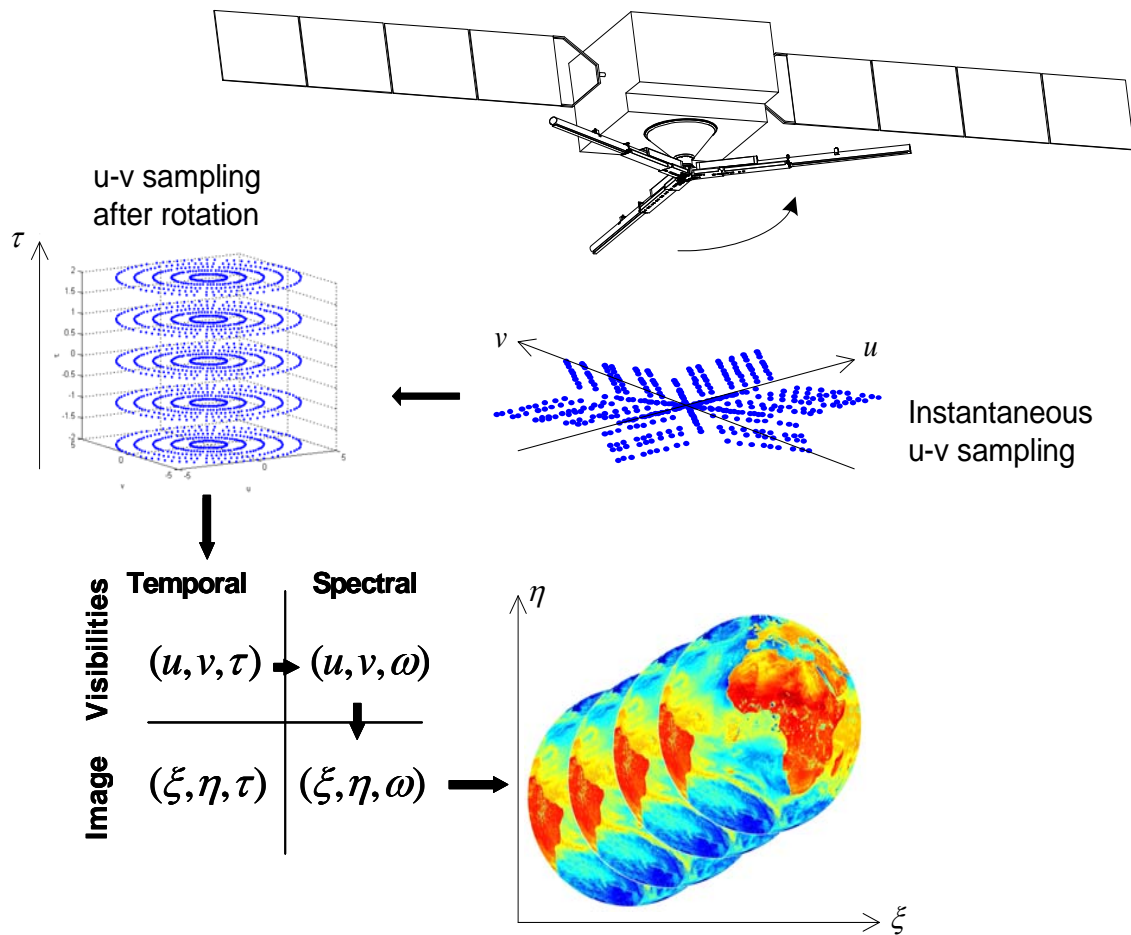
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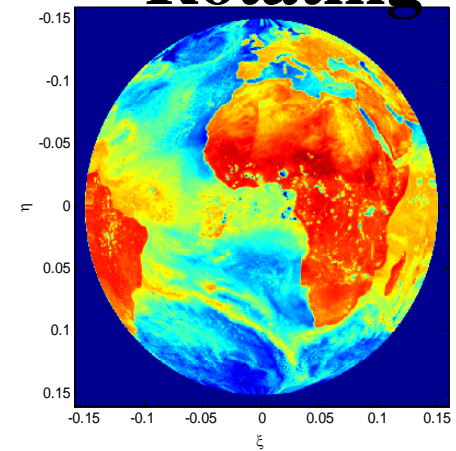
- TRP C1944900 - Geo Atmospheric Sounder, 2.5M (TEC-EEA)
 - **Phase 1 Feasibility**
 - **Phase 2 Demonstrator Development**



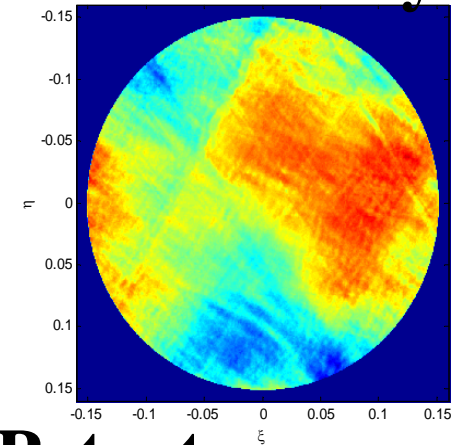
Rotating Interferometer Concept



Rotating

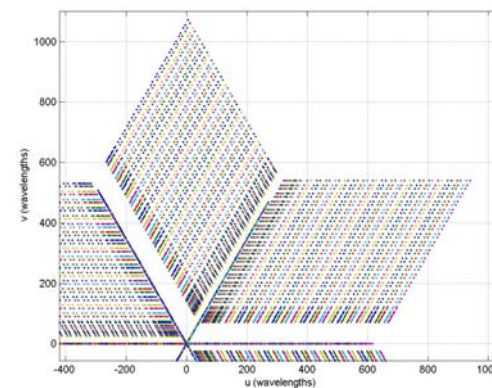
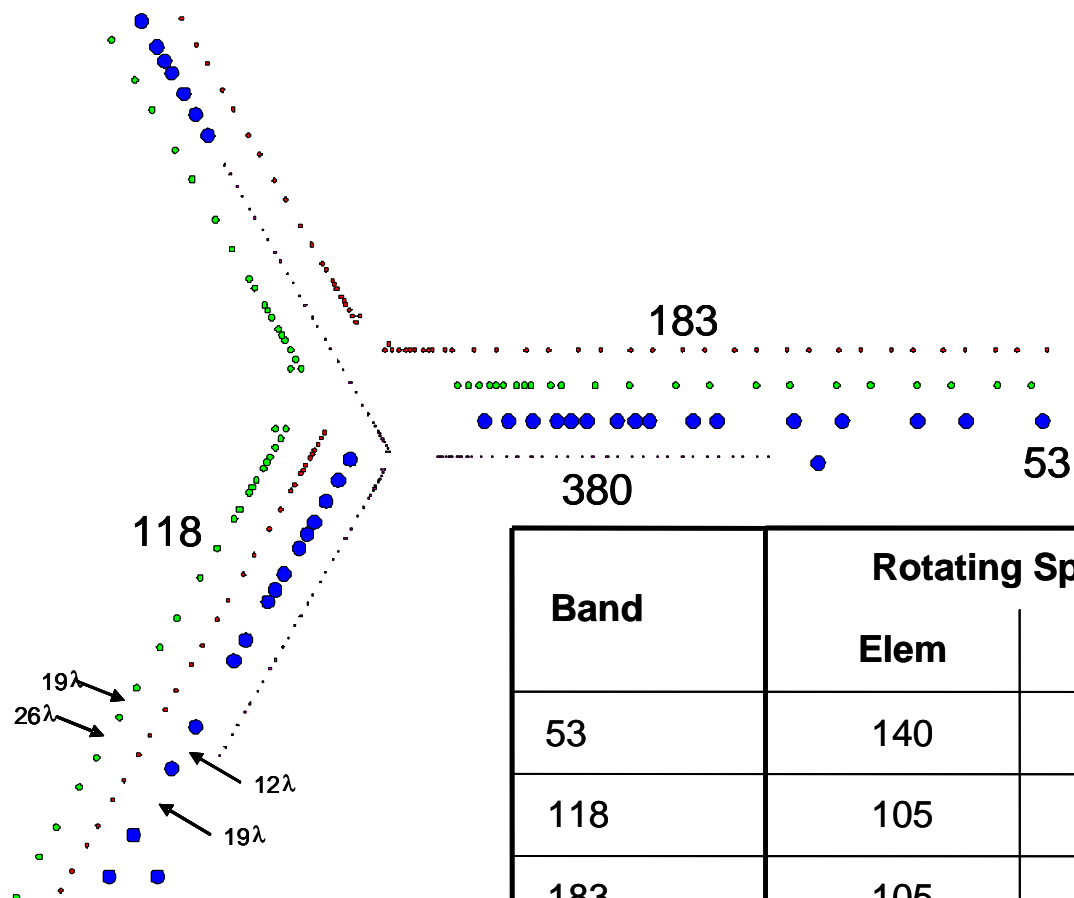


Stationary



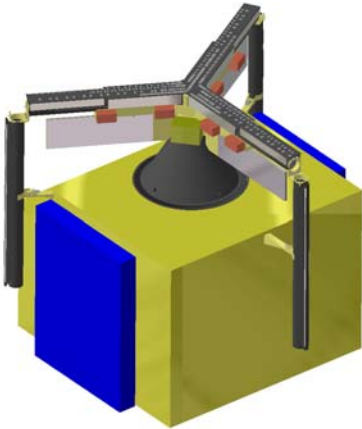
Concept is protected by ESA Patent

Element Layout

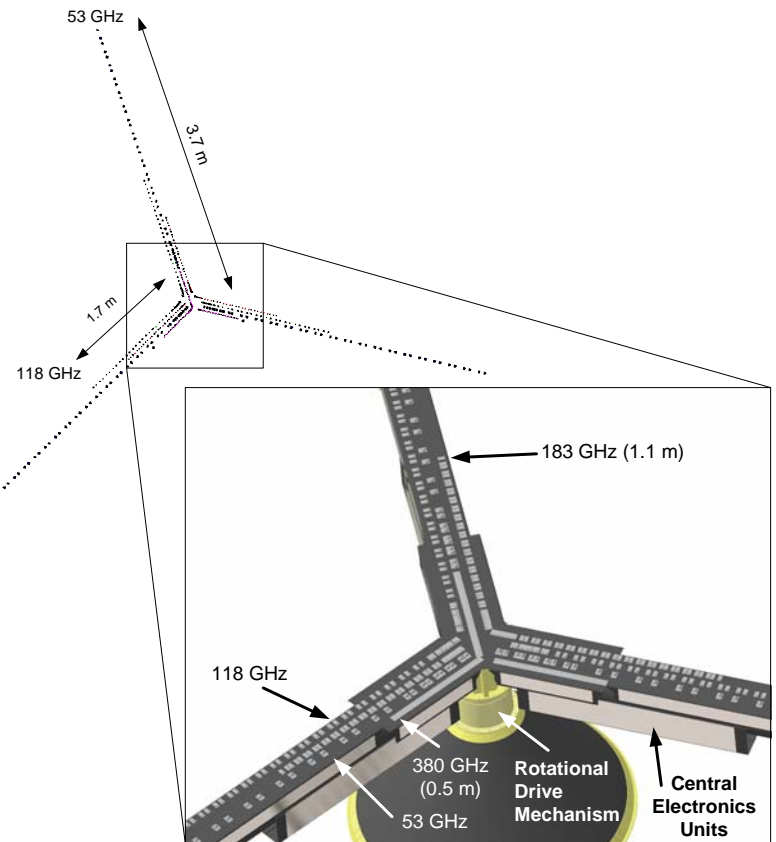


Band	Rotating Sparse Y		Stationary Full Y	
	Elem	Pairs	Elem	Pairs
53	140	10k	630	200k
118	105	5k	630	200k
183	105	5k	630	200k
380	105	5k	630	200k
Total	450	25k	2500	800k

Feasibility Results



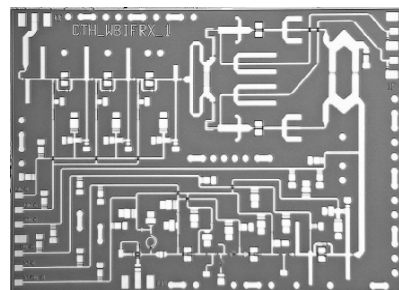
- Full polarization
- Power: 350 W
- Mass: 400 kg



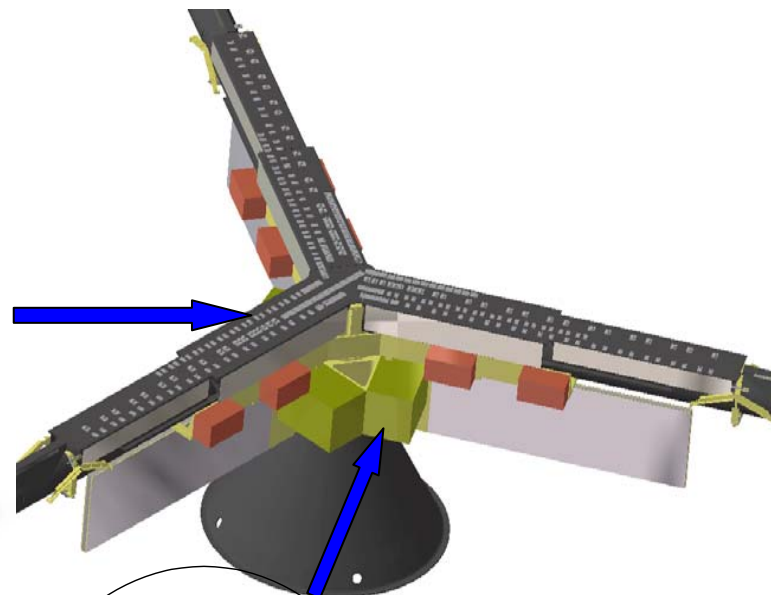
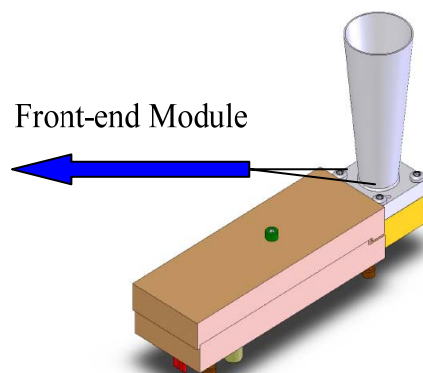
<i>Error contribution</i>	<i>Frequency band / no. of elements</i>			
	<i>53 GHz 136 elem</i>	<i>118 GHz 107 elem</i>	<i>183 GHz 107 elem</i>	<i>380 GHz 107 elem.</i>
<i>Thermal noise</i>	<i>0.35 K</i>	<i>0.7 K</i>	<i>0.8 K</i>	<i>2.2 K</i>
<i>Residual complex gain cal</i>	<i>0.15 K</i>	<i>0.4 K</i>	<i>0.4 K</i>	<i>0.8 K</i>
<i>Residual abs. amplitude cal</i>	<i>0.2 K</i>	<i>0.4 K</i>	<i>0.4 K</i>	<i>0.8 K</i>
<i>Antenna complex pattern</i>	<i>0.20 K</i>	<i>0.4 K</i>	<i>0.4 K</i>	<i>0.7 K</i>
<i>Pointing & Position errors</i>	<i>0.1 K</i>	<i>0.15 K</i>	<i>0.15 K</i>	<i>0.3 K</i>
<i>Total RSS error:</i>	<i>0.48 K</i>	<i>1.0 K</i>	<i>1.1 K</i>	<i>2.6 K</i>

Identified key components

Front-end MMIC

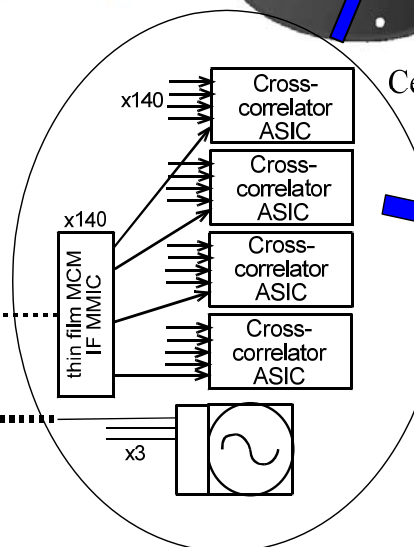
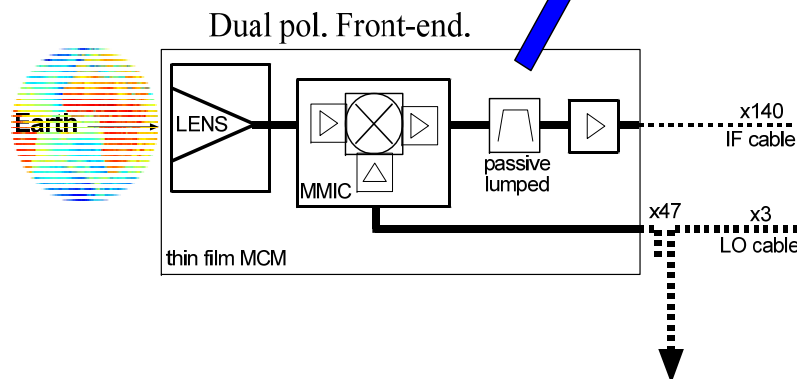
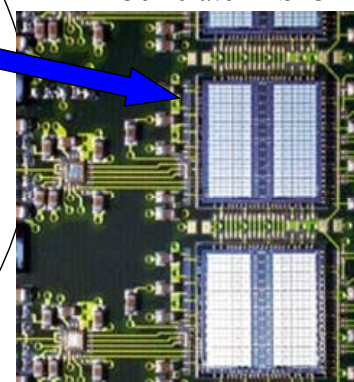


Front-end Module



Central Electronics

Correlator ASIC

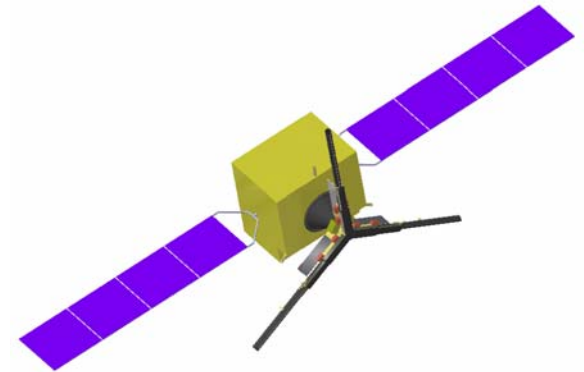
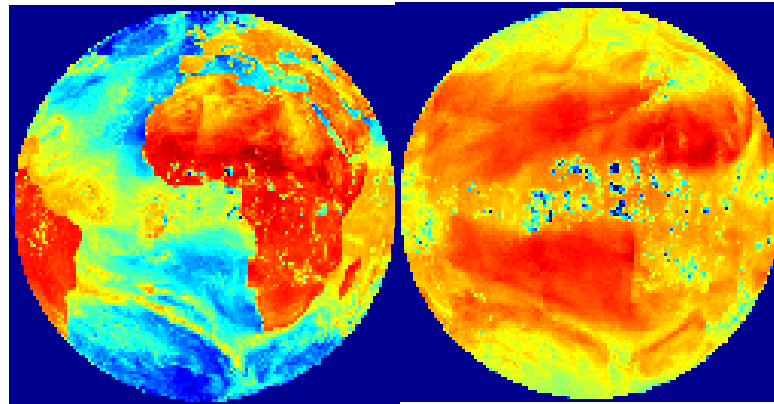
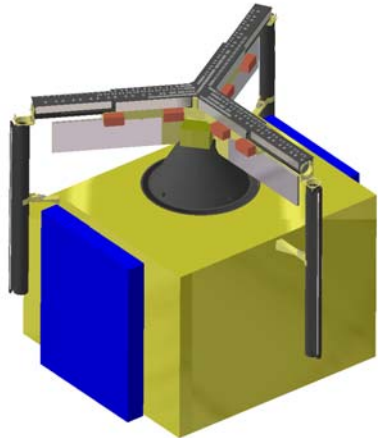


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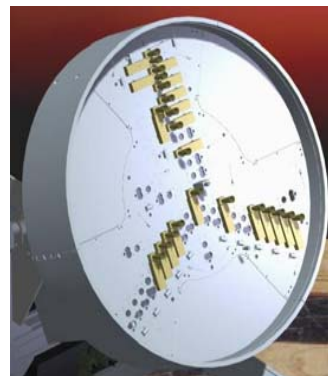
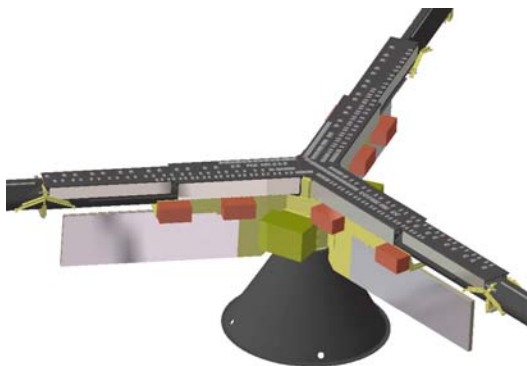


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TEC-EEA

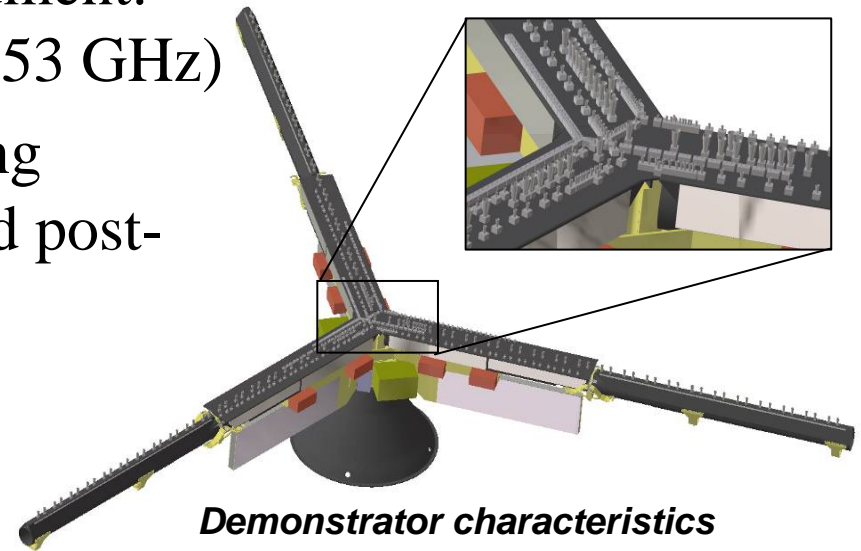
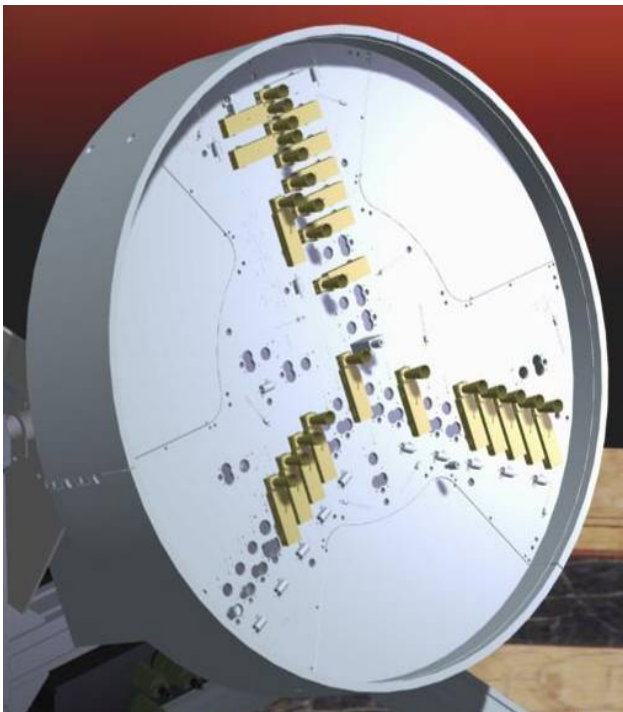


- TRP C1944900 - Geo Atmospheric Sounder, 2.5M (TEC-EEA)
 - Phase 1 Feasibility
 - **Phase 2 Demonstrator Development**



53 GHz demonstrator

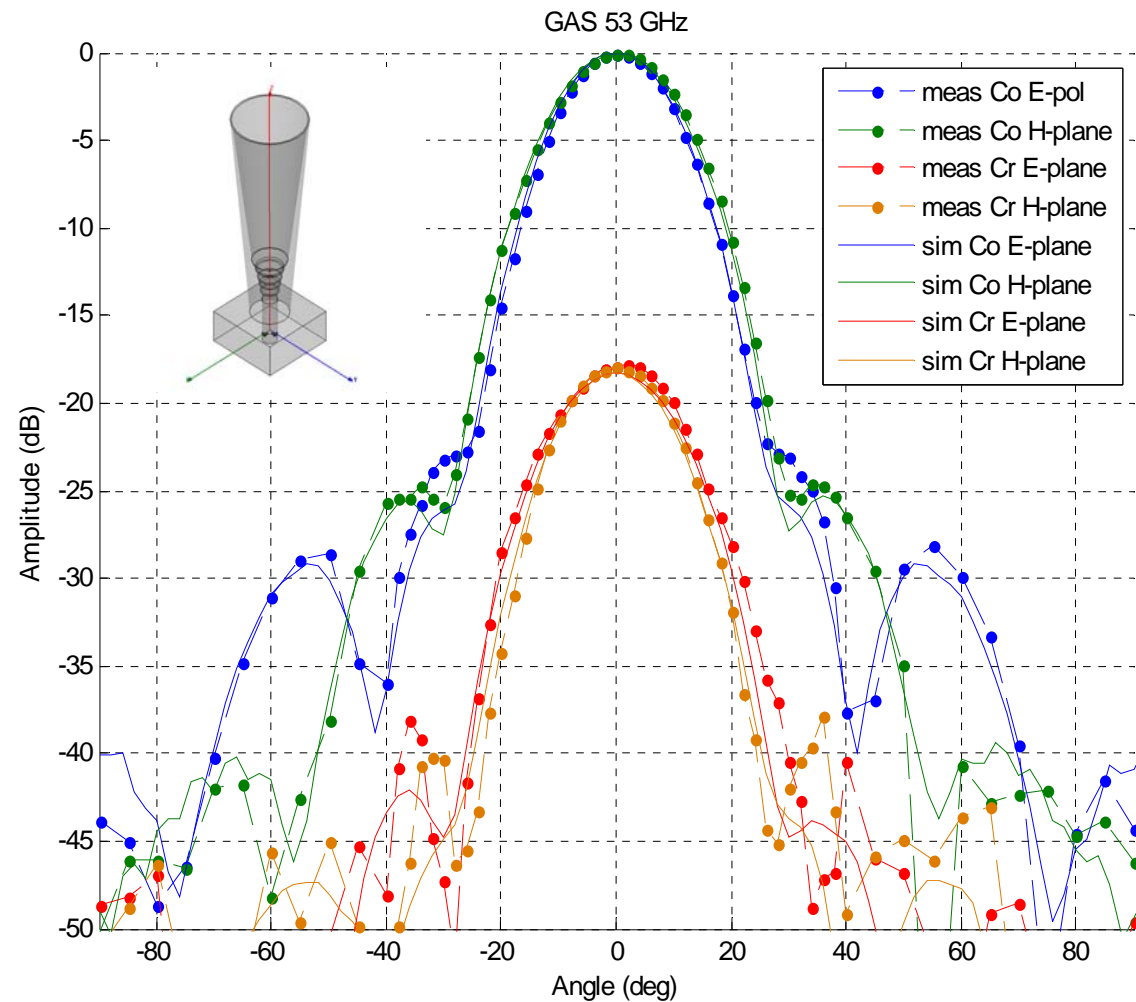
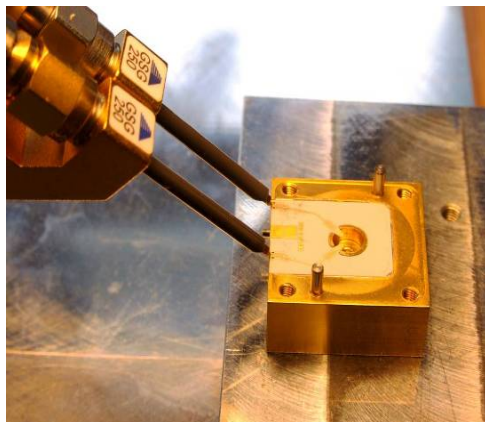
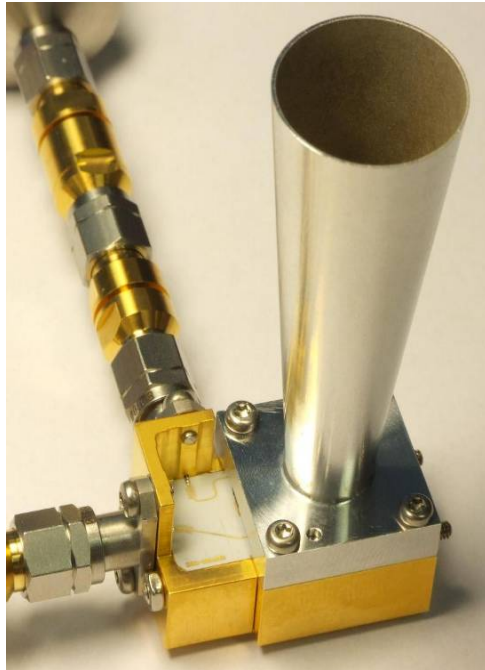
- Includes the central part of the instrument: 21 dual-pol interferometer elements (53 GHz)
- Objective: to demonstrate the imaging concept with rotation, calibration, and post-processing



Demonstrator characteristics

Parameter	Value	Remark
Frequency band	49-53 GHz	Single 90 MHz channel
Number of elements	21	
Longest baseline	75 cm	$\sim 140 \lambda$
Image Resolution	7 mrad	~ 300 km on earth
Relative accuracy	2K	

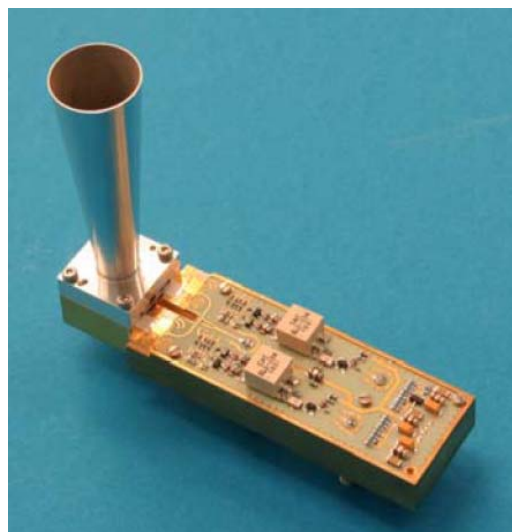
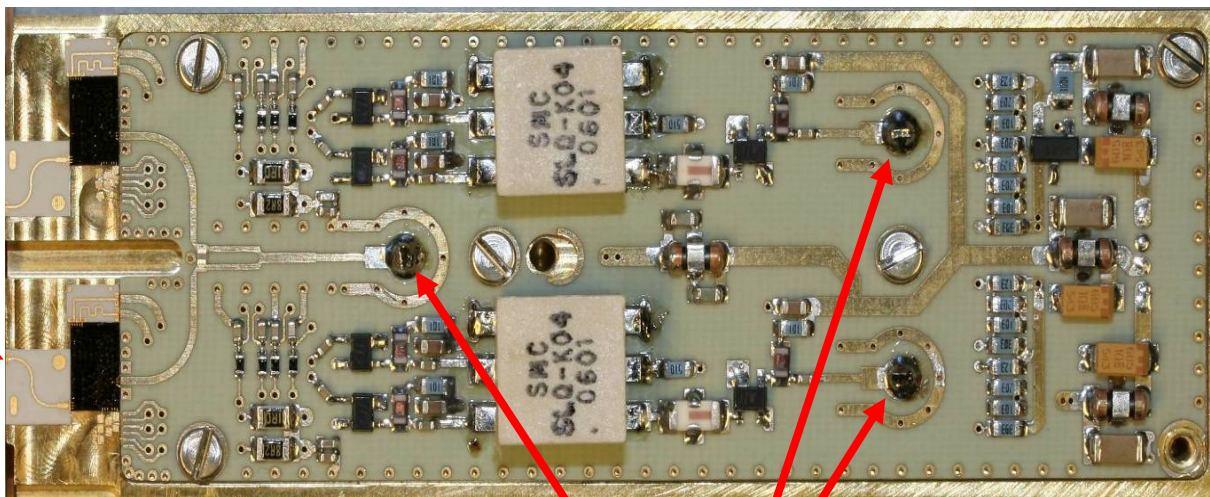
Antenna design and performance



Coupling between neighbouring elements: < -67 dB

Front-end design and performance

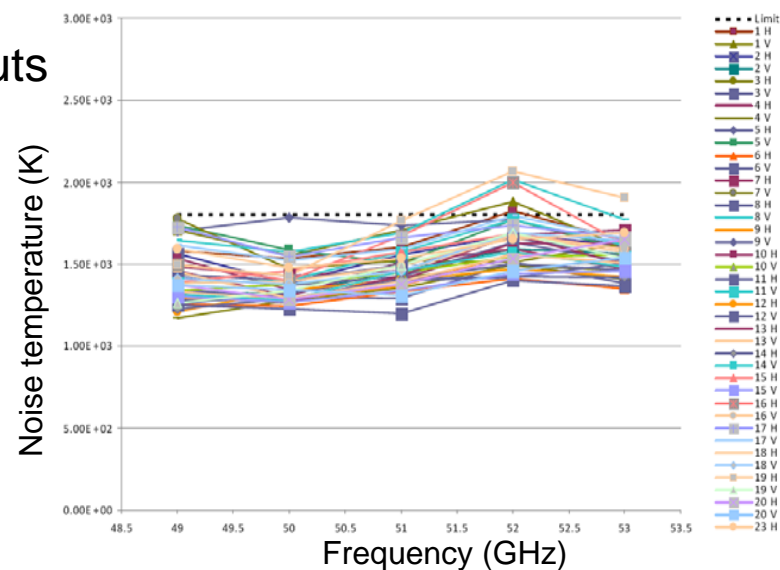
Antenna
RF
inputs
(2 pol)



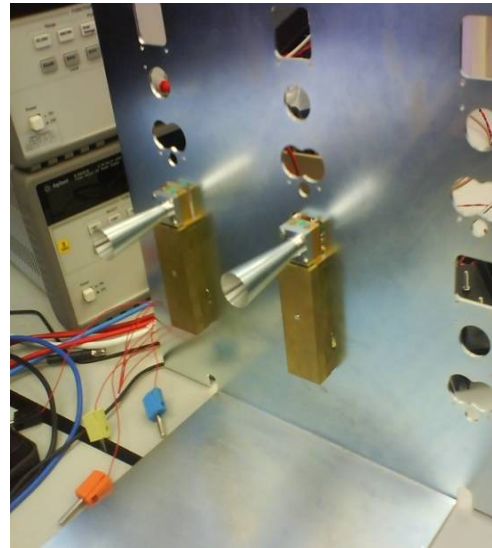
LO
input

IF outputs

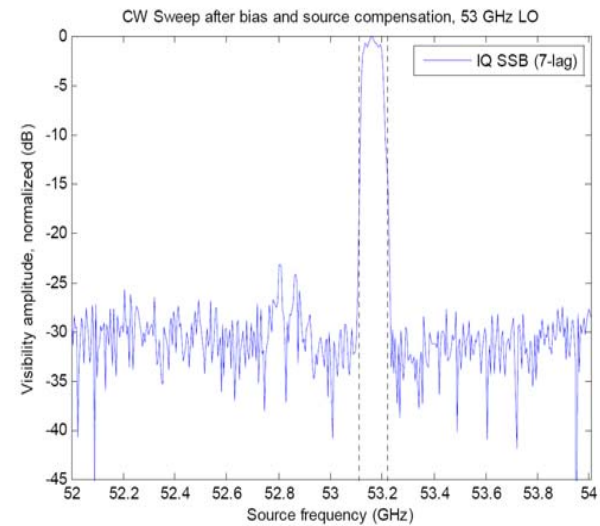
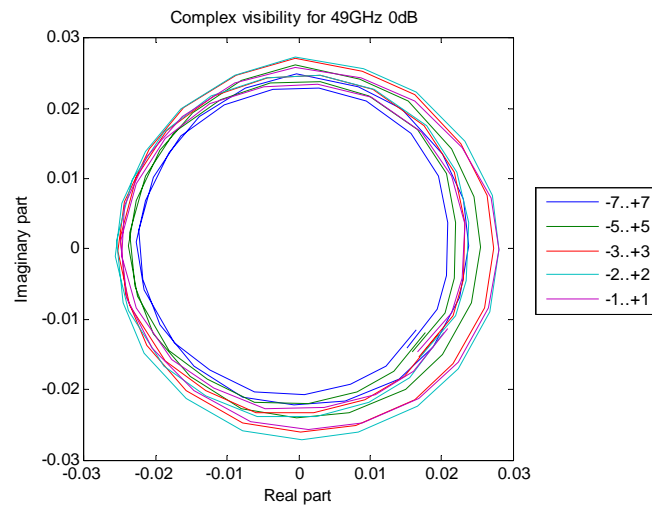
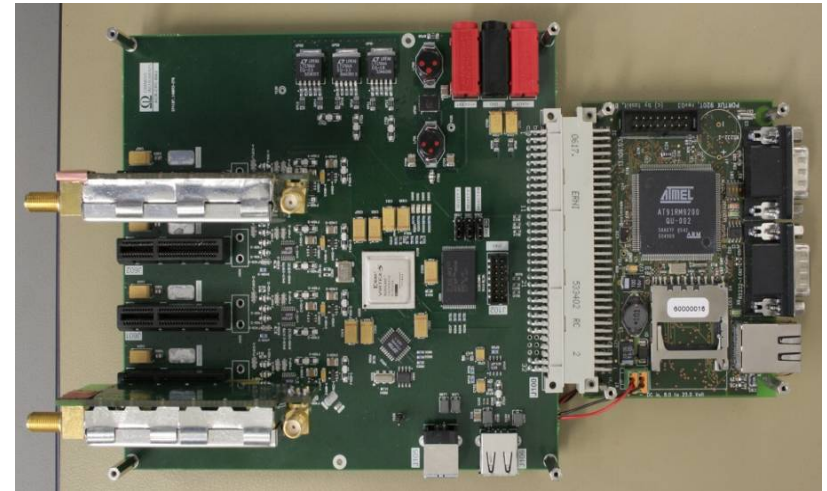
Measurements
with
front-end
electronics and
horn antenna
integrated



Back-end design and performance

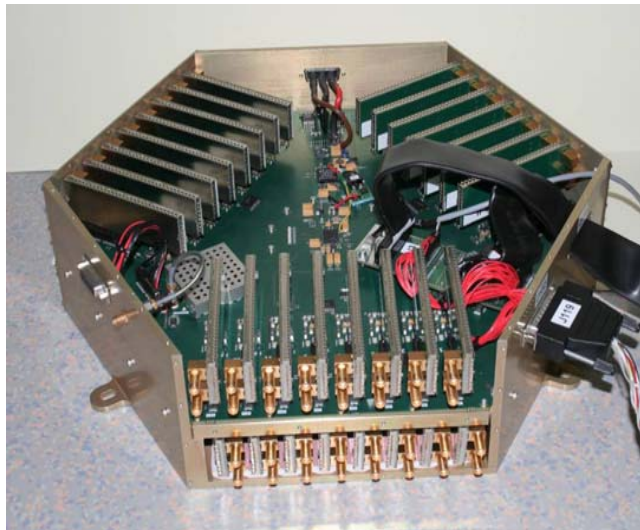


IF conditioning and 1.5 bit cross correlation in FPGA

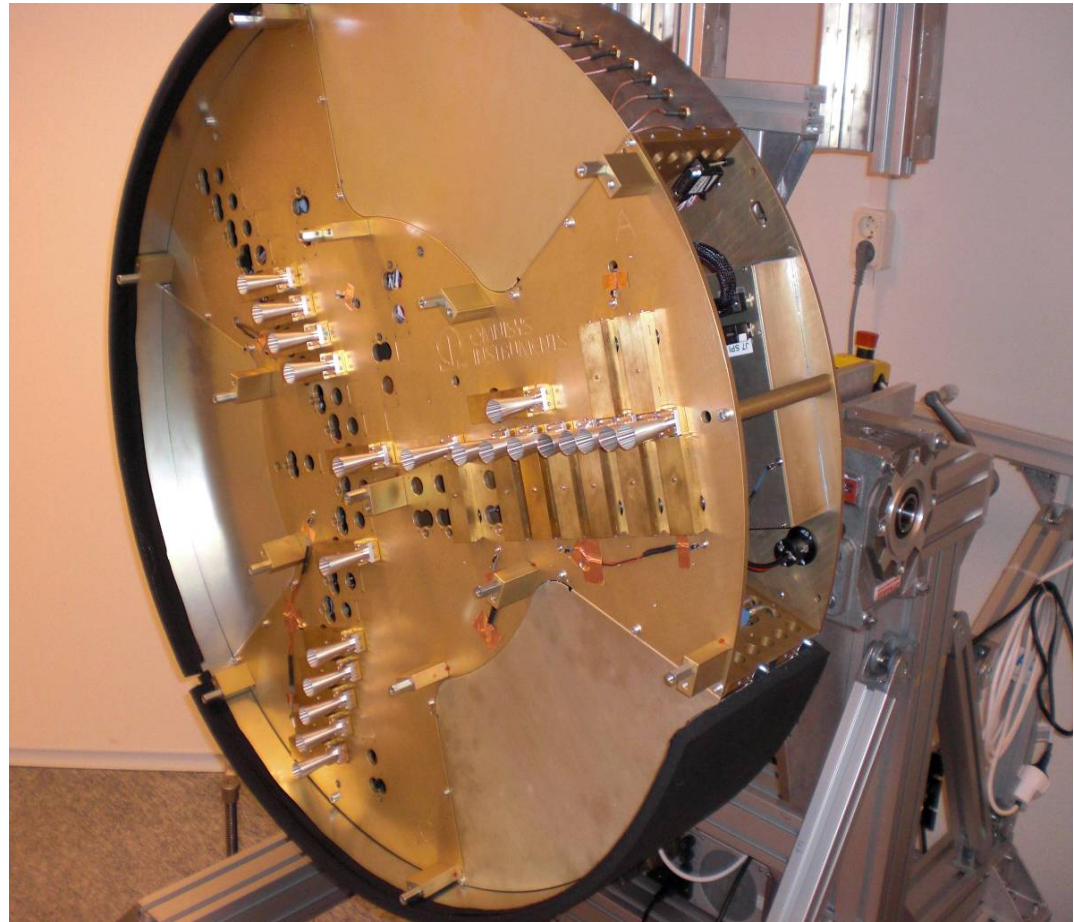


Demonstrator integration

21 front-ends with antennas



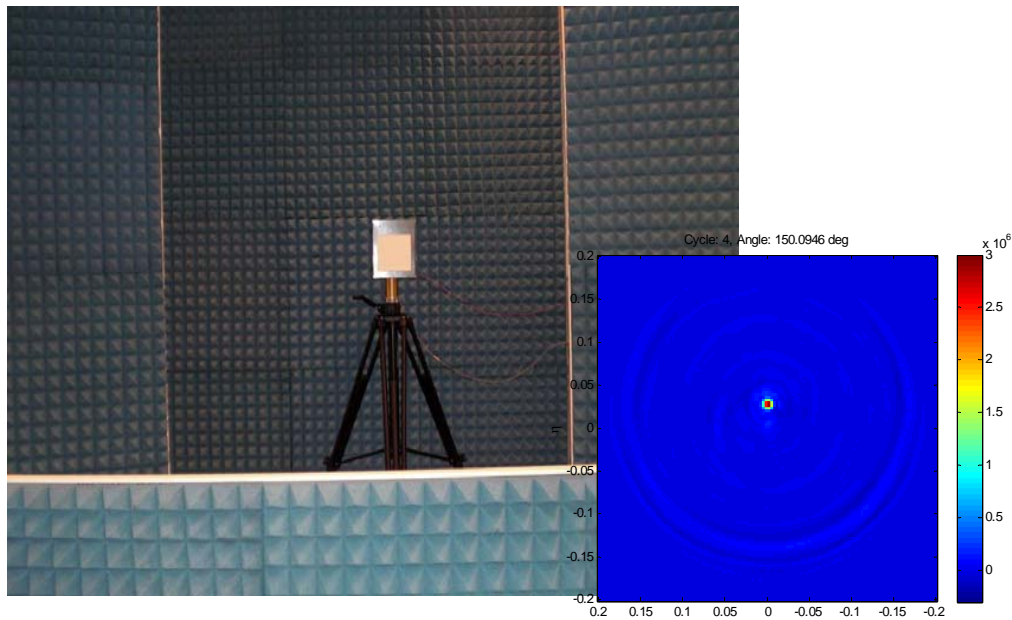
Cross-correlator core (42 inputs)



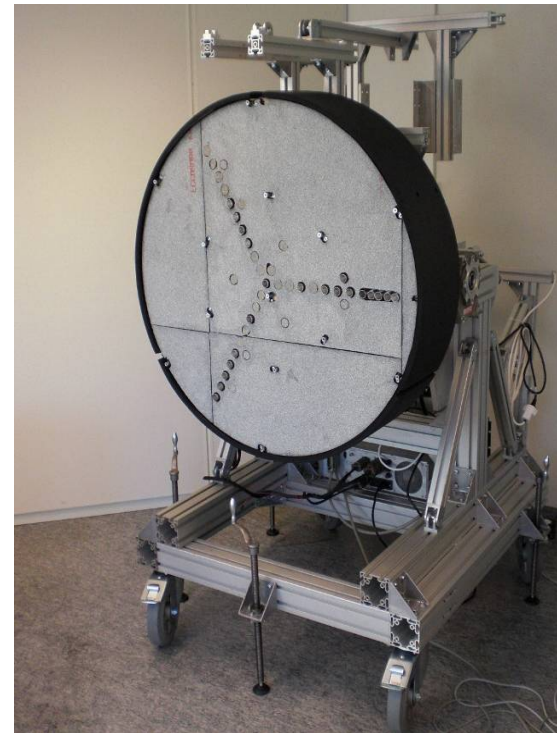
Assembled on rotational drive

Demonstrator test campaign

- *Sources*
- Calibration sources: Hot & Cold Loads
- Imaging sources; Noise point source
- CW point sources
- Distributed source
- *Parameters to verify*
- Image angular resolution
- Image beam efficiency
- Image polarisation isolation
- Image relative accuracy



Preliminary image result for a point source

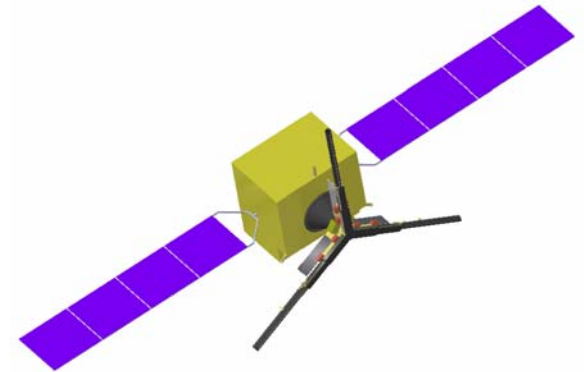
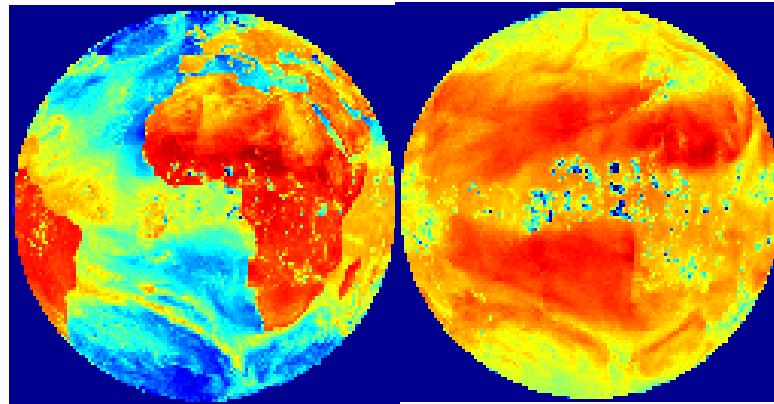
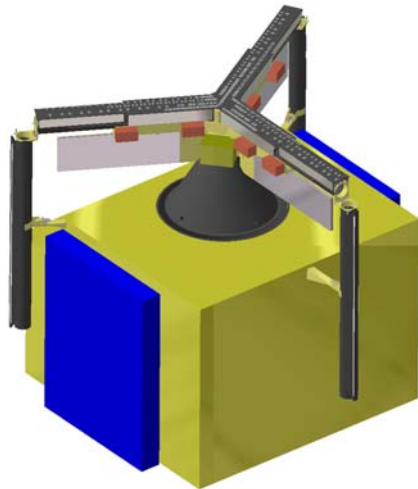


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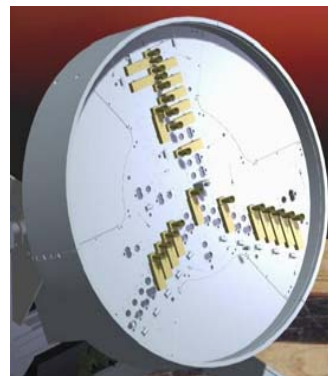
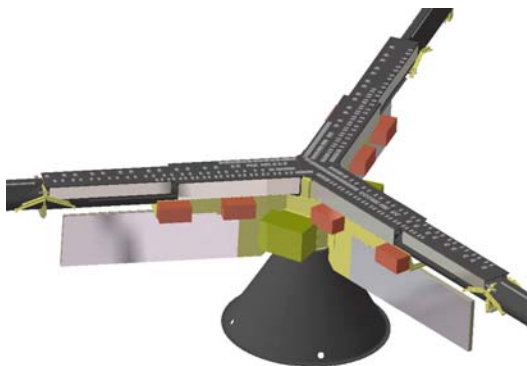


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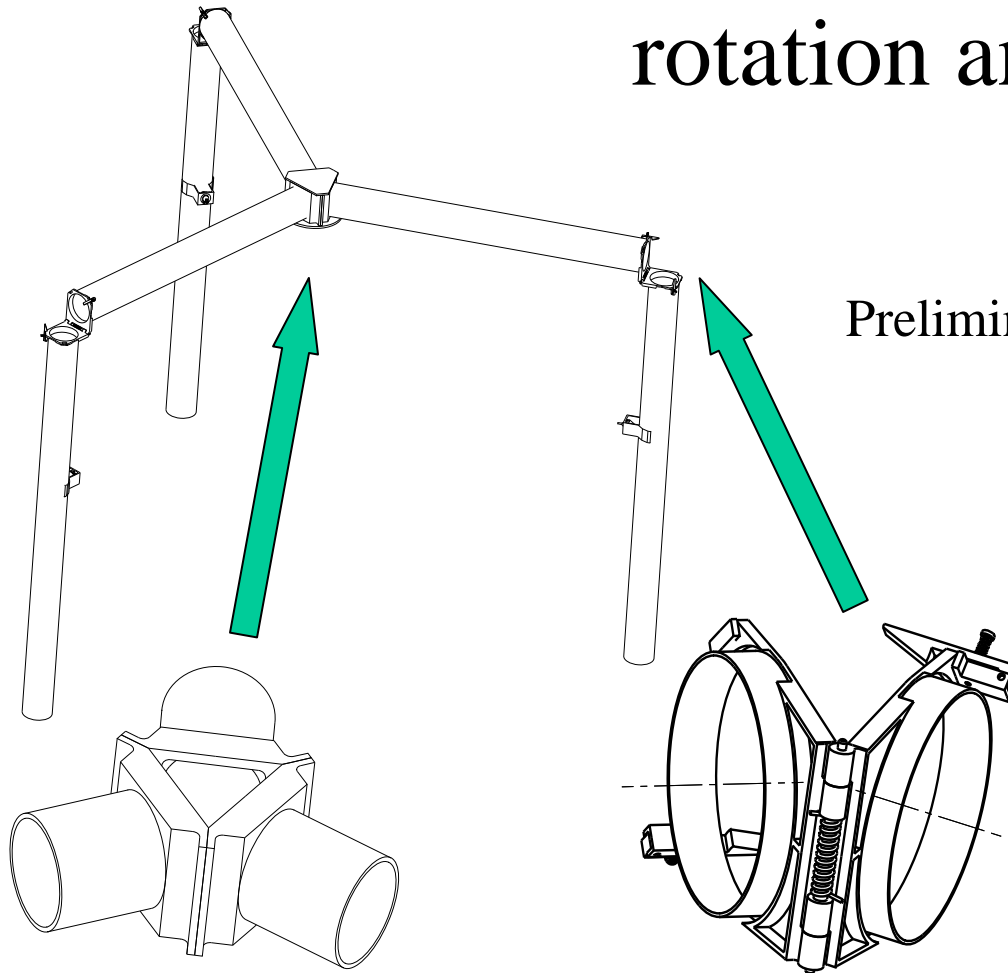


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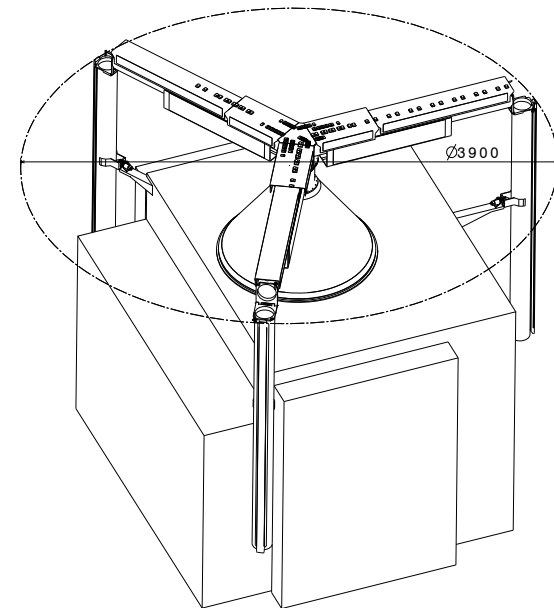


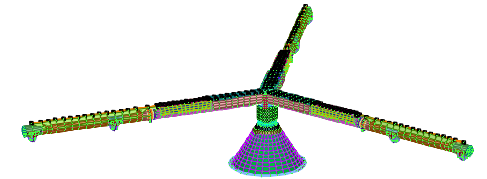
Boom System

- Focuses on the mechanical rotation and deployment.



Preliminary Launcher Accommodation

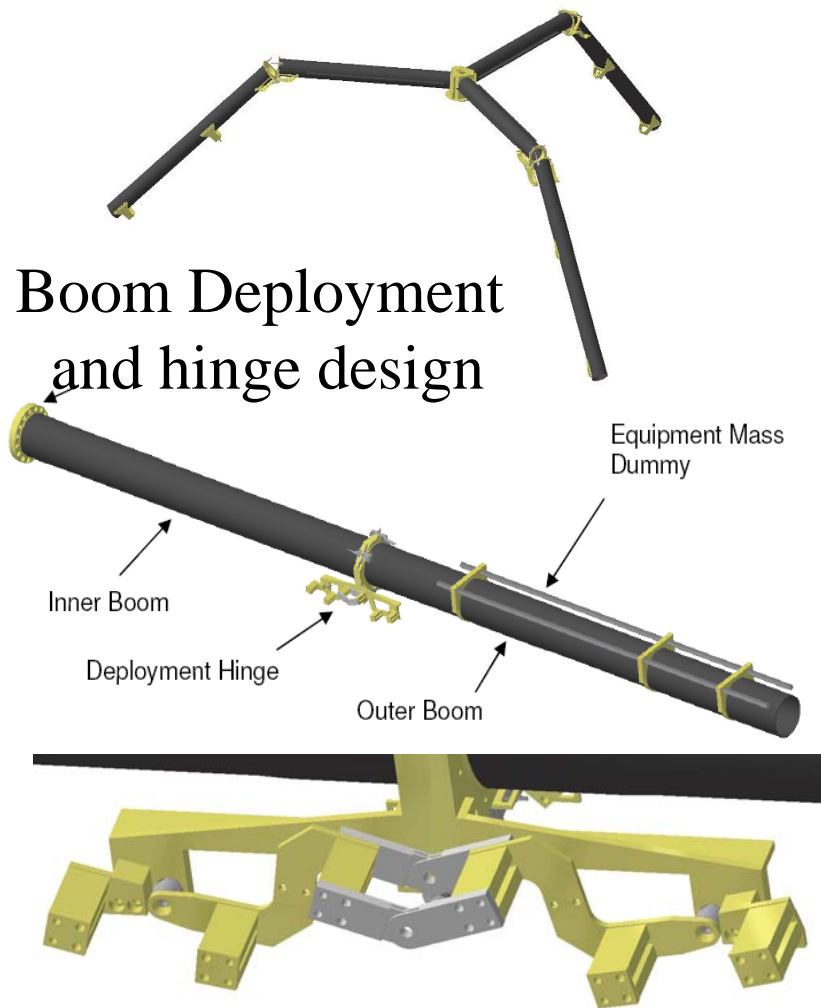




Main objectives:

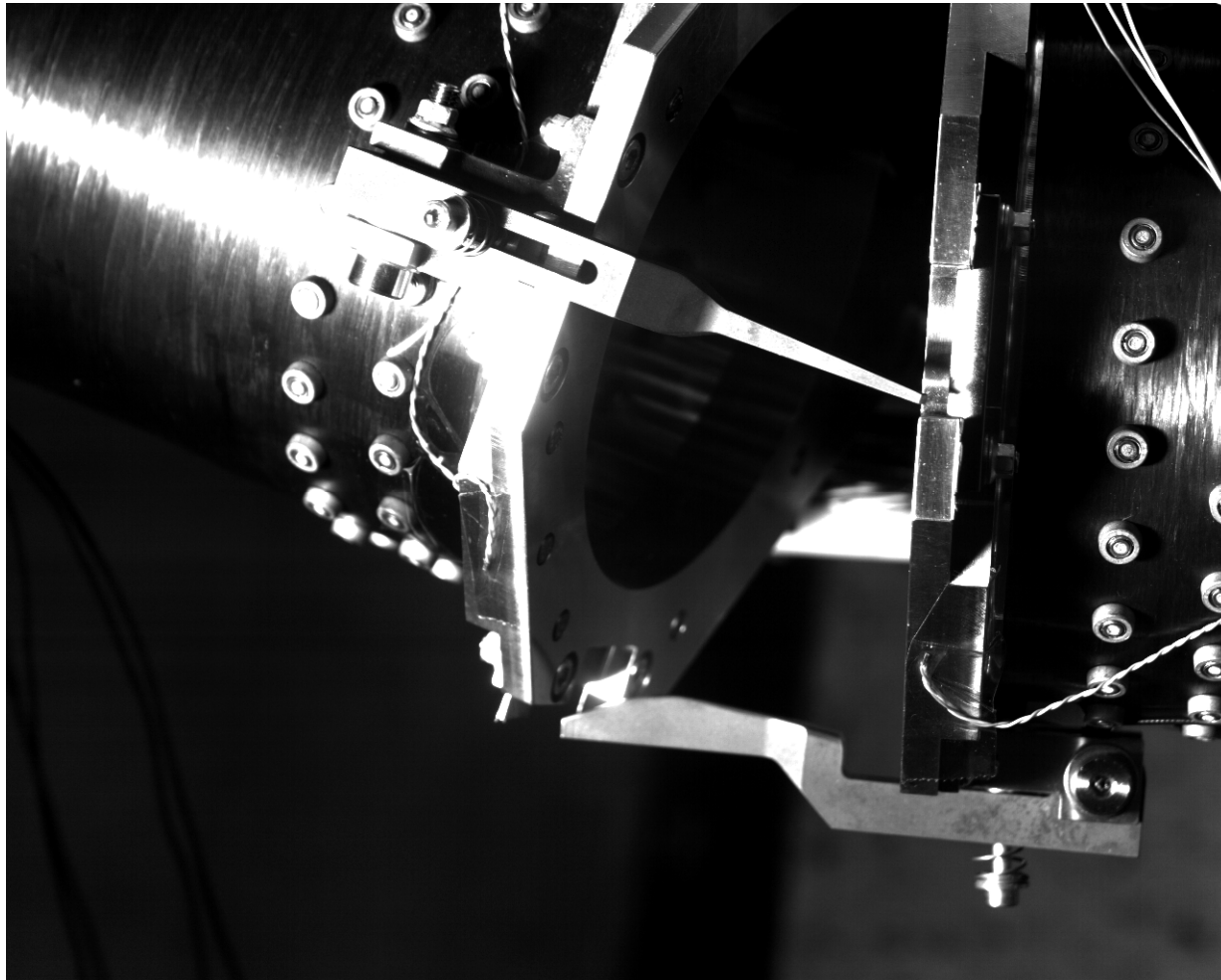
- Detailed design of Thermal and Mechanical Subsystem
- Rotational stability demonstration by simulation
- Design verification tests of boom deployment hinge

*Extensive measurement campaign conducted.
Preliminary conclusions of stability analysis and on-ground deployment testing allow to confirm the preliminary system requirements and no major showstoppers have been identified so far.*



- Deployment testing with RF cables

High Speed Video of Latch Mechanism

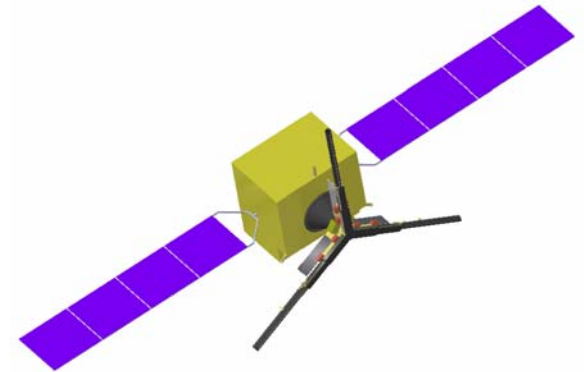
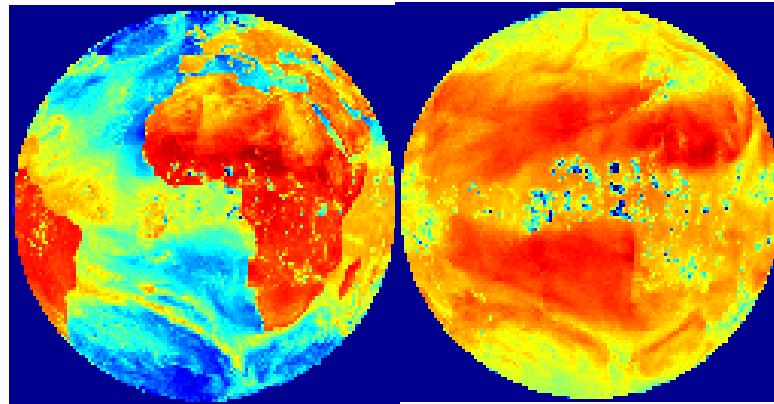
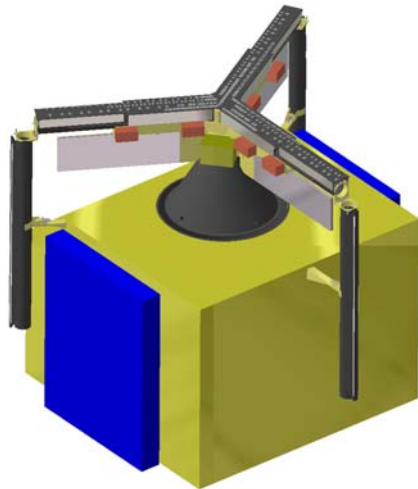


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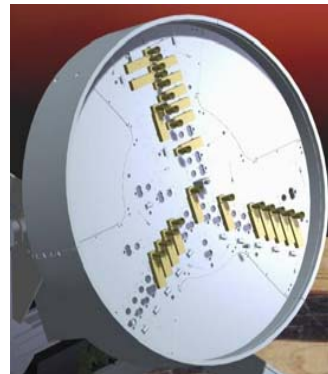
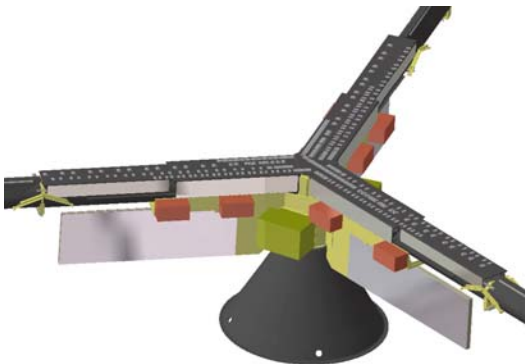


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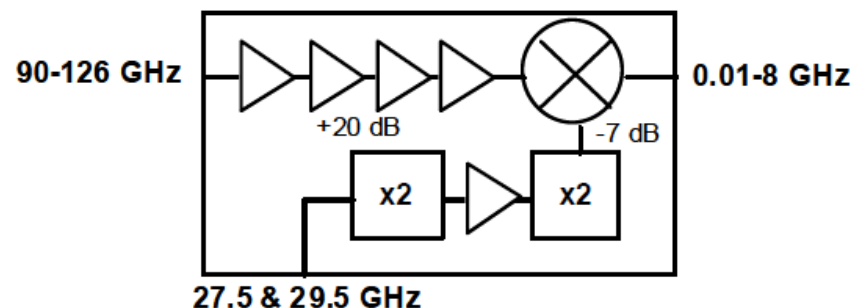
TEC-EEA



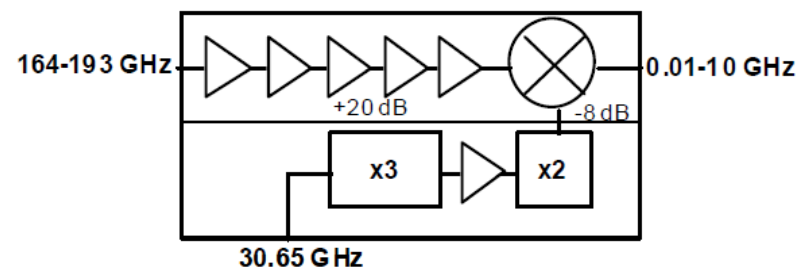
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- Omnisys Instruments & Chalmers University (design)
- Fraunhofer Institute IAF (manufacturing)
- 100 nm MHEMT MMIC process
- Preliminary (on-wafer) measurements:
 - $G_c = 12$ dB, $NF = 3$ dB @ 118 GHz
 - $G_c = 9$ dB, $NF = 7$ dB @ 183 GHz
- An activity has been started for packaging the chips into waveguide packages

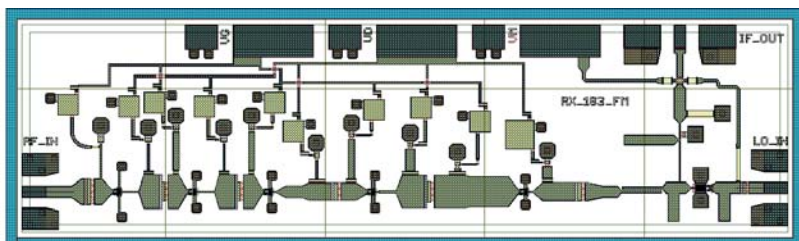


118 GHz front-end – single chip

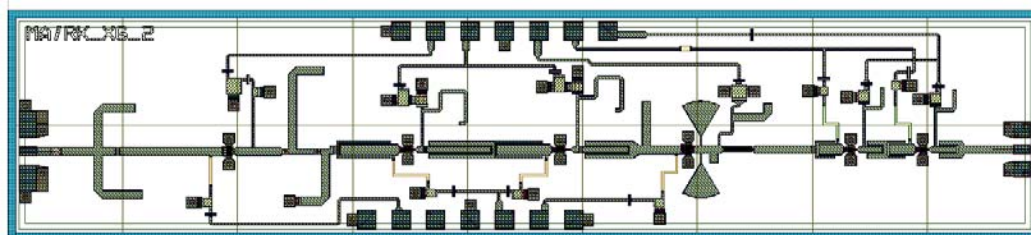


183 GHz front-end – two chips

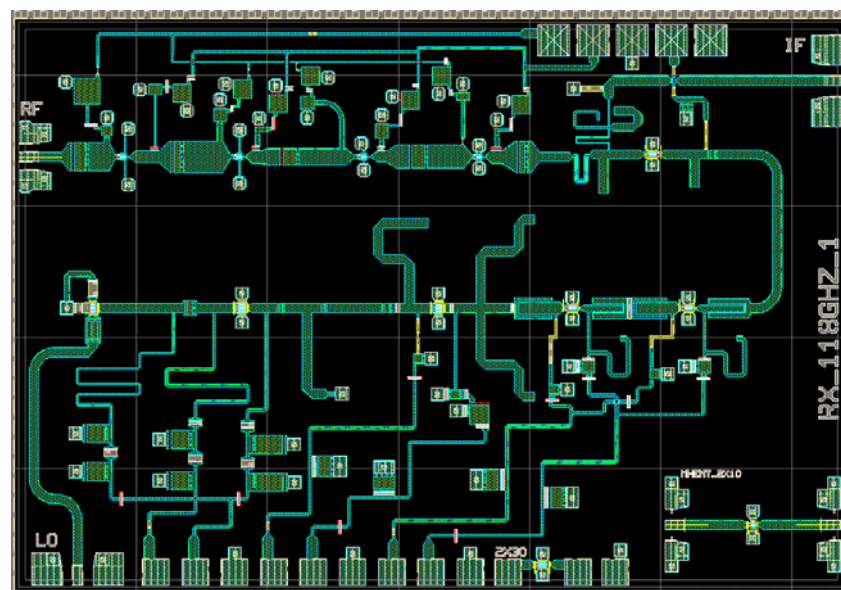
Geosounder MMIC



183 GHz LNA + mixer

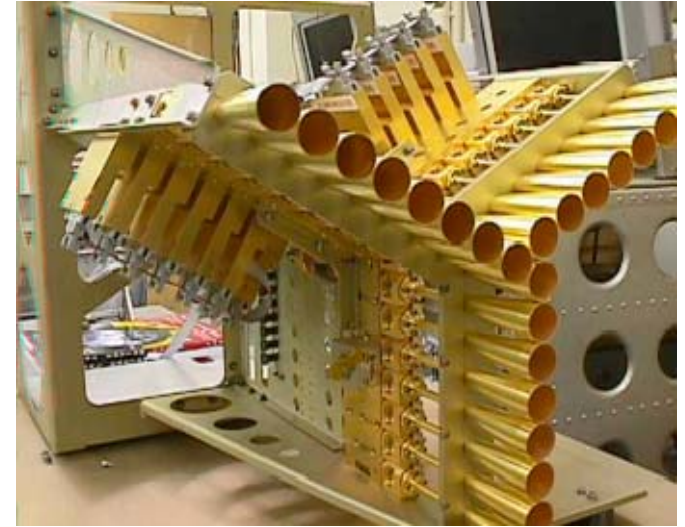


183 GHz LO chain

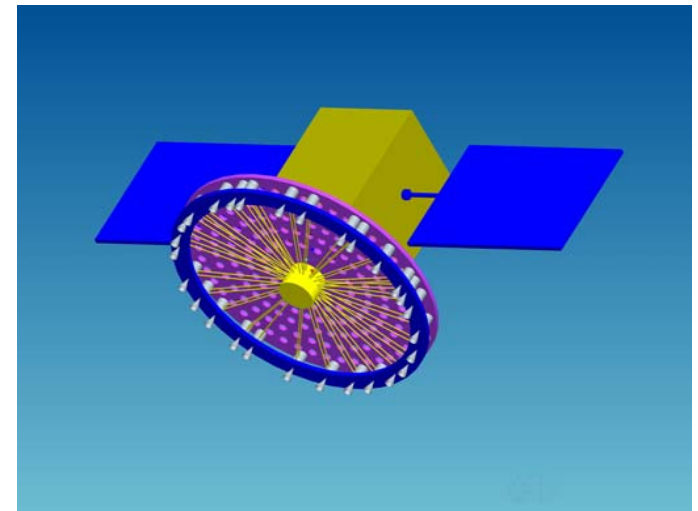


118 GHz front-end – single chip

Geosynchronous Synthetic Thinned Array (GEO-STAR)



Geostationary Interferometric Millimeterwave Sounder (GIMS)



Conclusion



- GAS enables brightness temp. measurements from GEO:
 - 15 min & 30 km resolution, f : 53,118,183,380 GHz.
 - Full disc coverage with dual polarization
- Mechanical rotation makes the concept feasible:
 - 75% saving of required number of mm-wave front-ends
 - Total mass and power budget: 400 kg / 350 W
 - Sparse arrays permits multiple interlaced interferometers
- Integration and test ongoing, results available July 2010