3EPE03

Development and characterization of the Superconducting Integrated Spectrometer for TELIS (part 1: SIR channel design)

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Abstract

The balloon borne instrument TELIS (Terahertz Limb Sounder) is a three-channel balloon-borne heterodyne spectrometer for atmospheric research by detections spectral lines of the stratospheric trace gases that have their rotational transition lines at THz frequencies. A fully superconducting integrated receiver (SIR) is implemented for one of the three TELIS channels. The main SIR idea is to integrate on a single crystal all the components needed for super heterodyne receiving such as an SIS-mixer with its quasioptical antenna, a Flux-Flow oscillator as a local oscillator, a harmonic mixer to phase-lock the FFO. Light weight and low power consumption combined with nearly quantum limited sensitivity make SIR a perfect candidate for many airborne missions. As a result of recent receiver's optimization the DSB noise temperature was measured as low as 120 K for the SIR with intermediate frequency band 4-8 GHz. The spectroscopic Allan stability time is about 20 seconds; required spectral resolution confirmed by gas cell measurements. Several algorithms for remote automatic computer control of the SIR have been developed and tested. Preliminary results of the first flight are presented.

TELIS - TErahertz LImb Sounder

TELIS Objectives:

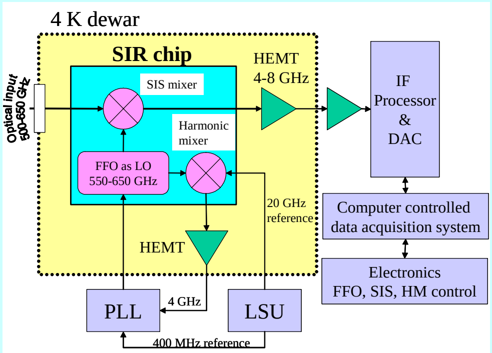
- Measure many species for atmospheric science (ClO, BrO, O_3, HCl, HOCl, etc);
  - Chemistry, Transport, Climate
- Serve as a test platform for new sensors
- Serve as validation tool for future satellite missions

Three independent frequency channels, cryogenic heterodyne receivers:

- 500 GHz by RAL
- 500-650 GHz by SRON-IREE
- 1.8 THz by DLR (PI)

- 495.04 GHz and 496.96 GHz for the water isotopes;
- 506.56 GHz for the BrO;
- 515.25 GHz for the pointing and H_2CO and H_2O_2;
- 519.25 GHz for the BrO and HNO_3;
- 607.78 GHz for the HCN and ozone isotopes;
- 619.10 GHz for the chlorine chemistry.

Superconducting Integrated Receiver



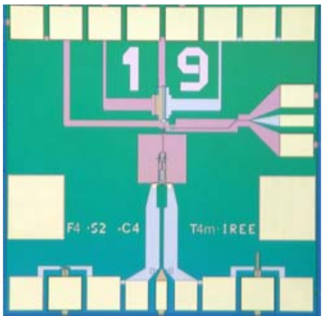
Schematics of the SIR with a phase-locked LO.

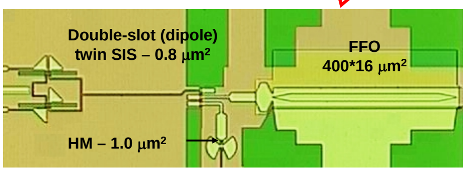
The FFO signal is mixed in the HM with the 19-21 GHz reference. The mixing product is amplified, down converted and compared with the 400 MHz reference in the PLL. The phase difference signal generated by PLL is used to feedback the FFO control line

SIR Chip Design

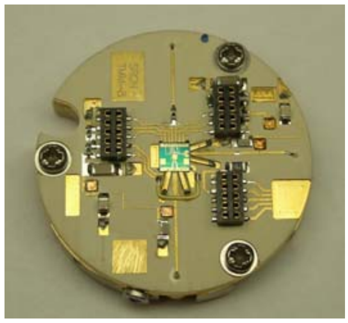
Silicon (Si);
4 x 4 x 0.5 mm^3
Nb-AlO_x-Nb or
Nb-AlN-NbN;
J_C = 5 - 10 kA/cm^2

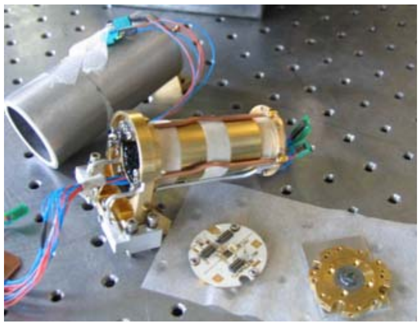
Optionally:
SIS – J_C = 8 kA/cm^2;
FFO + HM = 4 kA/cm^2

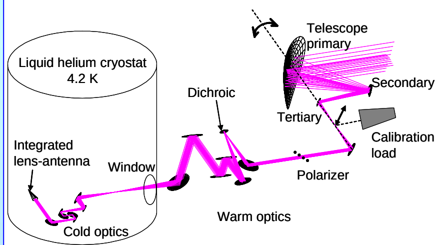




SIR Mixer Block and Schematics of the SIR Channel Optics

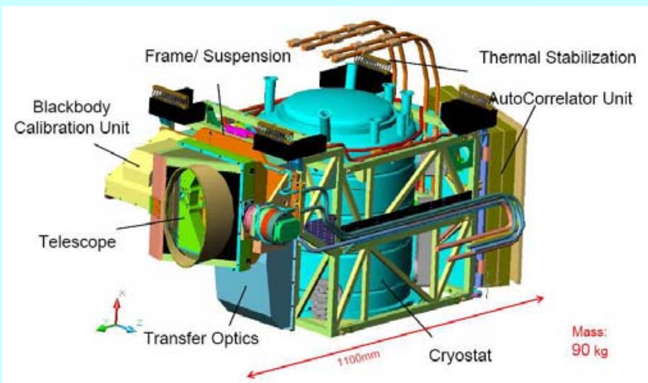


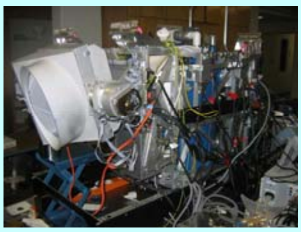




Wire grid polarizer and dichroic plate are used to separate this receiver from the two other frequency channels (not shown). The cold optics and mixer element are located inside the cryostat at the ambient temperature 4.2 K

TELIS Instrument Model and Photo





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Development and characterization of the Superconducting Integrated Spectrometer for TELIS (part 2: SIR channel characterization)

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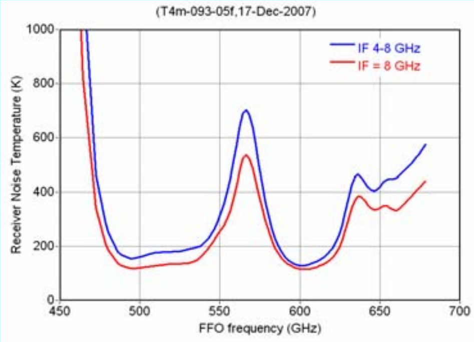
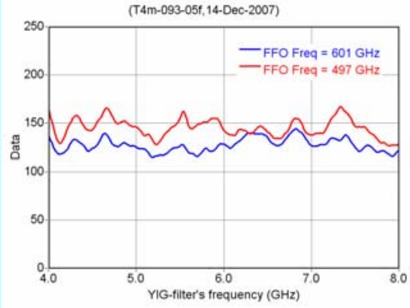
TELIS-SIR Main Parameters

#	Description	Value (Spec)
1	Input frequency range, GHz	500 – 650 (550 – 650)
2	Minimum noise temperature (DSB), K	120 (250)
3	Output IF range, GHz	4 - 8 (5 - 7)
4	Spectral resolution (width of the spectral channel), MHz	< 1 (2)
5	LO frequency net, MHz	< 300
6	Dissipated power at 4.2 K stage (including IF amplifiers chain), mW	<30 (100)
7	Operation temperature, K	< 4.5

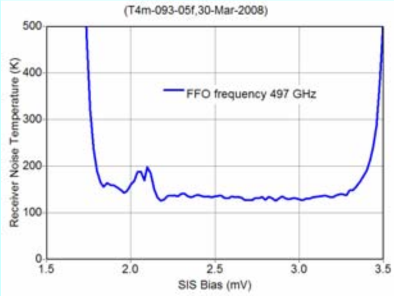
SIR Noise Temperature



DSB receiver noise temperature of the SIR device selected for flight measured at 8 GHz IF frequency (red line) and integrated in the 4-8 GHz IF range (blue curve)

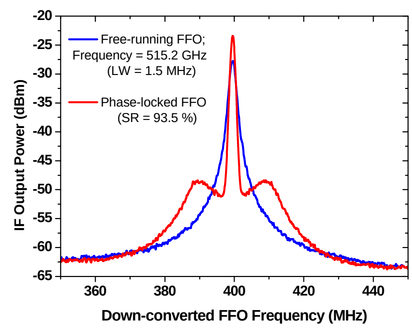


Receiver noise temperature as a function of IF frequency, taken at two FFO frequencies: 497 and 601 GHz

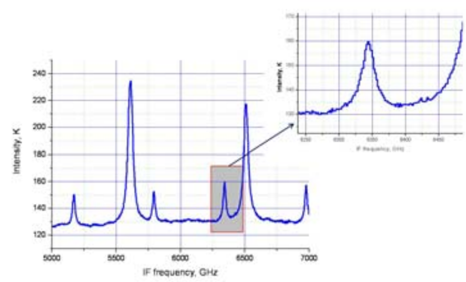


Receiver noise temperature as a function of the SIS bias measured at the FFO frequency 497 GHz

SIR Spectral Resolution

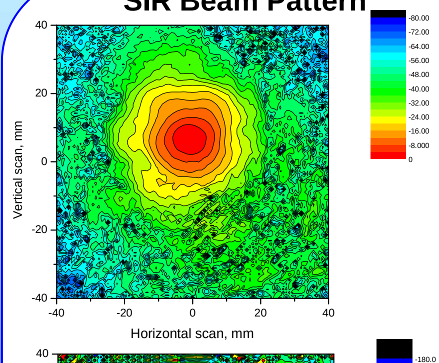


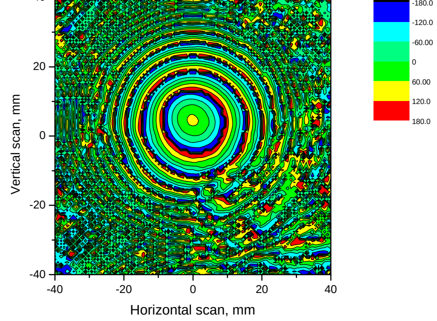
Spectra of the FFO operating at 515.2 GHz (red curve – frequency locked; blue curve – phase-locked). Linewidth (LW) = 1.5 MHz; Signal to Noise Ratio (SNR) = 36 dB; Spectral Ration (SR) = 93.5 %. Spectra measured with RBW = 1 MHz.



Deconvolved spectrum of the OCS emission lines at a gas pressure 2.6 mBar. LO frequency 601 GHz. Two strong lines are saturated; weaker lines are not saturated isotopes. The lines are detected, one in the LSB, the other one in the USB

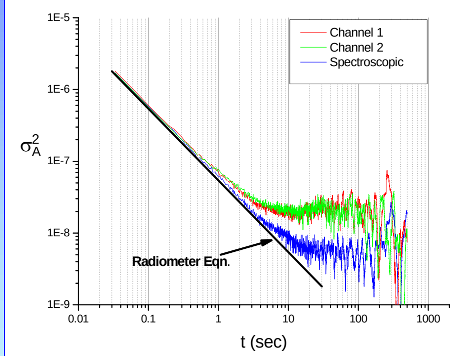
SIR Beam Pattern





SIR cold channel amplitude (upper panel) and phase (lower panel) distribution. Distance from the beam waist is 110 mm. Frequency is 600 GHz.

System Stability; Allan Variance



System stability of the SIR channel. FFO is phase locked at 600 GHz. Green and blue lines present individual channels variance, the black one is representative for the spectroscopic variance

TELIS-MIPAS launch in Teresina, Brasilia

Conclusions

Phase–locked SIR operation over frequency range 450 – 700 GHz has been realized, spectral resolution below 1 MHz has been confirmed by CW signal measurements. An uncorrected double side band (DSB) noise temperature as low as 120 K has been measured for the SIR with the phase-locked FFO and the intermediate frequency bandwidth 4 - 8 GHz. Capability of the SIR for high resolution spectroscopy has been successfully proven in a laboratory environment. To ensure remote operation of the phase-locked SIR several routines for its automatic computer control have been developed and tested.

The receiver has been installed into TELIS and integrated with the MIPAS gondola for the first flight. The maiden flight took place in June 2008. During the first few hours of the flight the instrument behaved normally, could be commanded and frequency switching algorithms worked well. However, due to thermal-mechanical problems no scientific data have been obtained. After the flight the TELIS-MIPAS gondola was successfully recovered, no damages occurred to both instruments. The housekeeping data is being currently analyzed to identify problems in order to improve system thermal design for the next flight, which is currently scheduled for winter 2009 in Kiruna, Sweden.

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