MILLIMETER WAVE RADIOMETER WITH ADJUSTABLE INTERNAL CALIBRATION LOAD FOR HIGH RESOLUTION MEASUREMENTS OF STRATOSPHERIC CONSTITUENTS

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Abstract – The advanced 268–280 GHz radiometer *MIRA2* for ground-based sounding of stratospheric minor constituents is presented. It is equipped with an internal adjustable calibration load that supplies every desired brightness temperature in between 80 K and 300 K. This enables very accurate balanced measurements of weak signals like the signature of ClO.

Keywords: adjustable calibration load, balanced measurement, millimeter wave radiometer

INTRODUCTION

Profiles of the volume mixing ratios of stratospheric trace gases can be retrieved by measuring the millimeter wave emissions that are caused by rotational transitions. The observable signatures are composed of pressure broadened contributions from a wide range of altitudes. The shape of the lines that are present in the measured spectra contains the specific information needed for inversion. In order to get accurate profiles it is necessary to achieve a high resolution both in frequency and intensity and to minimize disturbances caused inside the receiver.

MIRA2, the ground based radiometer developed at Karlsruhe, is optimized for simultaneous sounding of ClO and O_3 at 278 GHz and can also be tuned from 268 GHz to 280 GHz for detection of additional lines of O_3, HNO_3 and N_2O. It has been successfully operated during three measurement campaigns at Kiruna (1996 and 1998) and at Ny-Ålesund (1997, intercomparison of four ClO radiometers).

The advanced system, based on a heterodyne receiver, is operated in a balanced measurement mode making use of an adjustable reference load that was developed for this particular application.

SYSTEM DESCRIPTION

The front-end, that is manufactured by Radiometer Physics GmbH, uses free-space Gaussian beam optics to feed the atmospheric and LO signal into the mixer. All apertures are determined under consideration of twice the beam waist radius, which is mostly 10 mm. The components are mounted on two panels one above the other. See Fig. 1 for a sketch and Fig. 2 for a photography of the system.

The electromagnetic radiation originating from the atmosphere is fed into the system via the so-called periscope. That is a tube with a double bend incorporating two mirrors to guide the Gaussian beam. The outer end of the tube, carrying the external mirror, is rotatable for servo controlled adjustment of the elevation angle. This arrangement simultaneously acts as the wall penetration. A Brewster window, made of Mylar foil, is integrated in the periscope. Condensation on the foil, icing and precipitation are prevented by ventilation with hot air on the outside.

After leaving the periscope the beam is guided by two rotatable mirrors down to the lower plane. Here it passes the Martin-Puplett interferometer that acts as a sideband filter.

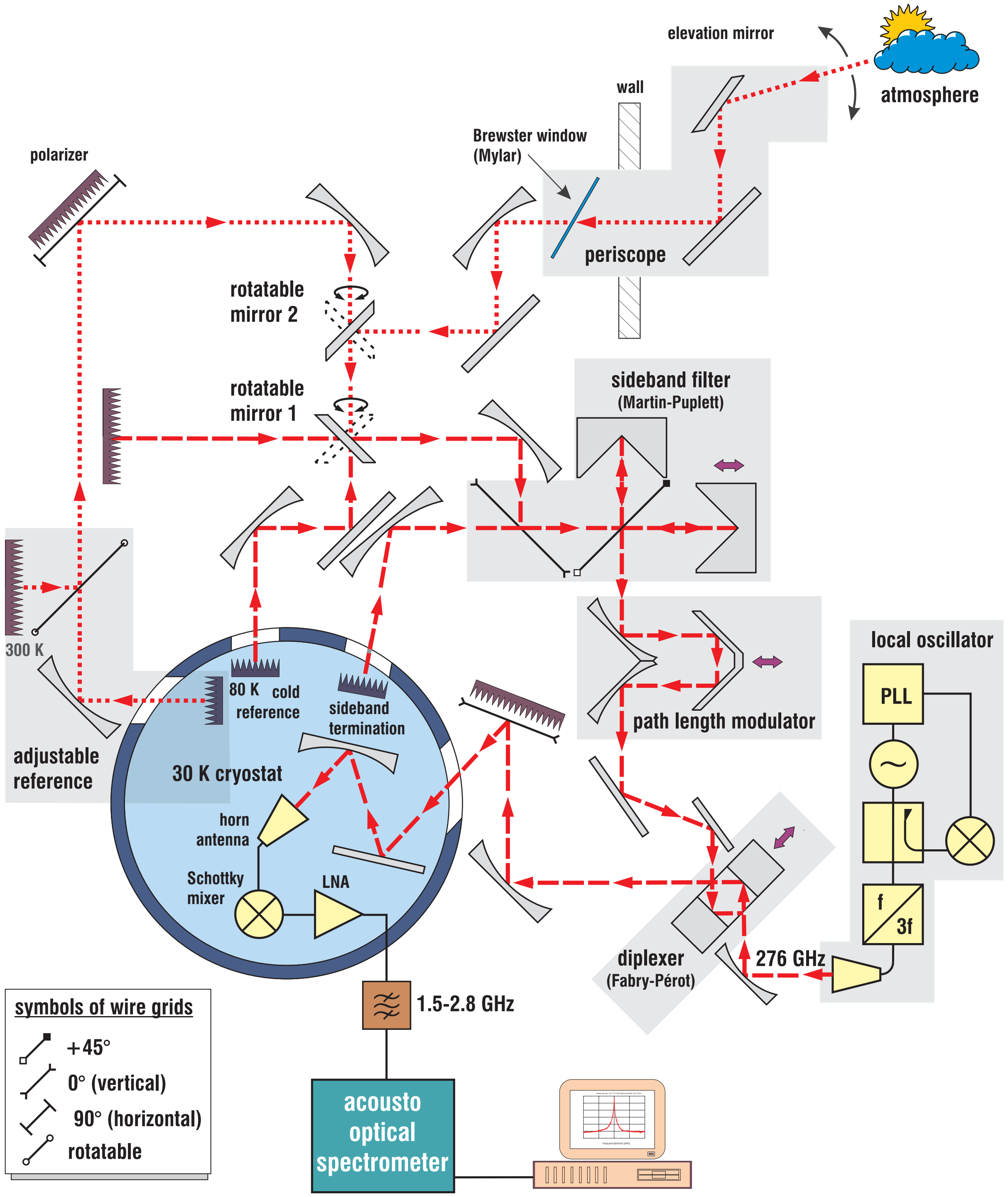

Fig. 1: Sketch of the 268–280 GHz radiometer. Beams marked by dotted lines run on the upper plane.

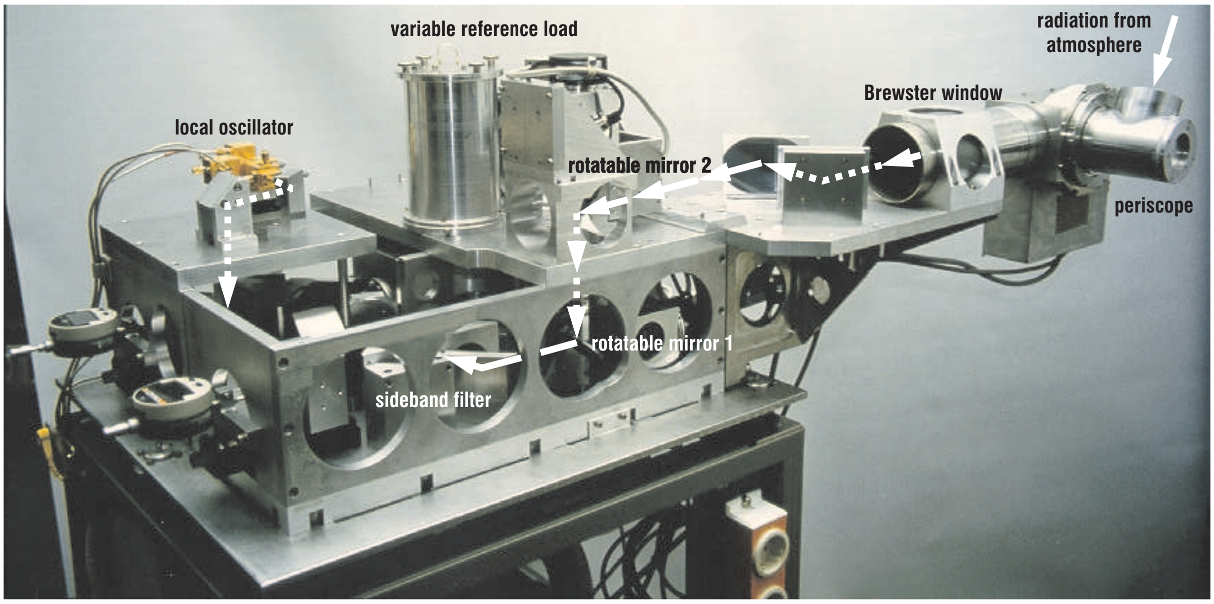

Fig. 2: Photography of the 268–280 GHz radiometer MIRA2. The acrylic glass cover has been removed.

Standing waves caused by multiple reflections are reduced effectively to ∼1% with the path length modulator. This is a rooftop mirror fixed on the coil of an properly modified loudspeaker. It is driven sinusoidally with a frequency of 80 Hz and an amplitude of ∼0.1 mm.

A Fabry-Pérot diplexer combines the atmospheric and LO signal. The latter is generated with a PLL stabilized Gunn oscillator and a subsequent frequency tripler.

Down-conversion to 2.1 GHz center frequency is done by a whisker contacted Schottky diode mixer. In order to reduce thermal noise it is mounted inside a cryostat together with the LNA. This cryostat, which is evacuated to 10^{-7} mbar and cooled to 30 K by a closed cycle helium refrigerator, includes also three microwave absorber plates (RAM, Thomas Keating Ltd.) serving as termination for the opposite sideband or as cold reference loads. The beams enter the cryostat through Mylar foil windows.

Further amplification (∼80 dB) and filtering (1.5-2.8 GHz bandpass) suits the IF signal to the acousto-optical spectrometer built at the University of Cologne. It performs a frequency analysis of a 1.3 GHz band using 1800 channels. The IF chain, the AOS and the quasi-optics, that is encased in an acrylic glass cover, are thermally stabilized by two circulating water thermostats.

Depending on the position of the upper and lower rotatable mirror other targets besides the atmosphere can be looked at. These are a hot load having ambient temperature, an internal cold load inside the cryostat, an optional external LN_2 cold load used for system checks and the adjustable reference load described below. Two complementary signal paths are available on the upper plane, one is occasionally used for a probe signal generator to ease the adjustment of the SSB filter, the other is available for component tests.

The system noise temperatures (SSB) for different tunings have been measured by the Y-factor method and are shown in Fig. 3. Investigations on the reasons of the artifact around channel 750 and the steep rise at high channel numbers are currently in process.

CALIBRATION LOAD

The reference load is based on the superposition of two quasi-optical beams originating from a hot and a cold load. The cold load is an absorber plate placed in the cryostat (∼80 K brightness temperature), the absorber serving as hot load is mounted in a cylindrical cabinet and has ambient temperature. As is shown in Fig. 4 a rotatable wire grid acting as a polarizing beam splitter combines both contributions, weighting them differently depending of the position of the wires.

Looking along the optical axis of the outgoing beam towards the reference load the wire grid is arranged in a 45° position. Therefore the seen radiation is composed of two contributions: the reflected, parallel to the wires polarized radiation coming from the hot load and the perpendicular polarized emission

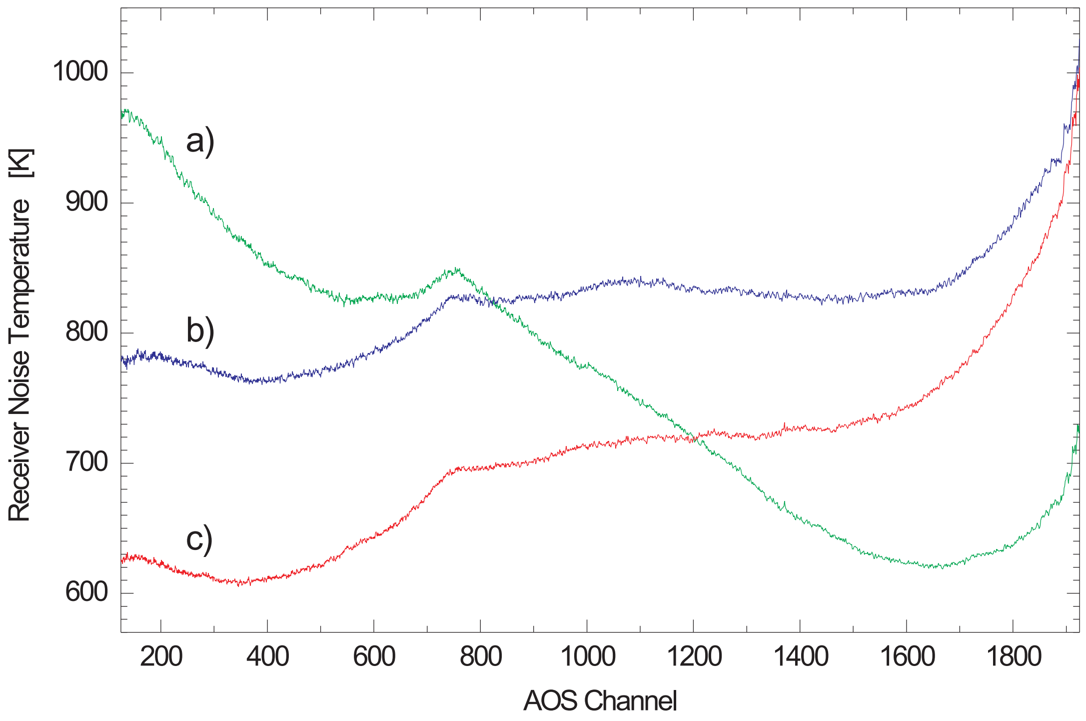

Fig. 3: System noise temperature (SSB) for different settings. The AOS channels shown in the diagram correspond to 1.3 GHz bandwidth. a) Tuned for O_3 signature at 274.5 GHz, lower sideband. b) Tuned for N_2O signature at 276.3 GHz, upper sideband. c) Tuned for ClO signature at 278.6 GHz, upper sideband.