Cartridge-type receiver system on ASTE

Masahiro Sugimoto, Yutaro Sekimoto,
Sozo Yokogawa, Takeshi Okuda,
Ken'ichi Tatematsu, Takashi Noguchi
National Astronomical Observatory of Japan
Kotaro Kohno
Institute of Astronomy, The University of Tokyo
Hideo Ogawa, and Kimihiro Kimura
Department of Earth and Life Sciences,
College of Integrated Arts and Sciences

Abstract

We have developed a cartridge-type receiver system composed of three cartridge-type receivers and a cryostat, which is designed to test on the Atacama Submillimeter Telescope Experiment (ASTE). It was preliminary evaluated at Pampa la Bola (alt. 4800 m) in the northern Chile since November 2002. The cryostat, which can house 3 cartridge-type receivers, has been developed with following technologies; a central pipe and bellows structure to reduce mechanical vibration; simple and efficient thermal links for plug-in cartridges; 3-stage Gifford McMahon cryocooler and an outdoor compressor. Engineering models of band 3 (100 GHz), band 8 (500 GHz), and band 10 (800 GHz) cartridge-type receivers were independently developed with cartridge-test cryostats. They were integrated into the cryostat at NAOJ, then the system was shipped to the site. We confirmed that the system including three receivers operates as designed and the concept of cartridge-type receiver system is very promising for the ALMA.

Instruments

A cartridge-type cryostat, which can house 3 cartridge-type receivers, has been developed for the ASTE. The ASTE 10 m telescope has been developed as a prototype antenna of the Large Millimeter Submillimeter Array. It was installed on Pampa la Bola following evaluation at Nobeyama. The detail of this cryostat was described by Yokogawa et al. (2003)[1]. The cryostat is shown in Figure 1. The cylindrical cryostat can accommodate 2 cartridges of 170 mm diameter and 1 cartridge of 140 mm diameter. The cryostat is composed of 3 stages, which

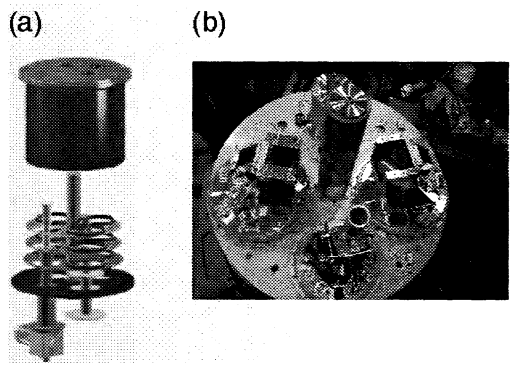

Figure 1: (a)A schematic drawing of a cryogenic system for the ASTE, which houses 3 cartridge-type receivers. (b)A photograph of the cryostat. 3 cartridge-type receivers (from right to left, 800 GHz, 100 GHz, 500 GHz) are installed.

are connected with corresponding stages of a cryocooler.

The concept of the thermal link for the ALMA receiver was proposed by the Rutherford Appleton Laboratory (RAL)[2]. We have designed and developed a simple and efficient thermal link with high heat conductivity [3]. Measured thermal conductance of ϕ170 mm links is 1.7, 5.6, 3.3 W K^{-1} for 4, 12, and 80 K stages. This simple and compact links have good performance and can be easily fabricated.

The concept of the cartridge for the ALMA was proposed by the RAL [2]. NAOJ have developed cartridges which have compatible interface to the ALMA receiver cartridges. The cartridge structure is supported by the central pipe as shown in Figure 2a, b. One can assemble and maintain receivers without decomposition of the NAOJ cartridge. The ϕ140 mm cartridge has been designed and

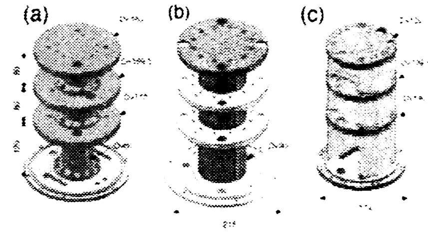

Figure 2: (a) A schematic drawing of the ϕ170 mm cartridge made by NAOJ. (b) The same in (a), but for ϕ90 mm central pipe. (c) A schematic drawing of the ϕ140 mm cartridge made by Osaka Prefecture University/Nagoya University.

developed by Osaka Prefecture University/Nagoya University is shown in Figure 2c. Support structure of their cartridge is composed of divided plates placed on the circumference. This cartridge provides accessibility and spaciousness.

An engineering model of band 10 cartridge-type receiver has been developed. We designed and developed a single mirror optics which couples between a feed horn and the subreflector of the antenna. The dielectric is used for coupling the RF signal with the LO signal. Receiver noise temperature was about 1000 K in DSB at a LO frequency of 812 GHz.

An engineering model of band 8 cartridge-type receiver has been developed. The optics is similar to that of the band 10 receiver. Receiver noise temperature was about 240 K (DSB) at 498 GHz. This receiver was used for noise measurements of hybrid photonic LO (for details, see [4]).

A engineering model of band 3 cartridge-type receiver has been developed as a scaled model of band 4 by Osaka Prefecture University and Nagoya University [5]. We designed flat and ellipsoidal mirror of room temperature and adopted frequency independent solution for receiver optics. The SIS mixer device of band 3 receiver is a parallel-connected twin-junction [6][7]. The measured receiver noise temperature is less than 25 K (DBS) in the frequency range of 95 – 120 GHz.

Integration and test observation

Three cartridge-type receivers have been independently developed with cartridge-test cryostats, which are developed for tests in laboratories [8]. Then, three receivers were integrated into the cryostat at the Mitaka campus of NAOJ. We confirmed that their performance is almost same as that measured with the cartridge-test cryostat. After the integration, the system was shipped to the ASTE site.

In November 2002, 3 cartridge-type receivers were installed to the ASTE. On 17 November 2002, we detected continuum signals from the moon with all three receivers. The moon and Jupiter efficiency of the band 3 receiver were 90 % and 73 % at 100 GHz, respectively. In spite of not adjusting tilt parameters of the subreflector, the moon and Jupiter efficiency were 82 % and 42 %, respectively at 498 GHz. The pointing accuracy was about 1″, which derived from measurements of the Jupiter and the Saturn. On 9 December 2002, we observed a spectrum of CI (rest frequency = 492.16 GHz) from Orion (Figure 3). At that night, the optical depth at zenith was ~ 1.0 and the system noise temperature was around 1000 K.

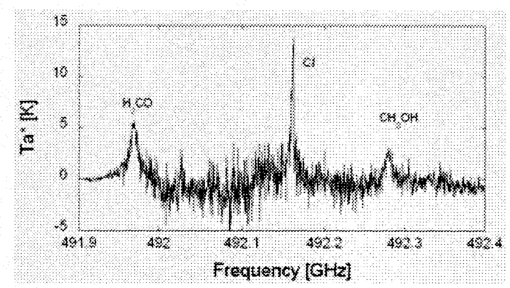

Figure 3: A spectrum of CI ($^3P_1 -^3 P_0$) from Orion KL.

We have confirmed that the engineering models of three cartridge-type receivers work as designed and the cartridge-type receivers are very promising for ALMA.

References

[1] Yokogawa, S., Sekimoto, Y., Sugimoto, M., et al. 2003, PASJ, 55, 519.

[2] Orlowska, A., Harman, M., Ellison, B. 2002, ALMA project book, Chapter 6.

[3] Sugimoto, M., Sekimoto, Y., Yokogawa, S., et al. 2003, Cryogenics, in press.

[4] Sekimoto Y, Ueda A, Okuda T, et al. 2003a ALMA memo 449.

[5] Ogawa, H., Yonekura, Y., Asayama, S., et al. 2002, Proc. IAU 8th APRM.

[6] Asayama, S., Noguchi, T., Ogawa, H. 2003a, International Journal of Infrared and Millimeter Waves, in press.

[7] Asayama, S., Ogawa, H., Noguchi, T., et al. 2003b, ALMA memo 453.

[8] Sekimoto, Y., Kamba, T., Yokogawa, S., et al. 2003b, ALMA memo 455.