Development of wide IF band Receiver for simultaneous observations of CO(J=4-3) and [CI] ($^3P_1$ - $^3P_0$) lines in 500-GHz band

Fuuta Takiguchi [1], Masumichi Seta [2], Takafumi Kojima [3], Nario Kuno [4]

(1) Faculty of Pure and Applied Sciences, University of Tsukuba, 1-1-1 Tennodai, Tsukuba, Ibaraki 305-8571, Japan, e-mail: s2230062@s.tsukuba.ac.jp

(2) School of Sciense and Technology, Kwansei Gakuin University, 2-1 Gakuen, Sanda, Hyogo 669-1337, Japan

(3) Advanced Technology Center, National Astronomical Observatory of Japan, 2-21-1 Osawa, Mitaka, Tokyo, 181-8588, Japan

(4) Faculty of Pure and Applied Sciences, University of Tsukuba, 1-1-1 Tennodai, Tsukuba, Ibaraki 305-8571, Japan

The Antarctic plateau is an excellent astronomical observation site because of its high atmospheric transparency for submillimeter/terahertz observations thanks to its high altitude of 3,000 to 4,000 meters, low temperature of -20 °C to -80 °C, stable low water vapor in the atmosphere, and high clear sky rate of 90 %. We are planning a survey of the Galactic Plane in CO(J=4-3) (461 GHz) and [CI] ($^3P_1$ -$^3P_0$) (492 GHz) using the 30-cm submillimeter telescope installed in the Antarctic plateau. CO(J=4-3) emission line is a good probe for high-density gas associated with star-forming regions, and by comparing the intensity of CO(J=1-0) and (J=2-1) emission lines, the physical state of the molecular gas such as temperature and density can be revealed. In addition, the neutral carbon [CI] ($^3P_1$ -$^3P_0$) emission line is a tracer of diffuse molecular gas related to the formation and destruction of molecular clouds where CO is photodissociated.

The 30-cm telescope has already succeeded test observations in Parinacota in northern Chile in 2010. At that time, the frequency was converted to 4-8 GHz in the cooled receiver and to 0-1 GHz, the spectrometer's band, in the IF system. For this project, we will observe CO(J=4-3) and [CI] ($^3P_1$ -$^3P_0$) simultaneously using a sideband-separated (2SB) receiver to get precise line ratio of these lines. Simultaneous observation of these two emissions lines requires an intermediate frequency (IF) band of 15.5 GHz or higher. Therefore, we must develop a wide IF band receiver.

The receiver system of the 30-cm telescope consists of a cooled receiver (1st IF), an IF system (2nd IF), and a spectrometer. The cooled receiver has two stages: the 4-K stage and the 40-K stage. An intermediate temperature shield is installed on the 40-K stage to suppress radiation to the 4-K stage.

Before our improvement, the SIS mixer was mounted on the 4-K stage, and the cooled low noise amplifier (CLNA) was mounted on the 40-K stage. We install two mixer modules that integrates an ALMA Band 8 type SIS mixer and a broad IF band (18 GHz) CLNA on the 4-K stage to increase the bandwidth and reduce the noise of the receiver system. The broad IF bandwidth makes it possible to observe CO(J=4-3) and [CI] ($^3P_1$ -$^3P_0$) lines simultaneously. However, the transfer of the CLNA on the 4 K stage increases the heat load on the chiller. Furthermore, since the frequency range of new spectrometers is 0-2.5 GHz, the IF system must convert the IF frequency to 0-2.5 GHz and amplifies the signal to 0 dBm/GHz, which is the optimum value for the spectrometer. First, we made the thermal design of the cooling receiver. We use low power consumption (1.3 kW) cryocooler for operations of the receiver in Antarctica where only limited electric power is available. We install two-layer infrared blocking filters in the signal windows and multilayer thermal insulator around an intermediate temperature shield to suppress radiation heat flow. The designed heat inflow to 4-K stage is 61 mW that is lower than the cooling capability of 100 mW. The measured temperature of SIS mixer, however, was 4.1 K, which is probably due to too much heat flow from the integrated CNA. Next, we estimated SSB noise of the new receiver based on our noise model describing the behavior of 2SB reception, including signal separation by Hybrid and signal mixing by the SIS mixer. We expect that receiver noise is reduced up to 20 % in the new 2SB receiver, that results from significant reduction of the loss between the SIS and CLNA. We also modified the IF system to accommodate the new 2.5-GHz spectrometers using new 15-GHz mixer, broad IF (16 GHz) amp and filter. In addition, for simultaneous observations of CO(J=4-3) and [CI] ($^3P_1$ -$^3P_0$) emission lines, we duplicate another IF system.

References