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Development of wide IF band Submillimeter Receiver for simultaneous observation of CO and CI lines in 500GHz band

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The Antarctic plateau is an excellent astronomical observation site because of its high atmospheric transparency for submillimeter/terahertz observations due to its altitude of 3,000 to 4,000 meters, temperature of -20°C to -80°C, stable low water vapor in the atmosphere, and 90% clear sky. We are planning a survey of the Galactic Plane in CO (J=4-3) (461GHz) and [CI] ($^3P_1$ -$^3P_0$) (492GHz) using the 30cm 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 dilute molecular gas related to the formation and destruction of molecular clouds.

The telescope has already succeeded test observations in Parinacota in northern Chile in 2010. We 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. The receiver system in this study consists of a cooled receiver (1st IF), an IF system (2nd IF), and a spectrometer. The cooled receiver has two stages: the 4K stage for cooling to 4K or lower and the 40K stage, which is an intermediate temperature shield to suppress radiation to the 4K stage. In the past, 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.

Before our improvement, the SIS mixer was mounted on the 4K stage, and the cooled low noise amplifier (CLNA) was mounted on the 40K stage. We have newly installed two mixer modules that integrates an ALMA Band 8 type SIS mixer and a broad IF band (18GHz) CLNA to increase the bandwidth and reduce the noise of the receiver system. The broad IF bandwidth makes it possible to observe CO and CI lines simultaneously. However, the transfer of the CLNA to the 4K stage increases the heat load on the chiller. 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 designed the thermal design of the cooling receiver. We use low power consumption (1.3kW) cryocooler for operations the receiver in Antarctica where only limited electric power is available so a strict thermal design was required. We installed 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 4Kstage is 61mW that is lower than an upper limit cooling capability of 100 mW. We succeeded in cooling the 4K stage down to 3.5K in cooling tests. The measured I-V characteristics of SIS mixer are good enough for operation of the SIS as a heterodyne mixer. The measured temperature of SIS mixer, however, was 4.1K, this is probably due to too much heat flow from the integrated CNA. Next, we designed the receiver noise model. We derived SSB noise of the new receiver based on our noise estimation model describing the behavior of 2SB reception, including signal separation by Hybrid and signal mixing by mixer. We expect 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. and we modified the IF system to accommodate the new 2.5GHz spectrometers, that include installation of new 15GHz mixer, broad IF (16GHz) amp and filer.

References