Development of multi-frequency mm-wave spectrometer for atmospheric observation

Akira Mizuno[1], Tomoo Nagahama[1], Taku Nakajima[1], Takahiko Kosegaki[1], Syoki Iriyama[1], Genma Mizoguchi[1], Kohei Haratani[1], Hiroyuki Iwata[1], Daichi Tsutsumi[2], Naoto Sekiya[3], Takuma Hayashi[3], Yoshihiro Tomikawa[4], Mitsumu K. Ejiri[4], and Kaoru Sato[5]

[1] *Institute for Space-Earth Environmental Research (ISEE), Nagoya University, Japan*

[2] *Department of Physics, Nagoya University, Japan*

[3] *Department of Electrical and Electronic Engineering, University of Yamanashi, Japan*

[4] *National Institute of Polar Research, Japan*

[5] *Graduate school of science, University of Tokyo, Japan*

We will upgrade the millimeter-wave spectrometer for atmospheric minor constituents in the stratosphere to lower-thermosphere at Syowa station under the 61th Japanese Antarctic Research Expedition (JARE). In this paper, we report the performance of the new spectrometer measured in our laboratory.

[Background]

Most of the present ground-based microwave instruments for atmospheric spectroscopy are dedicated to observe a single molecular line. That is mainly because the frequency separations among different molecular lines are larger than instantaneous observable frequency bandwidth of the microwave instruments. This is crucial difference between the microwave and the other wavelength. Simultaneous observation of several molecular species chemically and/or dynamically connected with each other and subsequent comparative study of such species provide more fruitful information to understand the mechanism of temporal variation of atmospheric molecules. So, to overcome the present situation of the ground-based microwave instruments, we developed new key device for multi-frequency observation, i.e., a waveguide-type frequency multiplexer that enable us to distribute the signal coming through a single optical system to 4 superconducting receivers, and the 4 receivers are cooled down by a single cryogenic refrigerator. We already reported the performance of the frequency multiplexer in the last symposium, and afterward, we successfully built a practical observing system equipped with the device.

[Results]

We developed a cryogenic system to cool down the multi-frequency receiver system, optical system that guides the signal from the atmosphere into the receiver system, integrated IF (intermediate frequency) circuit to re-assign the signal-band frequencies of the multiple channels into a single FFT processor having an instantaneous bandwidth of 2 GHz. For the observation at Syowa, we use the upper two channels of the frequency multiplexer. The scientific target is to study the influence of energetic particle precipitations (EPPs) on the middle and upper atmosphere, and the observable frequency windows are adjusted to observe NO, O_3, CO, NO_2, HO_2 between ~230 GH and ~250 GHz. In the cryogenic system, by using a power-saving small refrigerator (Ulvac UR4K03) whose cooling power is 0.3 W, we confirmed that the two receivers can be cooled down to ~ 4.3 K by utilizing a multi-layer radiation shield, super-insulation, and thermal anchors made of oxygen-free copper. For the optical system, we used a quasi-optical approximation method (Gonzalez, 2016) to design the shape of the parabolic and elliptical mirrors to configure a frequency independent optical system. In the integrated IF circuit, the three 1st IF signal bands at ~ 230GHz and ~ 250GHz are down-converted between 8 GHz and 12 GHz, and finally those signals fall into within the bandwidth of the backend FFT processor, 2 GHz (Figure 1) by adjusting the frequency configuration of band-pass filters (BPFs) and 2nd mixers. In addition, we use a superconducting band-pass filter developed by Yamanashi University as the 1st-stage band-pass filter that provides very sharp skirt characteristics to reduce the crosstalk between the passbands.

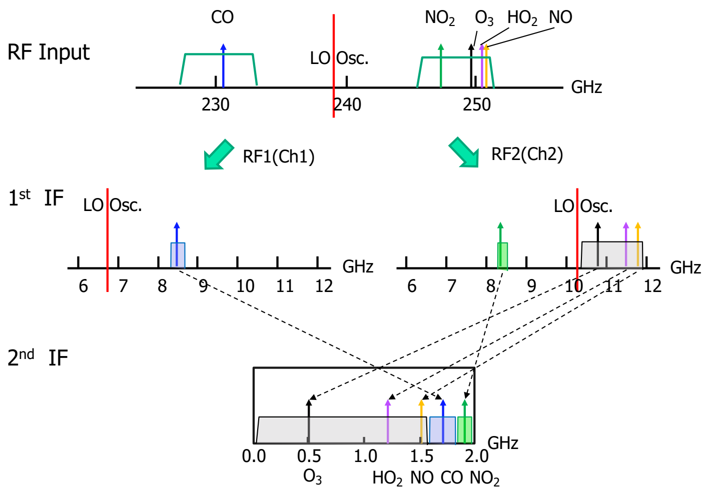

Figure 1. Frequency conversion chart of the new spectrometer system.

References

Gonzalez A., Frequency Independent Design of Quasi-optical Systems, Journal of Infrared, Millimeter and Terahertz Waves, 37, 147-159, 2016.