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# Submillimeter limb sounder for stratospheric and mesospheric temperature, wind, and chemical species

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Submillimeter-wave limb sounder has a potential for measurement of temperature, wind, and chemical species, such as $H_2O$ and $O_3$, over the wide altitude range of the Earth's atmosphere, ie. from the lower stratosphere to the lower thermosphere. The submillimeter sounder has receivers in a couple of frequency bands to observe emission lines of several chemical species and $O_2$. Each band will be detected with high-resolution spectrometer on the back end of the sounder. Supposed mission in the working group of our project consists of highly sensitive receivers of two or four frequency band and spectrometers with a bandwidth of 2 or 4 GHz and a resolution of around 1 MHz. Its specifications will be determined in the working group in next 3 years. In this paper, we will report the present status of our study toward the design of SMILES-2, which will be an advanced version of the successful mission, JEM/SMILES, deployed on the international space station (ISS) from 2009 to 2010.

The sensitivity of submillimeter receiver using superconducting technology shows one order better than semiconductor devices operated in ambient temperature. The sensitivity restricts the range of the variation of observable molecules and the altitude range. The observation of the higher atmosphere above the mesosphere is especially limited by the sensitivity, because the emission from the atmosphere is comparatively weak while the noise in the received signal, that is dominated by the receiver noise, is constant in spite of disappearing of background emission. Superconducting receiver is preferable for the observation in such upper atmosphere. JEM/SMILES adopted superconducting mixer at 625 and 650 GHz, and successfully demonstrated excellent observation of ozone and chlorine compounds and so on. The SSB system noise temperature of the JEM/SMILES receiver was 297 K, which is less than a tenth of that of Schottky receiver of those days. The frustration of JEM/SMILES users was that the mission observed no oxgen line and no atmospheric tracer. The limitation of JEM/SMILES bandwidth had come from safe design avoiding electromagnetic interference in ISS. The thermal design of the JEM/SMILES cryo system had been also safe so that only two receivers were loaded in the cryo system. In SMILES-2, wider range of frequency band will be used in instrument of smaller weight. It will realized by utilizing wide-band intermediate frequency and reducing optics system. The antenna of SMILES-2 is steerable in elevation angle. The altitude resolution of the limb observation is targeted to around 2 km. The azimuthal direction of the antenna is under discussion. The calibration load in JEM/SMILES was successful and contributed to measure precise spectral data, so that the load will be applied to multi frequency receiver.

The SMILES-2 mission will have a weight of about 200 kg. We estimate it is possible to reduce the weight of the system from that of JEM/SMILES, that is 476 kg. Besides the superconducting receiver, Schottky receivers will be installed in SMILES-2 to make the system reliable because expected lifetime of cryocooler is 3 years and we wish to prolong the mission life. An only Schottky receiver mission is also planned for a quick mission.

Keywords: middle atmosphere, limb observation, submillimeter wave, instrument development, future mission, SMILES