Feasibility of Superconducting Submillimeter-Wave Limb-Emission Sounder (SMILES-2) on an M-class satellite

*Satoshi Ochiai[1], Philippe Baron[1], Yoshihisa Irimajiri[1], Toshiyuki Nishibori[2], Makoto Suzuki[2], Yoshinori Uzawa[3], Hiroyuki Maezawa[4], Takeshi Manabe[4], Akinori Saito[5], Masato Shiotani[5]

1. National Institute of Information and Communications Technology, 2. Japan Aerospace Exploration Agency, 3. National Astronomical Observatory of Japan, 4. Osaka Prefecture University, 5. Kyoto University

The Superconducting Submillimeter-Wave Limb-Emission Sounder-2 (SMILES-2) is a proposed mission for comprehensive observation of temperature, wind, and atmospheric compositions in the middle and upper atmospheres using limb observation technique at submillimeter-wave from an satellite on a non-sunsynchronous low Earth orbit. The proposal of SMILES-2 is assumed to be one of M-class missions of the Japan Aerospace Exploration Agency / the Institute of Space and Astronautical Science (JAXA/ISAS). SMILES-2 will enable us to observe temperature profile between the tropopause and the lower thermosphere below an altitude of 150 km, horizontal wind profile between the upper stratosphere above 30 km and the lower thermosphere, and atmospheric compositions including water vapor, ozone, and other minor species in the stratosphere and mesosphere and atomic oxygen in the lower thermosphere with a vertical resolution of 2.5 km or 5 km. Those observation will be daily and sampled at numerous positions spread in global scale. Diurnal cycles can be estimated. The local time of observing point will be shifted by 24 hours in about 3 months.
The observation of the diurnal cycles is one of the most important targets for the SMILES-2 science. To meet the scientific requirements, SMILES-2 shall have the superconducting receivers at bands of 638 GHz, 763 GHz, and 2 THz, and observe limb atmosphere from a satellite on an orbit at an altitude of 550 km and an inclination of 66 degree. Atmospheric vertical profiles are observed at every 690 km on the sun-shade side along the orbit. Each vertical profile is observed two times from different directions with a time interval of about 8 minutes so that horizontal wind vector can be retrieved. Approximately 830 vertical profiles will be observed in one day.Estimated precision of those measurements is summarized in another paper of this meeting. The wind measurement precision is estimated to be comparable or slightly better than a typical amplitude of diurnal cycle of the wind variation. The measurement precision depends on the receiver sensitivity and the spatial and time resolution of measurements. Because the average number of the wind observation can hardly increase, the receiver sensitivity is extremely important to keep a good measurement precision. Superconducting devices, which show the best performance among heterodyne receivers in the frequency range, are essential for the SMILES-2 receiver.
SMILES-2 will use a technological heritage of JEM/SMILES, which is a mission operated on the Japanese Experiment Module in the International Space Station for a half year from 2009 to 2010. JEM/SMILES successfully demonstrated submillimeter limb observation for the first time with superconducting heterodyne receivers cooled by spaceborne cryocooler. Although no cryocooler in Japan was demonstrated in space for much longer lifetime, an improved model of 4-K cryocooler for space has been tested on the ground and showed a lifetime of more than 4 years. The power consumption of the cryocooler for JEM/SMILES was measured about 153 W on the ground, and that of the JEM/SMILES payload was about 320 W. The power resource of an M-class satellite is very limited comparing to that of JEM missions. The available power for the mission is estimated about 323 W when the orbit comes at the maximum sun-shading ratio. That seems larger than the required power, but it is not enough because the SMILES-2 mission includes telecommunication systems and data recorders that are not in the JEM/SMILES payload. Moreover, the power consumption by the SMILES-2 cryocooler may be larger by increasing the number of frequency bands and requiring power margin for compensating the decrease of

cooling efficiency of the cryocooler for 3 or 5 year operation.
The design of power balance, as well as the cost evaluation, is the largest issue in judging the feasibility of SMILES-2 on M-class satellite. We are studying measures of reducing the cryocooler power consumption. For example, we are estimating power consumption with a detailed design of the cryostat for the receivers and cooling system. We are also developing a new receiver configuration that saves heat flow into the cooling stage, and designing the radiation cooling system to reduce the base temperature of cryocooling system. With additional reductions of the power consumption by the other mission components, we believe that the power consumption of the SMILES-2 mission can be kept within the available power.
The SMILES-2 mission will be proposed to JAXA/ISAS for the next opportunity of M-class mission, which is targeting a launch in 2026 or later.

Keywords: satellite observation, middle atmosphere, upper atmosphere, microwave observation, cryocooler, wind measurement

