SMILES-2, satellite mission for observation of the stratosphere, mesosphere, and lower thermosphere with THz receivers

*Satoshi Ochiai[1], Philippe Baron[1], Yoshihisa Irimajiri[1], Akira Kawakami[1], Toshiyuki Nishibori[2], Makoto Suzuki[2], Yoshinori Uzawa[3], Yasunori Fujii[3], Hiroyuki Maezawa[4], Akinori Saito[5], Takatoshi Sakazaki[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 Satellite Observation of the Whole Atmosphere - Superconducting Submillimeter-Wave Limb-Emission Sounder (SMILES-2) is a satellite mission for observation of the stratosphere, mesosphere, and lower stratosphere with submillimeter-wave receivers at frequencies of 638 GHz, 763 GHz, and 2 THz. SMILES-2 will measure submillimeter-wave limb emission spectra from atmospheric molecules and atom, that is molecular oxygen, atomic oxygen, water vapor, ozone, and many chemical species. Atmospheric temperature and horizontal wind can be retrieved from the limb spectra as well as the concentrations of those species. The SMILES-2 satellite is planned to have an orbit at an altitude of 550 km and an inclination of 66 degree. with which the latitude coverage of limb observation reaches 80 degree. Since the non-sunsynchronous orbit precesses at a rate of one round per 119 days, SMILES-2 can observe diurnal cycles in 1.5 or 3 month. Height profiles will be measured with a horizontal interval of 690 km along the satellite subtrack. By measuring the same atmosphere two times at an interval of 8 min., horizontal wind vector can be retrieved from two measurements in different looking directions. Superconducting heterodyne receivers will be used to receive the submillimeter-wave limb emission. Receiver configuration is basically same with that of JEM/SMILES, which is a predecessor of SMILES-2 and was operated on the International Space Station in 2009. Unlike JEM/SMILES, SMILES-2 has three frequencies, two antennas, and digital spectrometers. The precision and altitude range for temperature and wind are improved in SMILES-2 comparing with JEM/SMILES. The estimated precisions of temperature and wind measurements would be 0.2 K and 3 m/s in the stratosphere, and 40 K and 20 m/s in the lower thermosphere, respectively, when the vertical resolution is 2.5 km. Those measurement precisions can be achieved only with superconducting receivers. If we use Schottky mixers for submillimeter-wave receivers, we will get 10 times worse noise level and cannot get enough data for latitude-altitude section even with 1 day mean.

Mission part of SMILES-2 is being designed to have 3 year lifetime, using a mechanical 4-K cryocooler that is demonstrated 4 year life in a ground test. The design of the cryostat, which contains superconducting mixers to be cooled, follows that of JEM/SMILES, so that a risk of the development is largely mitigated. Superconducting mixer (HEB mixer) for the 2 THz receiver us developed at NICT and also at Osaka Prefecture University.

We estimated the resource requirement of the SMILES-2 mission to study feasibility of SMILES-2 on a JAXA M-class mission. The power resource is very limited in an M-class satellite comparing with the case of JEM/SMILES. The power consumption of the cryocooler, which is the largest power consuming component, is estimated to be about 159 W after three year operation on orbit. The estimation is made on the assumption that the cooling power required receiver components is less than that of JEM/SMILES and that a recent efficient compressors are used. The total power consumption of the mission system can be balanced with the satellite bus power provision, which will be 323 W for the mission system when the satellite is at the status of a maximum sun-shade ratio of 37 % for the SMILES-2 orbit. Another issue is to keep the development cost low. We studied measures to reduce the cost on the condition that we use superconducting receivers for the mission and that the satellite takes non-sunsynchronous orbit. The cost

estimated is within the scale of M-class mission if we suppose that some receiver components are developed in collaboration with outside-funded partners.
The SMILES-2 proposal was submitted to the competitive M-class missions announced by JAXA/ISAS.

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