PERFORMANCE VERIFICATION AND CALIBRATION OF SUPERCONDUCTING SUBMILLIMETER-WAVE LIMB-EMISSION SOUNDER (SMILES)

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1. INTRODUCTION

Superconducting Submillimeter-Wave Limb-Emission Sounder (SMILES) is a highly sensitive submillimeter limb sounder to observe stratospheric chemical species such as O_3, HCl, ClO, HO_2, HOCl, HNO_3, CH_3CN, and BrO. SMILES is one of the experiments deployed at the Exposed Facility of the Japanese Experiment Module (JEM) "Kibo" in the International Space Station (ISS). SMILES was launched on 11th September 2009 aboard the H-II Transfer Vehicle (HTV), and was attached to the JEM on 25th September (Fig. 1). The atmospheric observation by SMILES successfully started in the middle of October 2009. SMILES was developed jointly by National Institute of Information and Communications Technology (NICT) and Japan Aerospace Exploration Agency (JAXA).

In this paper, SMILES instruments and the performance of it is briefly introduced. In addition, the radiometric and field-of-view calibrations are discussed based on the results of the ground test of the flight model and the analysis of the on-orbit data.

2. SMILES INSTRUMENTS

SMILES employs two superconducting (SIS) mixers in the frequency bands of 625 and 650 GHz. The SIS mixers are cooled down to less than 4.6 K by a mechanical cryocooler consisting of J-T and two stage Stirling refrigerators. The SMILES backend is two 1.2-GHz bandwidth acousto-optical spectrometers (AOS) which has a frequency resolution of about 1.4 MHz. Two of three SMILES bands, A: 624.25 – 625.59 GHz, B: 625.04 – 626.39 GHz, and C: 649.03 – 650.37 GHz, can be observed at once. In normal SMILES operation, the combination of observation bands is switched every day, The main reflector, whose size is 400 mm vertical and 200 mm horizontal, allows an altitude resolution of approximately 3 km at the tangent point of the line-of-sight when the altitude of the ISS takes typical value of 350 km. The antenna is vertically scanned with a cycle of 53 s in the range from the bottom of the atmosphere to near the mesopause. In a scan cycle the antenna is also pointed toward the direction of a tangent height of about 200 km for calibration purpose. The AOSs measure the spectra with an integration time of 0.5 s during antenna scanning. The detailed description of the SMILES project can be found in [1]. SMILES is also described in [2].

SMILES had been working in health and functioning normally since it was installed on 25th September 2009. The atmospheric observation was started in the middle of October. We got atmospheric submillimeter spectra of good quality for several months. The atmospheric observation by SMILES was, however, halted on 21st April 2010 unfortunately due to the failure of the submillimeter-wave local oscillator. The latest status of SMILES can be found in the web page [3].

3. PERFORMANCE OF SMILES RECEIVER

A remarkable feature of SMILES is the high sensitivity of the receiver thanks to the SIS technology. The SMILES submillimeter receiver shows a system noise temperature of around 350 K for single sideband operation on orbit. The measured performance on orbit is consistent with the results of prelaunch tests on the ground and fully satisfies the specifications [4]. The root-mean-square of the output fluctuation of each channel by radiometric noise is around 0.4 K for each spectrum that acquired every

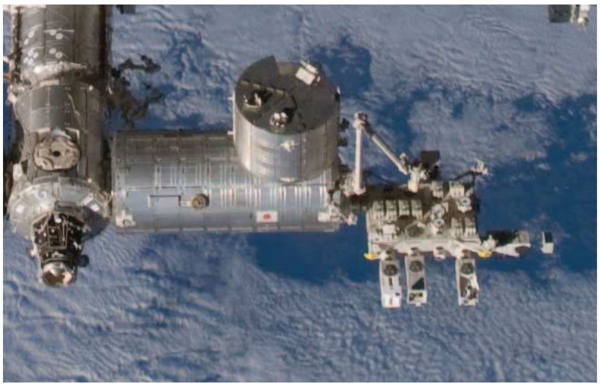

Fig. 1. Japanese Experiment Module (JEM) in the International Space Station (ISS). The right half of the photo is the Exposed Facility (EF). The ISS flies downward of the photo. The second from the left in three payloads attached on the front side of the EF is SMILES. (photo courtesy of NASA)

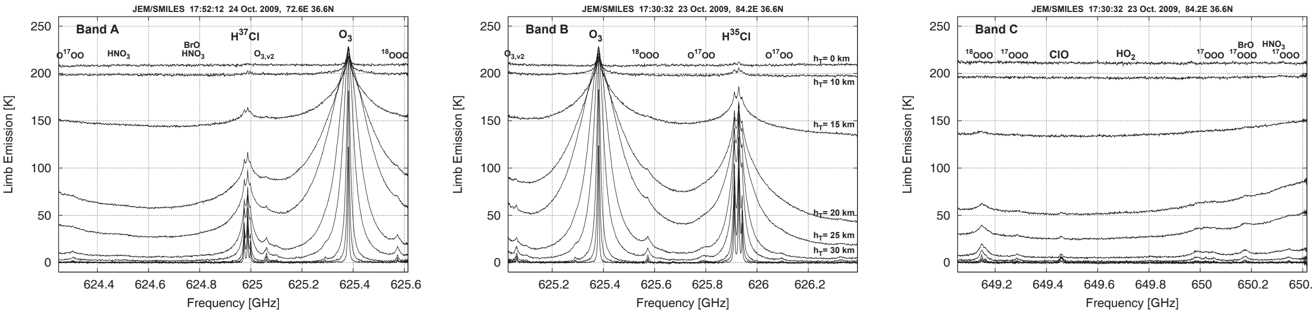

Fig. 2. Observed spectra during the initial checkout

0.5 s. The uncertainty due to time variation of the system gain in a time scale of 53 s is one order less than the radiometric noise of the single AOS channel. The level of the undulation in the spectral baseline is one of the most important characteristics for limb sounding spectrometer. We found the undulation of the SMILES baseline was at most 0.5 K or better. No distortion can be observed in almost all the spectra of SMILES data. The figure 2 shows one of the preliminary observed data during the initial checkout phase. Each spectrum was taken with an integration time of 0.5 s. The weak emission lines can clearly be seen and no spectral baseline undulation is observed in this scale.

4. RADIOMETRIC AND FIELD-OF-VIEW CALIBRATION

The SMILES radiometric calibration is made basically based on the data of the prelaunch tests on the ground[5]. According to the initial validating study of the SMILES data the scaling uncertainty of the spectra may rise to the order of 5%. In the ground tests we measured the gain stability, the gain non-linearity, the single sideband separation ratio, and the reflection loss of the materials used in the SMILES antenna system. The far-field antenna beam pattern was also measured using a near-field phase-retrieval method[6]. It is still going on to improve the radiometric calibration by compiling the ground measured results.

The absolute attitude of the SMILES is measured by on board star trackers. The orbit information given by the guidance, navigation and control system of the ISS is also used to calculate the location of the field-of-view at each limb measurement. The beam direction knowledge against the mechanical direction of the antenna, which is based on the results of the ground measurement, is almost negligible comparing with the errors of the measured attitude.

the guidance, navigation and control system of the ISS are also used The The attitude and the orbit information acquired by the guidance, navigation and control system of the ISS are also used In SMILES data processing the beam pointing offset in a single scan can be retrieved from the measured spectra. The beam pattern and pointing direction will be directly calibrated by seeing the moon or other planets which occasionally come into the field-of-view.

5. CONCLUSION

SMILES has successfully made atmospheric limb observation. The initial verification of the performance of the SMILES submillimeter receiver was satisfactory. The radiometric and field-of-view calibration are being improved based on the knowledge of the instruments measured in the ground tests and from the analysis of on-orbit data.

6. REFERENCES

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