Hardware Specification and System Performance of Dual-channel Radiometers for Earth and Atmosphere Monitoring (DREAM) Flight Model

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Abstract—The first Korean spaceborne microwave radiometer has been developed since 2004. Its name is the Dual-channel Radiometers for Earth and Atmosphere Monitoring (DREAM). It is the main payload of the Science and Technology SATellite-2 that will be launched in 2008. Recently, the development and performance test of DREAM flight model (FM) was completed. This document presents the hardware specification and performance test results of DREAM FM.

Keywords- DREAM, Radiometer, Spaceborne radiometer, STSAT-2

I. INTRODUCTION

Since the Russian satellite of Cosmos 243 was launched for earth observation based on the microwave radiometers firstly, several nations have developed and launched the spaceborne radiometers for earth remote sensing [1]. In Korea, the first Korean satellite-based microwave radiometer for earth’s surface and atmosphere sensing has been developed since 2004. It was named as Dual-channel Radiometers for Earth and Atmosphere Monitoring (DREAM). Its primary objective is to develop the technology and application of spaceborne microwave radiometer system and to study the physical parameters: precipitation, water vapor and cloud liquid water from DREAM measuring data. It is the main payload of the Science and Technology SATellite-2 (STSAT-2) which is scheduled to launch in 2008. The DREAM protolflight model was implemented and integrated with the protolflight model of the satellite in the end of 2005 [2]. Lately the development and performance test of DREAM flight model (FM) were finished. The DREAM FM is shown in Fig. 1. This paper describes the hardware specifications and the performance test result of DREAM FM.

II. DREAM REQUIREMENT

The STSAT-2 is a 100-Kg microsatellite [3]. Because of the space restriction in the satellite, the DREAM is not available to adopt the scanning mechanism. The swath width is the same as the footprint of the antenna. Since the STSAT-2 is planned to orbit at the perigee 300 Km and the apogee 1500 Km with 80° inclination looking at the nadir direction to earth, the swath width is varied from 52.5 Km to 262 Km. The DREAM will operate on minimum 50 percent duty cycle over 2 years of life time. It will generate 1 MB of data per orbit, or 14 MB data a day on operation.

Figure 1. DREAM FM Integration with Pseudo-satellite panel
III. DREAM SYSTEM DESCRIPTION

Fig. 2 depicts a drawing of DREAM FM configuration with the major element indicated. As the full name of DREAM implies, it consists of two total power radiometers with the center frequency of 23.8 GHz and 37 GHz. It measures the electromagnetic energy emitted, scattered, and reflected from the earth and atmosphere. This is divided by 4 subsystems, such as antenna subsystem, radiometer receiver subsystem, LF & thermometer subsystem, and data acquisition & processing subsystem.

A. Antenna Subsystem

This subsystem has total 4 antennas; a 23.8 GHz calibration antenna (CA), a 37 GHz CA, a 23.8 GHz measurement antenna (MA), and a 37 GHz MA. Two measurement antennas observing earth are a type of corrugated horn satisfying the low sidelobe level (<-22 dB) and the high mainbeam efficiency (> 98%). Their antenna 3dB beamwidths are 10°. Two calibration antennas look at the deep space which is the reference source for the radiometric calibration. They are horn-type antenna with 3dB beamwidth of 20°.

Fig. 3. presents both radiometer block diagram. The radiometer receiver subsystem comprises a 23.8 GHz receiver and a 37 GHz receiver. Since a total power radiometer type has high sensitivity with simple hardware architecture, both are implemented as this type. Each was designed as a heterodyne type operated in a double-side band. The receivers cover dynamic range of 3 ~ 340K. Each receiver includes a RF switch, a RF LNA, a mixer, a local oscillator, an IF AMP, and an IF BPF. Calibration is external and internal, both. The first is the deep space as a cold source which each channel’s calibration antenna looks at. The latter is matched loads embedded in both receivers as a hot source. Two-point calibration is used. Using a SP3T RF switch at the RF front-end, the observation path is determined among the measurement antenna, the calibration antenna, and the matched load. The switch is controlled by the data acquisition and processing subsystem. Its switching period is 10.2 seconds: 0.6 second for the calibration antenna, 0.6 second for the matched load, and 9 seconds for the measurement antenna. The RF LNA is used to reduce the system noise figure. The total gain of amplifiers is adjusted to a suitable level because the detector must be operated in the square-law detection region.

B. Radiometer Receiver Subsystem

The radiometer receiver subsystem comprises a 23.8 GHz receiver and a 37 GHz receiver. Each receiver includes a RF switch, a RF LNA, a mixer, a local oscillator, an IF AMP, and an IF BPF. Calibration is external and internal, both. The first is the deep space as a cold source which each channel’s calibration antenna looks at. The latter is matched loads embedded in both receivers as a hot source. Two-point calibration is used. Using a SP3T RF switch at the RF front-end, the observation path is determined among the measurement antenna, the calibration antenna, and the matched load. The switch is controlled by the data acquisition and processing subsystem. Its switching period is 10.2 seconds: 0.6 second for the calibration antenna, 0.6 second for the matched load, and 9 seconds for the measurement antenna. The RF LNA is used to reduce the system noise figure. The total gain of amplifiers is adjusted to a suitable level because the detector must be operated in the square-law detection region.

C. LF & Thermometer Subsystem

The LF & Thermometer subsystem is subdivided into 3 units; the 23.8 GHz LF unit, the 37 GHz LF unit, and the thermometer unit. The 23.8 GHz LF unit consists of a detector, a series of amplifiers, and a passive integrator. The 37 GHz LF unit is the same as 23.8 GHz. The role of LF unit is to convert the IF signal from the radiometer receiver to the DC-level voltage having the range from 0 V to 10 V. In addition, the DC-level voltage signal is integrated. The thermometer unit measures the real physical temperature using the platinum resistors. They are used to gauge the real physical temperature for the calibration of the DREAM measuring brightness temperature. The number of temperature sensing points are 12 points: 2 assigned for each CA, 2 for each MA, 1 for each receiver, 1 on the LF unit, and 1 on the plate mounted DREAM.

D. Data Acquisition and Processing Subsystem

The data acquisition and processing subsystem contains a dc-dc conversion unit (DCU) and a data acquisition and processing unit (DAPU). The DCU distributes power supplied by the STSAT-2 power distribution unit to the DAPU and the other DREAM subsystems requiring power. The DAPU plays two kinds of important roles. The first is to communicate with the STSAT-2 spacecraft. It analyzes and executes the telecommands received from the on-board computer in the STSAT-2. The other is to collect the brightness temperature from earth, deep space, and the matched source and the physical temperature data from the platinum resistors. After that, the DAPU packetizes the whole obtained data and sends them to the mass memory unit of the spacecraft.
IV. Radiometric Performance Test

The DREAM FM has been fully tested and characterized at the subsystem level until the beginning of July 2006. In the middle of July, the environmental tests were performed such as the vibration test and the thermal vacuum test. After that, the system level performance test had been performed until the end of September 2006. To characterize the linearity and sensitivity of DREAM FM, liquid nitrogen was used as the reference source maintaining at 77 K. Putting a container which was full of liquid nitrogen in the front of the MA and adjusting a variable attenuator between the antenna and the receiver, the output voltage was measured. The linearity of both channels is shown in Fig. 4. In case of 23.8 GHz, the output voltages were measured at 100.3, 117.7, 141.2, 164.6, 189.8, 212.3, 237.7, 260.4, 279.3, and 292.9 K. In case of 37 GHz, they were done at 94.1, 112.2, 136.3, 154.0, 175.6, 196.4, 217.6, 253.3, 278.7, and 292.7 K. The standard deviations at all measured data at each point do not exceed 0.2 K. The test results are summarized in TABLE I. The results showed that the radiometric performance of DREAM FM was enhanced compared with that of DREAM PFM. Remarkably the sensitivity was lower. The major items are briefly tabulated in TABLE II.

V. Conclusion

The DREAM is the Korean first microwave radiometer payload that will be launched in 2008. The program was started from October 2005. The DREAM PFM was developed and tested in December 2005. The DREAM FM was implemented in September 2006. It was equipped in STSAT-2 FM in October 2006. From the end of 2008, DREAM will start the mission.

ACKNOWLEDGMENT

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REFERENCES


TABLE I. DREAM SYSTEM PARAMETERS

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Channels</th>
<th>23.8 GHz</th>
<th>37 GHz</th>
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<tr>
<td>Center frequency</td>
<td></td>
<td>23.8 GHz</td>
<td>37 GHz</td>
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<td>3dB beamwidth of MA</td>
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<td>&gt; 98 %</td>
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<td>Noise figure</td>
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<td>&lt; 6.4 dB</td>
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<tr>
<td>Integration time</td>
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<td>204 ms</td>
<td>208 ms</td>
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<tr>
<td>Sampling time</td>
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<td>200 ms</td>
<td>200 ms</td>
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<tr>
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<td>3 ~ 340 K</td>
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<td>&lt; 0.2 K</td>
<td>&lt; 0.2 K</td>
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<tr>
<td>Linearity</td>
<td></td>
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TABLE II. COMPARISON OF FM AND PFM PERFORMANCE

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<tr>
<td>Linearity</td>
<td></td>
<td>&gt; 0.99</td>
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Figure 4. Linearity of DREAM FM. (a) 23.8 GHz (b) 37 GHz