DESIGN OF HIGH SENSITIVE SPACEBORNE MICROWAVE RADIOMETER DREAM ON STSAT-2

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ABSTRACT:

Dual-channel Radiometers for Earth and Atmosphere Monitoring (DREAM) is the Korean first spaceborne microwave radiometer which is the main payload of Science and Technology SATellite-2 (STSAT-2). STSAT-2 will be launched by Korea Space Launch Vehicle-1 (KSLV-1) at NARO Space Center in Korea in 2007. DREAM is a two-channel, total power microwave radiometer with the center frequencies of 23.8 GHz and 37 GHz. The spaceborne radiometer is composed of an antenna unit, a receiver unit, and a data acquisition/processing unit. The bandwidths of radiometer are 600 MHz at 23.8 GHz and 1000 MHz at 37 GHz. The integration time of two channels is 200 ms. The sensitivity of DREAM is less than 0.5 K. This paper presents the required performance and system design of DREAM in detail.

KEY WORDS: DREAM, STSAT-2, Remote Sensing, Radiometer

1. INTRODUCTION

For many years, the spaceborne microwave radiometer has contributed to investigate the earth environmental phenomena such as soil moisture, precipitation, snow, liquid water and water vapour. In recent years, the radiometer plays an important role more and more in the research of earth environment because it has a capability of global, day and night, nearly all-weather remote sensing. The several advanced spaceborne radiometers such as AMSR, MWR, TMR, and ATSR have been developed for the environmental monitoring of the earth such as weather, atmosphere, ocean and soil observation[1]-[7].

In Korea, the Science and Technology SATellite (STSAT) project has progressed for the domestic development of a low earth orbit 100 Kg satellite by Korea Aerospace Research Institute (KARI) since 1998. The STSAT-1 was launched for the development of a low earth orbit micro-satellite and the study of a celestial observation of ultraviolet spectrum on 1992[8]. The STSAT-2 will be launched by the Korea developed first launch vehicle at the NARO space center in Korea in 2007. The payload of STSAT-2 consists of Dual-channel Radiometers for Earth and Atmosphere Monitoring (DREAM) and Satellite Laser Ranging (SLR). The mission of SLR is to measure precise distance between STSAT-2 and a ground SLR station and to determine precise orbit of STSAT-2. The mission lifetime of STSAT-2 is 2 years and the mission orbit is an elliptical low earth orbit with the perigee 300 km and the apogee of 1,500 km[9].

DREAM is the Korean first spaceborne radiometer and a two-channel microwave radiometer. It receives linearly polarized radiation at 23.8 and 37 GHz. Since DREAM is loaded in the micro-satellite, the design capacity of DREAM is limited and some system parameters depend on the restriction on spacecraft. So, it measures the brightness temperature from the earth at the direction of nadir without the antenna scanning. The allowed mass and power are 15 Kg and 20 W, respectively. The payload requirements are listed in Table 1.

The main objective of DREAM is to develop the fundamental technology of spaceborne microwave radiometer and to study the earth environmental parameters such as precipitation, water vapor and cloud liquid water from the measured DREAM data. The design of DRAM is presented in the following sections.

Table 1. Payload Requirement

Parameters	Specification
Mission life	2 year
Orbit	Apogee 1500 km, Perigee 300 km
Inclination	80 °
Mass	< 15 Kg
Volume	330 × 270 × 200 mm (electronic box)
Power	20 W
Minimum duty cycle	50 %

2. RADIOMETER SYSTEM DESIGN

2.1 DREAM System Description

The system specifications of DREAM are listed in Table 2. The DREAM is composed of two channel radiometers with center frequencies of 23.8 GHz and 37 GHz. The bandwidths of receiver are 600 MHz at 23.8 GHz and 1000 MHz at 37 GHz, respectively. The integration time of both two channels is 200 ms. The required sensitivity and accuracy of DREAM are less than 0.5 K and 2.0 K, respectively. The swath width is the same with the field of view (FOV) of DREAM because DREAM antennas do not scan. The FOV of the observation antennas for both frequencies is 10 °. And the swath width shall be changed from 52.5 km to 262 km depending on orbit. The payload will operate on 50-percent minimum duty cycle and the data size is 1 Mbytes per orbit. The DREAM is mounted on the third floor platform of STSAT-2. The observation antennas are pointed to the nadir and mounted on the earth panel of STSAT-2. The calibration antennas are pointed to the deep space and mounted on the sensor platform, which is the top platform of SASAT-2. Fig. 1 shows the configuration of DREAM[10]. The DREAM consists of 4 subsystems functionally; mechanical structure subsystem, antenna structure subsystem, radiometer receiver subsystem, and data acquisition/processing subsystem. Fig. 2 shows the system block-diagram.

2.2 Antenna Structure Subsystem

The DREAM antennas consist of two observation antennas and two calibration antennas[11][12]. In DREAM, the corrugated horn antennas with low side-lobe and high main-beam efficiency are used as the observation antennas, as shown in Fig. 3. Their 3-dB beam-widths are about 10 °. The main beam efficiency of the observation antennas is larger than 90 %. The simulation results of observation antennas are listed in Table 3. The calibration antennas are the horn antennas and have the 3-dB beam-width of 20 °.

Table 2. System Specification

Parameters	Specification
Center frequency	23.8 GHz, 37 GHz
Bandwidth	600 MHz(23.8 GHz), 1000 MHz(37 GHz)
Noise Figure	< 4.5 dB(23.8 GHz) < 5.5 dB(37 GHz)
Integration time	200 ms
Observation antenna Beam-width	< 10 °
Dynamic range	3 – 340 K
Radiometric accuracy	< 2.0 K
Radiometric sensitivity	< 0.5 K
Linearity	0.99
Antenna polarization	Linear polarization
Look angle	Nadir
Swath width	52.5 km – 262 km

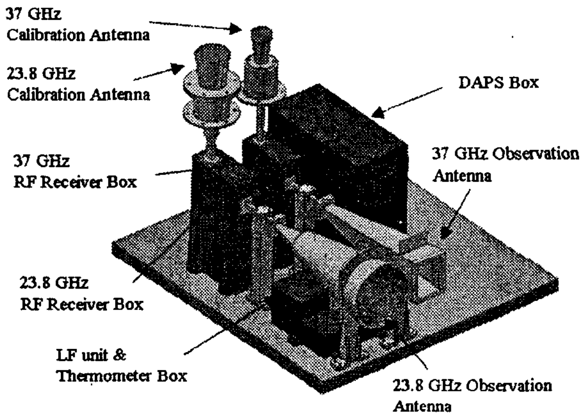


Figure 1. DREAM Configuration

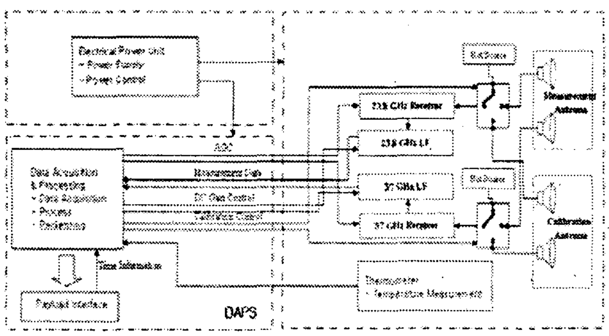
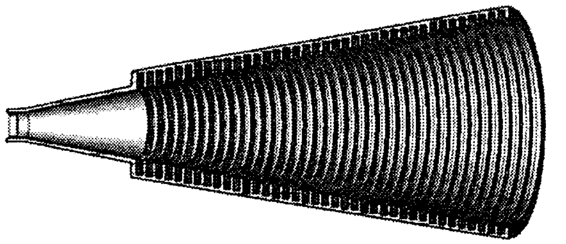
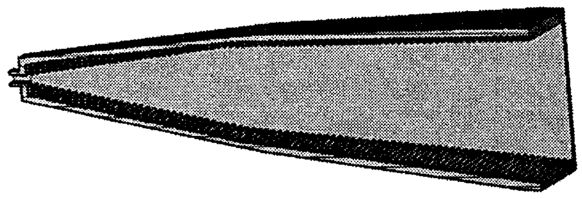


Figure 2. DREAM System Block-diagram



(a)



(b)

Figure 3. DREAM Observation Antennas. (a) 23.8 GHz antenna, (b) 37 GHz antenna

Table 3. Simulation Results of Observation Antennas

Center frequency	23.8 GHz	37 GHz
Gain	24.4 dB	25.6 dB
3-dB beam-width	10.8 °	9.5 °
Side-lobe	-31.5 dB	-22.2 dB
Return loss	-25.2 dB	-28.9 dB
Beam efficiency	> 90 %	> 90 %

2.3 Radiometer Receiver Subsystem

The radiometer receivers are composed of two frequency RF receivers, two LF units and a thermometer[11][12]. Fig. 4 shows the configuration of the radiometer receiver. In design of a radiometer receiver, the most important parameters in many considerations are the sensitivity of radiometer system. To get the high sensitivity with a simple structure, the radiometers use a type of total power instead of a Dicke type. The radiometers have a heterodyne receiver and operate in a double-side band mode. The local oscillator (LO) frequency is the same as the center frequency of DREAM. The total system noise figures of the radioemter are 4.5 dB at 23.8 GHz and 5.5 dB at 37 GHz, respectively. The RF receiver includes a RF switch, a RF LNA, a mixer, a local oscillator, a IF amplifier, and a IF BPF. To calibrate the measured data from the radiometer, two point sources are used.

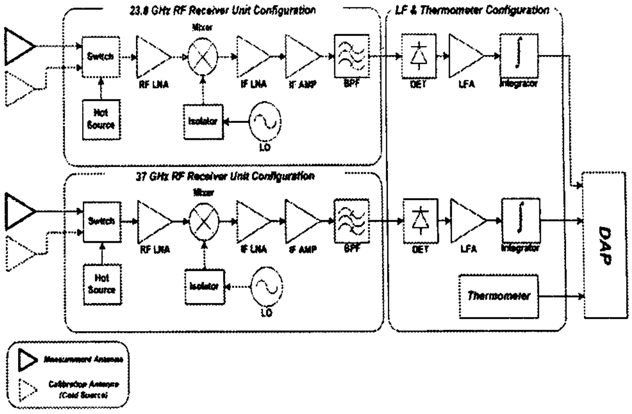


Figure 4. Radiometer Receiver Block-diagram

A cold source is the deep space radiation received by the calibration antenna and a hot source is an on-board matched load. From these calibration sources, the dynamic range of the radiometer is 3 K to 340 K. To switch the receiver to the matched load, the calibration antennas, and the observation antennas, a SP3T RF switch is used at the input port of each of the two RF front-ends. In nominal mode, the radiometer receives the observation antenna temperature. In the calibration mode, it receives the brightness temperatures both the deep space and the matched loads repeatedly. In DREAM, the period including two calibration and observation is 10.2 seconds and each calibration is executed every 9 seconds.

The LF box includes a detector, a LF AMP, and an integrator. The noise signal down-converted from RF module is amplified and then converted into the voltage signal by the detector with the voltage sensitivity of 2 mV/μW. The total gain of amplifiers is adjusted to a suitable level because the detector must be operated in the square-law detection region. For the integration of the measured data, low pass filter is implemented after a LFA.

The thermometer is used to inspect the system temperature variation for the calibration of the measured DREAM data. It measures 12 points of radiometer receiver in DREAM; two observation antennas, two calibration antennas, two matched load, four waveguides, and two RF front-end. The accuracy of the thermometer is less than 0.5 K.

2.4 Data Acquisition/Processing Subsystem

The data acquisition/processing unit used to process the measured data and control system[11][12]. First, It receives the data from 23.8/37 GHz receiver and the status of DREAM during the earth observation. Second, it is also used for data and command communication between DREAM and spacecraft bus. All data are transferred to the ground station. The electrical power unit converts the power from the spacecraft into the voltage levels required by the subsystem of DREAM.

3. CONCLUSIONS

This paper presents the DREAM system design on STSAT-2. The DREAM consists of the antennas, the radiometer receiver, and the data acquisition/processing unit. The spaceborne radiometer measures the brightness temperature at 23.8 GHz and 37 GHz to provide a meaningful data for the investigation of atmosphere and ocean. The radiometric performance of DREAM is limited by the restriction on spacecraft. However, the study on the application of the DREAM data has processed by scientists.

The Preliminary Flight Model (PFM) of DREAM will be implemented in November 2005. Two Flight Models (FM) will be manufactured in November 2006. DREAM will start the mission after launch in the end of 2007.

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