RADIATION BUDGET INSTRUMENT ON-BOARD SOLAR CALIBRATION TARGET – CONCEPT AND OPERATION

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ABSTRACT

The Radiation Budget Instrument (RBI) on-board Solar Calibration Target (SCT) concept and operation are presented in this paper. The SCT used during solar calibration of RBI is based on reflection properties of sintered Polytetrafluoroethylene (PTFE), an extremely stable, near perfect, Lambertian diffuser. The SCT incorporates three identical space grade sintered PTFE diffusers for on-orbit degradation monitoring. The SCT is used for calibration of the Shortwave (0.3 – 2.5 µm) and Total (0.3 – 100+ µm) channels of RBI. System level calibration test design and pre-flight calibration of each diffuser is also presented.

1. INTRODUCTION

The Earth's radiation budget components are the entering, reflected, absorbed, and emitted by the Earth system energy. The Earth radiation budget has to be balanced as the out-of-balance radiation budget may cause the Earth's system temperature to increase or decrease thus affecting our climate. The Radiation Budget Instrument (RBI), originally manifested on the JPSS-2 spacecraft will follow the successful legacy of the Clouds and Earth's Radiant Energy System (CERES) and Earth Radiation Budget Experiment (ERBE) instruments to continue monitoring the Earth's radiation budget [1], [2], Fig.1. The goal of RBI is to provide an independent measurement of the reflected solar radiance and Earth's emitted thermal radiance by using three spectral bands (shortwave, longwave, and total). To ensure precise NIST-traceable calibration in space, the RBI sensor is designed to use three stable on-board calibration targets – the visible calibration target (VCT), the solar calibration target (SCT), and the infrared calibration target (ICT), Fig.2. Traceability will allow the RBI measurements in the future to be compared with other instrument measurements performed at a different time or place. In addition to looking at calibration targets, the three telescopes of RBI will be use the moon as a calibration target as well as deep space observations [3].

Fig.1 Radiation Budget Instrument

2. DESCRIPTION AND OPERATION

The SCT incorporates three identical space grade sintered PTFE solar diffusers for on-orbit calibration. The design is straightforward with space heritage dating back to the design used on Advanced Baseline Imager (ABI) on Geostationary Operational Environmental Satellite — R Series (GOES-R). The diffusers are in a cube orientation within a sealed enclosure. They are mounted on a turret with a protective cover comprising the fourth side, Fig.3.

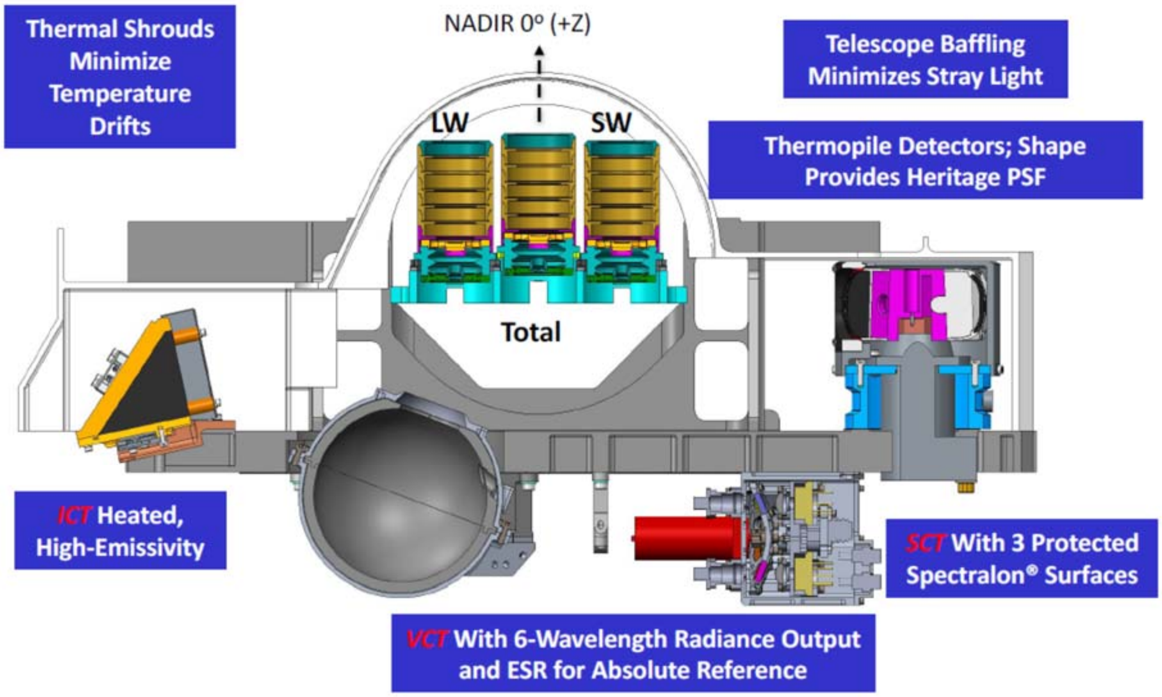

Fig.2 Calibration Targets, ICT, SCT and VCT

Sintered PTFE is an extremely stable, near-perfect, Lambertian reflecting diffuser and calibration standard material that has been used by national labs, aerospace, and commercial sectors for over two decades. The aging of solar diffusers presents challenges for calibration accuracy especially in the UV region of the spectrum. The first sintered PTFE diffuser will be used bi-weekly, the second quarterly, and the third one, also known as the reference diffuser yearly. The three diffusers monitored at different time intervals one to detect and correct for reflectance changes [4], [5]. The suite of stable on-orbit references will ensure that calibration stability is maintained over the RBI sensor lifetime. Finally, Bidirectional Reflectance Distribution Function (BRDF) measurements of witness sintered PTFE diffusers were used in the process of calculating the diffuser degradation impact on the science products.

RBI looks at a different scenes of interest and generates a numeric output signal. The SCT is used to convert the instrument's reflectance measurements to radiance measurements by knowledge of the solar irradiance by determining the relationship of the RBI signal to a radiometric quantity. The calibration approach for RBI using the SCT is based on the reflectance properties of the instrument's onboard diffusers. This technique uses RBI as a reflectometer, measuring the reflected solar irradiance from the Earth and from the onboard diffuser. Because the Sun is the common source of light for both measurements, the ratio of the RBI measured radiances from the Earth and the diffuser provide the ratio for the reflectance's of the two. The reflectance characterization of the onboard diffuser is the calibration reference. The calibration requires pre-flight calibration of onboard diffusers and the response of RBI channels for measurements of the diffusers simultaneously. This is achieved during pre-flight system level instrument calibration over the spectral range of interest.

The RBI on-orbit calibration using the SCT will be performed directly above the North Pole with the full Sun illumination of a diffuser for approximately 2.5 min. The SCT utilizes the Sun as extraterrestrial calibration source to facilitate detection of responsivity changes in the shortwave and total channels. The shortwave channel covers the spectral range from 0.3microns to 2.5microns, the total channel covers 0.3microns to 100+microns. RBI is capable of viewing the Sun indirectly with the shortwave and total channels as frequently as once per day for calibration.

The SCT is an important component of the long term on-orbit calibration of the RBI and is required along with the VCT and the ICT in order to meet the RBI science requirements. The SCT is NOT intended as an absolute calibration source. It will provide information on the degradation of the VCT sources and provide broadband calibration outside of the six discrete band calibration provided by the VCT. The SCT provides an additional ability to track changes in the shortwave channel, but not to the radiometric uncertainty levels stated in the Instrument Performance Requirements Document (IPRD).

3. SCT COMPONENT AND SYSTEM LEVEL TESTING

The SCT provides very precise calibration over mission lifetime. It is used for calibration of the shortwave channel (reflected solar energy measurement) and the total channel (reflected solar plus emitted thermal energy measurement).

The total hemispherical spectral reflectance provides a good measure of general performance, but without angular characterization of diffusers by measuring their BRDF, critical data is missing for instrument calibration. Therefore, the hemispherical reflectance and BRDF of the three witness diffusers were calibrated pre-flight at a NIST traceable laboratory. Eighteen locations were measured on the three diffusers surfaces in-plane. The incident angle was 0^o; the scatter zenith angles were 30^o, 35^o, and 40^o. The scatter azimuth angle was -90^o, the fiducial mark was at 0^o scatter azimuth. The measurement precision at 40^o, 35^o and 30^o scatter azimuth was 0.00023, 0.00017, and 0.00012 respectively for witness diffuser No.1.

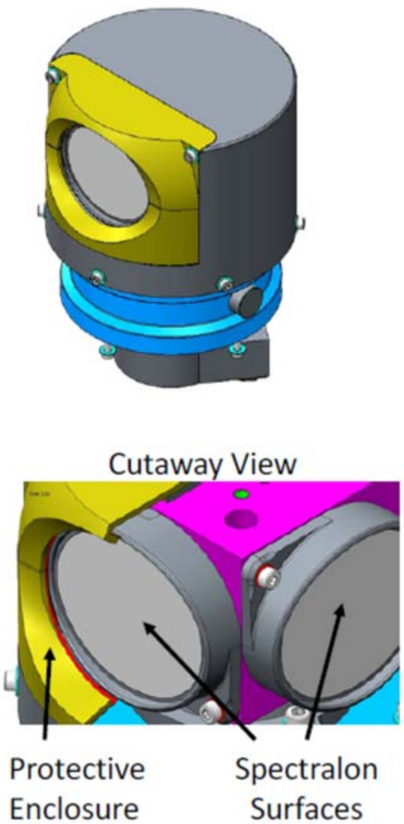

Fig.3 Solar Calibration Target

System level test had been designed for testing SCT at ambient temperature in addition to the calibration of the standalone diffusers. Both Short wave and Total channels will be used at this test. FEL lamp is used as a light source at system level calibration of the SCT integrated in the RBI instrument Engineering Development Unit (EDU). Mechanical positioning equipment for varying the incident zenith and azimuth angles to simulate the sun moving across the diffusers on-orbit is used. The receiver, RBI in this case is positioned at 35^o relative to diffuser normal at all incident angles. Raster scanning will be performed under the same illumination and viewing conditions to determine the uniformity of the diffuser. All diffusers will be tested at the center to address the positioning repeatability by rotating the turret and repositioning. The system level test of the SCT includes range of angles of +/-17° in incident zenith and azimuth angles. The lamp will be fixed at the SCT central incident angle. The change of the incident angle will be achieved by rotating the SCT turret. A silicon photodiode will be used to detect the scattered light. The test will be performed in a class 10,000 clean room.

4. CONCLUSIONS

All on-board calibration source uncertainties, including the SCT are included in the Radiance Measurement Expanded Uncertainties. The RBI total expanded uncertainty in each channel is less than 0.2% of that channel's maximum value of radiance. The uncertainties are calculated according to NIST Technical note 1297.

5. ACKNOWLEDGEMENTS

The authors gratefully acknowledge the support of Howard Yoon of NIST, Craig Turczynski, Glenn Hines, Mike Cisewski of LaRC for their encouragement and fruitful discussions. We also thank Chris Durell of Labsphere for his consistent help on measurement setups and discussions.

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