VNIIOFI's developments in measurement assurance of Earth remote sensing

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The results of VNIIOFI's developments during last decade and current activities in measurement assurance of Earth remote sensing are presented. Two standard radiometric facilities developed at VNIIOFI for preflight calibration of the remote sensing instruments are briefly characterized. The first facility is intended for calibrations in the visible and near IR spectral range, and the second facility based on a vacuum cryogenic chamber is for the thermal IR spectral range. A brief overview of performed calibrations of the instruments launched on board satellites for scientific and the Earth resources investigations is also presented. Completed and upcoming space-flight experiments aimed at creating space-born fixed-point blackbodies for onboard calibrations of IR remote sensing instruments are also described.

STANDARD RADIOMETRIC FACILITIES FOR PREFLIGHT CALIBRATION OF REMOTE SENSING INSTRUMENTS

For preflight radiometric calibration of remote sensing instruments with apertures up to 500 mm in the solar reflective range (from 0.3 to 3.0 μm) VNIIOFI has developed and created at 2010 the standard radiometric facility consisting of two large-area radiant sources [1]. The first is a monochromatic collimated radiation source (MCRS) measured for relative distribution of spectral radiant power with traceability to VNIIFI's cryogenic radiometer. The MCRS is intended for measuring the relative spectral responsivity of the remote sensing instruments with broadband spectral channels. The second is an integrating sphere diffuse source (ISDS) measured for spectral radiance against VNIIOFI's high-temperature fixed-point blackbodies (see [2] and refs therein). Calibration against the ISDS results in measuring the absolute radiance responsivity of hyperspectral remote sensing instruments.

Standard radiometric facility for preflight radiometric calibration of remote sensing instruments in the thermal IR spectral range (from 3 to 14 μm) was designed by VNIIOFI on the basis of vacuum cryogenic chamber modelling space environment conditions for the instruments under calibration inside it [3]. Monochromatic source of IR radiation for measuring the relative spectral responsivity consists of placed outside the chamber a set of detectors with traceability to VNIIFI's cryogenic radiometer, a monochromator, a high temperature blackbody and located inside an optomechanical system for spectral comparing. A set of low temperature blackbodies developed and manufactured at VNIIOFI and a Fourier-spectrometer are used for measuring the absolute spectral responsivity [4]. The gallium fixed-point black body is used as reference radiation source, and large-area blackbody in the form of a V-shaped 500 mm diameter aluminium-alloy plate covered by the black Aeroglaze Z306 dull paint stands for illuminating the instrument under calibration.

PERFORMED PREFLIGHT RADIOMETRIC CALIBRATIONS

Regular radiometric calibrations for spectral radiance responsivity of hyperspectral remote sensing instruments GSA-RP are performed against the ISDS [5]. GSA-RP was designed and manufactured by JSC «Krasnogorsky Zavod» under the contract with Progress Space Rocket Centre for hyperspectral imaging on board the Earth observation spacecraft of Resurs-P series [6]. Launches of the first three spacecrafts Resurs-P No.1, Resurs-P No.2 and Resurs-P No.3 with GSA-RP on board were performed on June 25, 2013, December 26, 2014 and March 13, 2016.

Multispectral Imaging System KMSS-2, consisting of two identical 3-channel multispectral imaging units MSU-100TM, was launched aboard satellite Meteor-M No.2-2 in a sun-synchronous orbit on July 5, 2019. KMSS-2 was developed by the Space Research Institute of the Russian Academy of Sciences (IKI RAN) for satellite monitoring of weather and climate. Measurements of the relative spectral responsivity against the MCRS and the subsequent measurements of the absolute radiance responsivity against the ISDS for

each channel of the both units MSU-100TM were performed during the preflight radiometric calibration [7].

Four surveillance cameras are installed on the surface platform of the ExoMars 2020 mission for obtaining overview colour, radiometrically corrected static images of the surface and atmosphere of Mars in the visible spectral range, formation of circular closed panorama of the landing site and measuring the spectral radiance of surrounding objects at three wavelengths - 0.45, 0.55 and 0.65 μm [8]. IKI RAN has developed the cameras and the radiometric calibration of the cameras was performed against the ISDS at VNIIOFI.

TOWARDS TO IN-FLIGHT CALIBRATIONS

Since 2008, VNIIOFI has continued activities aimed at creating a highly stable space-born fixed-point blackbodies for onboard radiometric calibrations of IR remote sensing instruments.

One series of space-flight experiments is testing the performance of low temperature blackbody prototypes with radiating cavity surrounded by a phase-changing working substance. The first experiment of this series was performed in 2014 on board the "Foton-M" No.4 reentrant vehicle. As a result of the experiment, stable melting plateaus of Ga (29.8 ºC) were obtained with the temperature drift no more than 30 mK [9]. The next analogous experiment is planned for In-Bi eutectic system fixed point (72.5 ºC) on board the "Bion-M" No.2 reentrant vehicle in 2024.

The second series of experiments is planned on board the International Space Station and consists in experimental studies of the microgravity influence on phase transitions of working substances with those melting/freezing temperature fixed points in the range interesting from the remote sensing viewpoint. The first experiment of this series for the fixed points Ga-In (17.7 ºC), Ga-Sn (20.5 ºC), (Ga-Zn (25.2 ºC), Ga (29.8 ºC) is planned in 2020, and the second experiment is for the fixed points H_2O (0 ºC) and In-Bi (72.5 ºC).

CURRENT ACTIVITIES

At present, VNIIOFI develops a comprehensive system of measurement assurance for remote sensing instruments of the visible, near IR and thermal IR spectral ranges during their development, preflight testing and orbital operation. Implementation of the system involves the following activities.

1. Development, manufacturing and certification of a complex of facilities for preflight radiometric, spectral and photogrammetric calibrations, including the harmonized with the international document “Quality Assurance Framework for Earth Observation” regulatory and methodological base that ensures traceability of the instrument characteristics to VNIIOFI’s measurement standards.

2. Development and creation of a center for pursuance remote calibration, remotely sensed data verification and associated products validation on the basis of

- onboard facilities for radiometric calibration including diffused plates, LED based integrating spheres, large-area blackbodies and blackbodies with radiating cavity on the fixed points;
- ground sites equipped with a mobile instrumentation providing spectral surface reflectance and atmospheric conditions.

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