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Calibration Target for Evaluating of the Spatial Frequency and Energy Resolutions of Digital Infrared Systems to Obtain the Imagery Information in Full-Scale Experiments

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This article contains the results of work on creating a mobile test object for evaluating the main parameters of digital infrared systems for obtaining airborne imagery information.

Keywords: infrared system, spatial resolution, energy resolution, test object

Introduction

By analogy with optoelectronic systems of the visible range, as a result of the development of the element base, modern infrared air-based systems for remote sensing of Earth are systems of the next (third [4]) generation, its main difference is radiation receivers.

Nowadays the radiation receivers of infrared systems are represented by various solid devices (cadmium-mercury-tellurium compounds, materials of the A_3B_5 group, quantum-well structures, superlattices) and microbolometers. In modern infrared radiation technology receivers the following basic parameters are implemented [4]: format - up to 1920 × 1280, sensor size - from 12 μm, dynamic range - up to 80 dB, frame rate - up to 100 Hz. Working spectral ranges [3]: 0.5-5 μm, 1-5 μm, 1.5-4 μm, 2-6 μm, 3-5 μm, 5-17 μm, 6-14 μm, 8-12 μm and 8-14 μm.

Modern infrared systems are characterized by small size, low power consumption and recording (transmission) of the imagery information in digital format. Digital format allows implementation of algorithms for geometric and radiometric correction in the infrared system before recording (transferring) the product image to the information carrier (from board of aircraft) is made, that significantly increases the efficiency of infrared systems.

Tests of new and future models of infrared systems remain indisputable in its relevance and importance. The development of the infrared systems requires improvement of both the test methods and the metrical and instrumentation base.

In this work, laboratory tests of infrared systems will not be considered in detail. They are improved to a greater extent on the way from automated to automatic processes.

Present work is devoted to the consideration of ways and concrete proposals for carrying out flight tests of infrared systems by estimation of the resolving power.

1. Requirements to test object

The International Open Skies Treaty (hereinafter referred to as the Treaty) was signed in Helsinki on 24 March 1992 and involves the observation of any point throughout the territory of the member-state using air-based sensors. The categories of sensors and restrictions imposed on their operation capabilities are fixed in the fourth article of the Treaty.

At the time of the Treaty signing, infrared systems were represented by infrared line-scanning devices, and ground resolution was determined by the limitation no better than 0.5 m.

According to the Treaty sensors are allowed to be used during an observation flight only after the international certification using the methods adopted by the Open Skies Consultative Commission on the basis of consensus. The methodology involves the definition (establishment - in terms of the Treaty) of a minimum height above the ground level from which sensors can be used during an observation flight in accordance with the ground resolution.

In 2013 Russian Federation became the first country among all the States Parties of the Treaty that conducted an international certification of digital sensors for visible and near infrared band and since 2014 Russian Federation has successfully been applying it during the observation flights over the territories of foreign participating States.

Currently preparations are being held for the international certification of the Russian Tu-214OS observation aircraft, including preparations for infrared sensors, and in the framework of the Open Skies Consultative Commission, international experts are working on a draft of Revised Decision No. 15 to the Treaty "Method to calculate minimum height over the ground level at which each infrared line-scanning devices installed on the observation aircraft is allowed to be used during the observation flight".

Test objects (calibration targets) are used as a tool to measure the resolution.

The main problem that we face during flight tests is to maintain the specified temperature contrast of the test object. We come across this problem when creating a calibration targets to estimate the resolution of infrared systems.

Active, passive and semi-active infrared test objects were created to maintain the specified temperature contrast. In addition to the operational and physical characteristics, these calibration targets, as a rule, had a high cost. For example, taking into account the limitation of the ground resolution no more than 0.5 m, a passive test object was made of aluminum with a thickness of 0.005 m, painted with three shades of gray, with a total mass more than 600 kg. Using such mass-dimensional parameters it is not possible to provide mobility of the calibration target without the use of additional forces and means.

Abovementioned determines the requirements for the test object (constancy of the temperature contrast, mobility) and indicates the direction of its improvement (weight reduction).

2. Creation and experimentative processing of test object

Various materials and overcoats were consideredto create infrared calibration target. Polypropylene nonwoven thermally bonded material metallized with aluminum by the method of magnetron ion-plasma sputtering [2] was usedto create the test object.

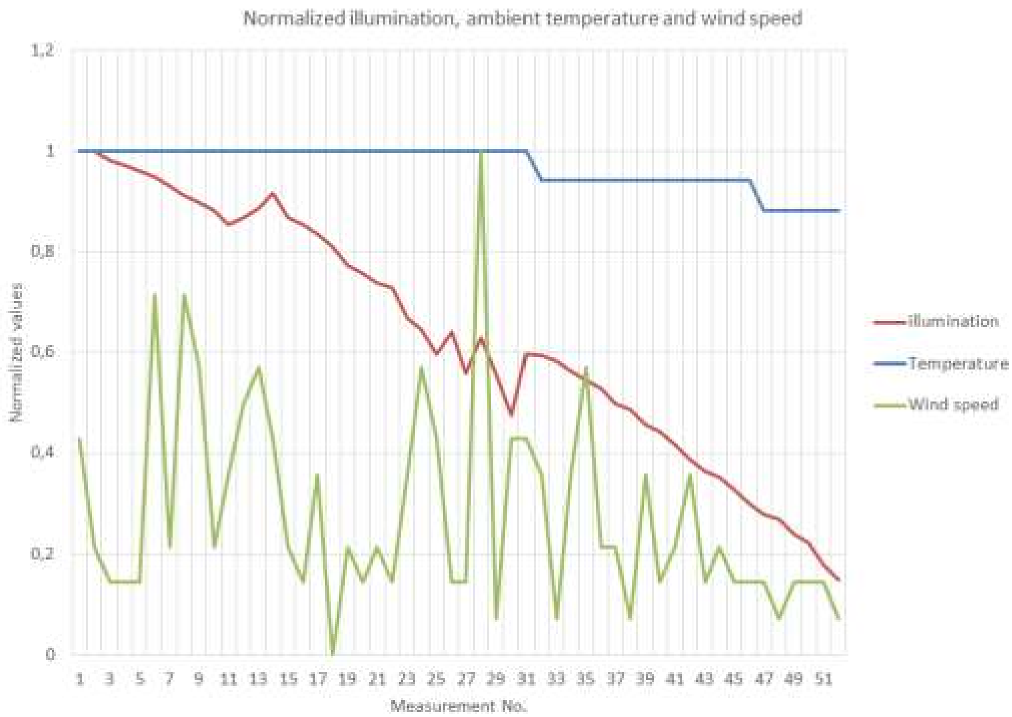
The aluminum metallization of a dark polypropylene nonwoven thermally bonded material was carried out during 30 s, 1 min, 2 min and 3 min. Aluminum coating homogeneityof the material surface and depth of aluminum penetration into the material depend on the time of metallization.

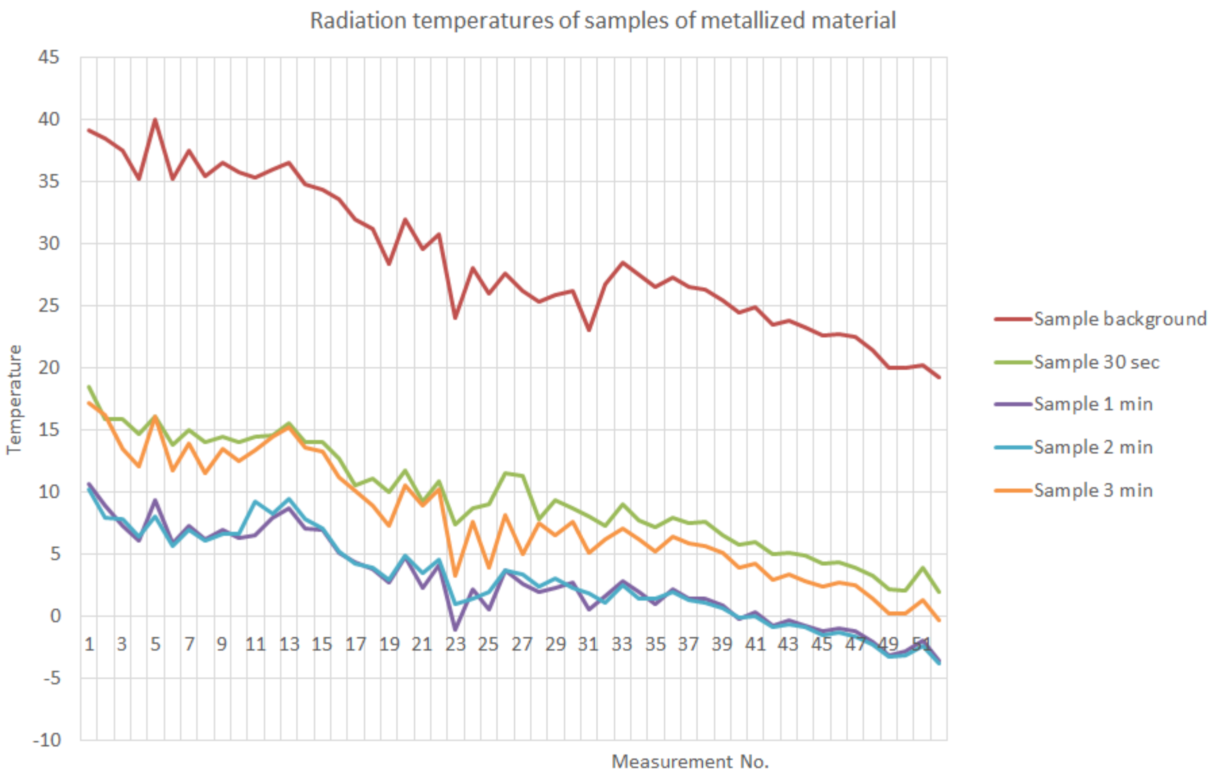
At the first stage of the experiment a scaled straight calibration target and brightness fields of a material with different duration of metallization were made.

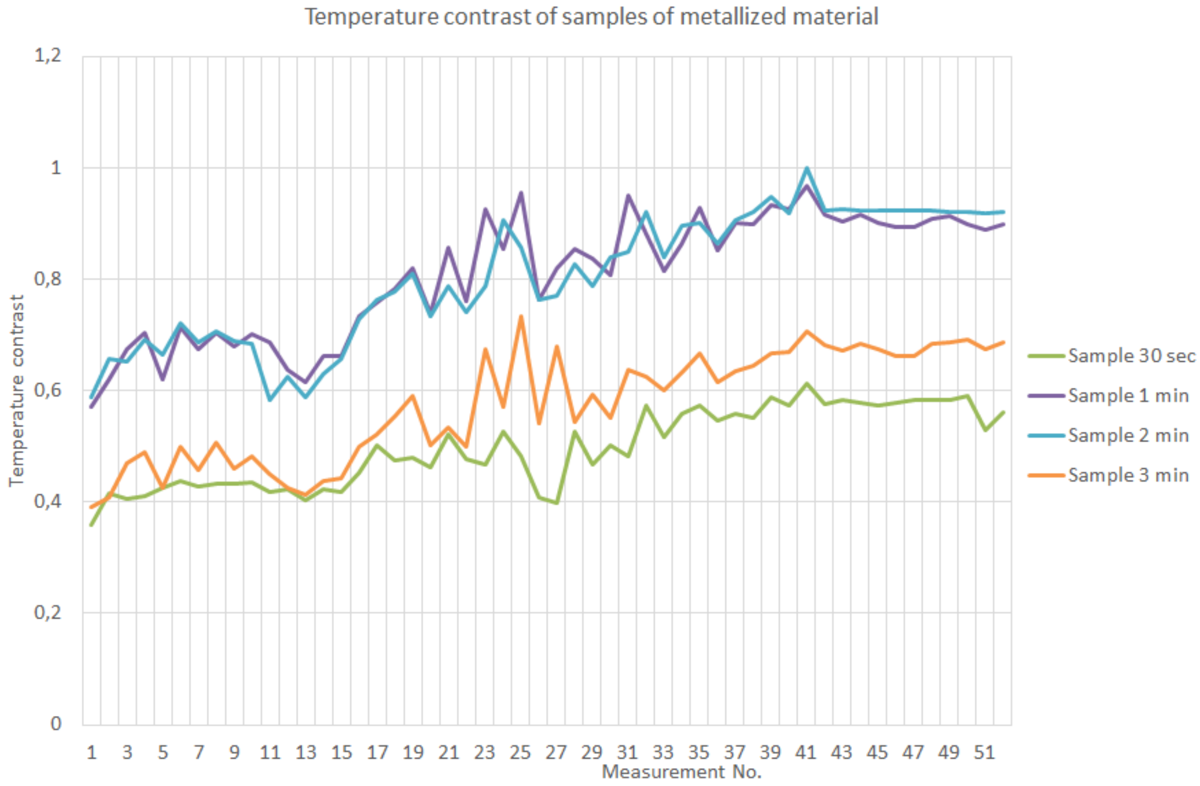
We will understand straight calibration targetas groups of strokes made of metallized material and located against the background of dark material.

The straight calibration target and brightness fields were placed on thetesting range equipped with a radiometer, luxmeter,brightness meter and meteorological station.

During the time corresponding to the sun heights above the horizon from 43 ° to 8 °, measurements of the radiation temperature of samples and parameters of the atmosphere and illumination were performed. The results of these measurements are shown on pic. 1.

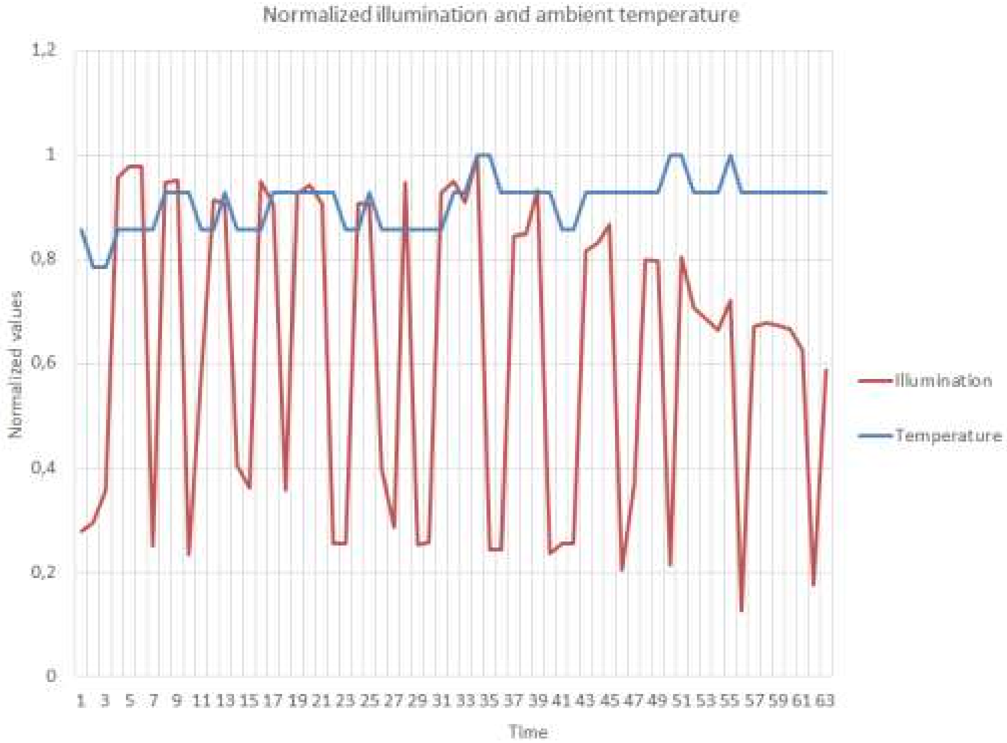


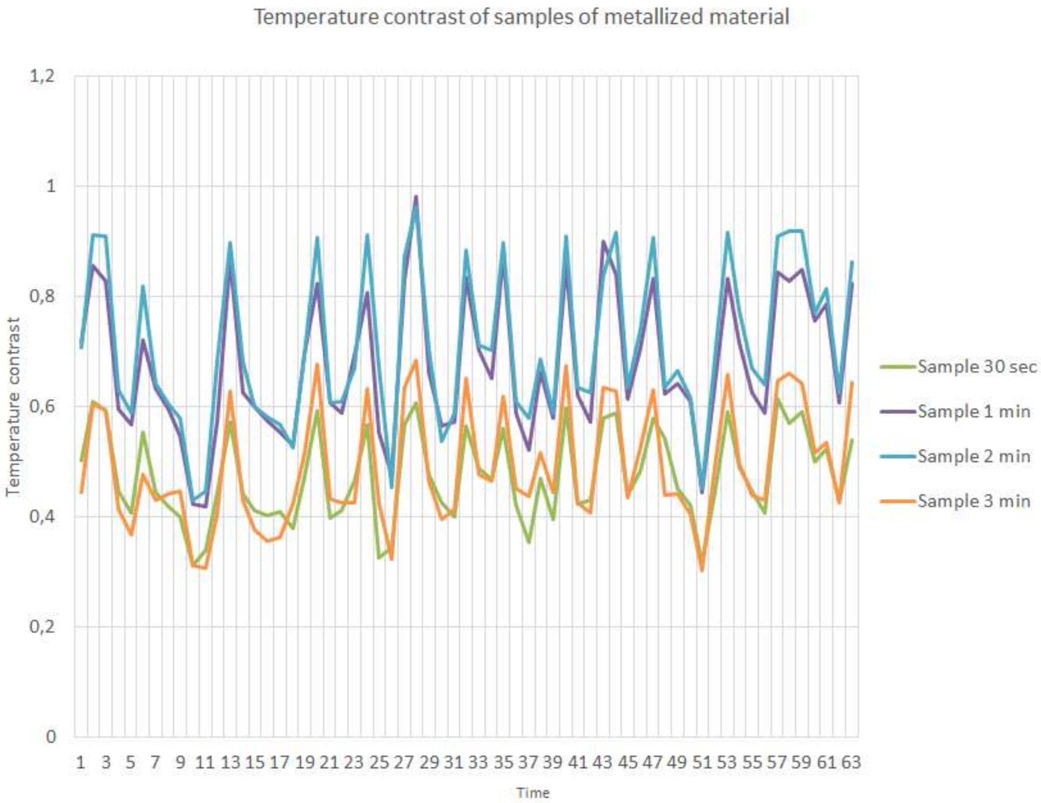

Radiation temperatures of samples of metallized material
Temperature
Measurement No.
Sample background
Sample 30 sec
Sample 1 min
Sample 2 min
Sample 3 min


Temperature contrast of samples of metallized material
Temperature contrast
Measurement No.
Sample 30 sec
Sample 1 min
Sample 2 min
Sample 3 min

(Picture 1)

Picture 2 shows the results of measurements under the conditions of a significant change in illumination when partly cloudy.





(Picture 2)

The analysis of the results has shown temperature contrastindependence of the developed test object from the temperature and wind (direction and speed) of environmental parameters.

In partly cloudy conditions with significant changes in illumination, the temperature contrast of the calibration target proportionally changes but remains sufficient to evaluate the resolution capability.

According to the results of the first stage of the experiment, it was decided to metallize with aluminum polypropylene non-woven thermally bonded material.

The aluminum metallization of a light polypropylene nonwoven thermally bonded material was also carried out during of 30 s, 1 min, 2 min, 3 min and 4 min.

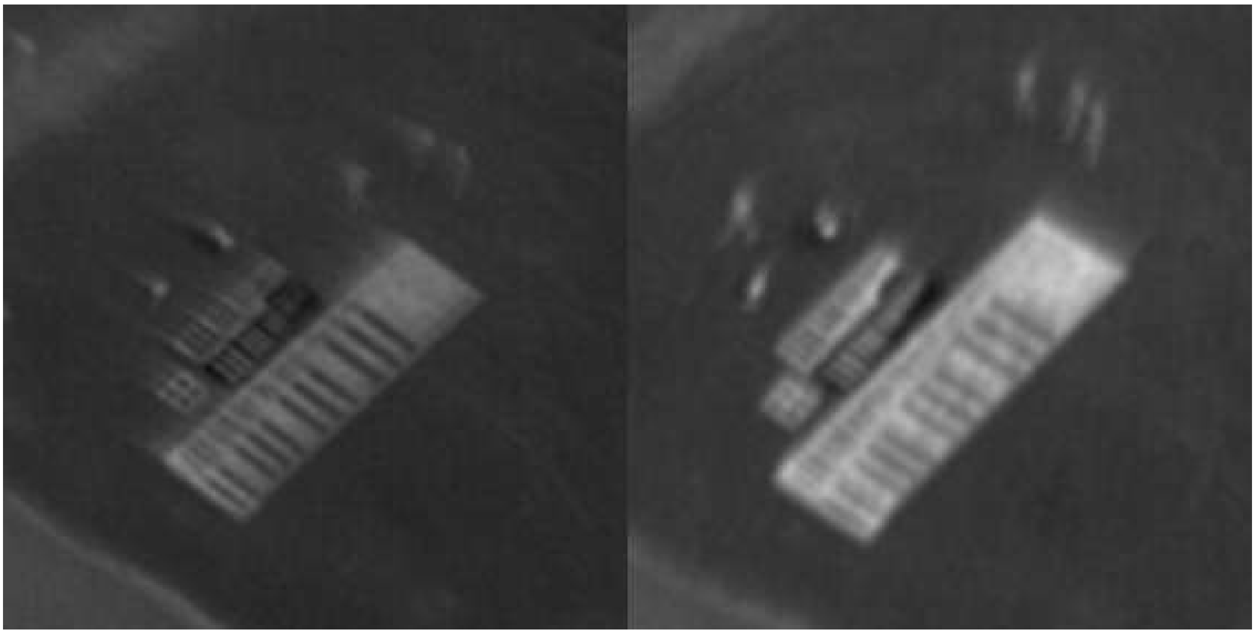
For the second stage of the experiment, scaled straight and inverse calibration targets were made as well as brightness fields from a material with different metallization duration.

Under the term «inverse calibration target» we understand groups of strokes made of dark material and located against the background made of metallized material.

All the created test objects as well as the visible range calibration target were placed on the testing area equipped with measurement instrumentation.

During the second stage of the experiment, an aerial survey of the testing range was carried out by an infrared airborne system.

Aerial photographs of the testing range area with all the test objects located there are shown on pic. 3.



(Picture 3)

Visual analysis of aerial photographs allowed to obtain an assessment of the resolution capability of a digital infrared system that is very close to the predicted one [1] and to the results of mathematical modeling [5].

Conclusion

The results of the experiments allow us to make a conclusion that it is possible to create a test object from the materials proposed in this article for evaluating of the resolution capability of digital infrared systems toobtainairborne imagery information in flight conditions.

The proposed calibration target made of polypropylene nonwoven thermally bonded material, metallized with aluminum by the method of magnetron ion-plasma sputtering, has a permanent temperature contrast, independent from the temperature and wind parameters of the environment. Moreover, while maintaining the dimensional specifications, the mass of the above-described aluminum calibration target will not exceed 90 kg. Thus, the task of reducing weight and providing mobility for the passive infrared calibration target has also been successfully resolved in this work.

Further work is connected with the creation of a full-scale experimental model of the calibration target with a half-period of the central group of strokes of 0.5 m and with aerial photography realized from cruising heights using infrared sensors.

The mode of metallization of a light material for the creation of a full scale experimental model should be chosen with duration of 2 min, becausethis mode provides an optimal balance of the aluminum coating homogeneity of the material surface and the depth of penetration of aluminum into the material. In other words,average temperature contrast of 0.8 and sufficient wear resistance are provided.

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