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ALGORITHM FOR DARK CURRENT CHARACTERIZATION OF IMAGING SPECTROMETER MODULE

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Abstract
The paper presents some of the results obtained in the process of laboratory tests of an imaging spectrometer model for remote sensing applications. The main dark current characterization procedures are described and highlighted. An algorithm for dark current characterization is proposed and implemented and the obtained results are shown.

Keywords: *remote sensing, imaging spectrometers, dark current characterization.*

1. Introduction

Imaging spectrometry (spectroscopy) has established itself as a basic method for studying the Earth's surface [1, 2]. At the same time, imaging spectrometry measurements, as a new area in remote sensing, require new approaches with regard to data handling, preprocessing and information extraction from spectral images. These approaches are an important part of the analysis of imaging spectrometry data and are binding on a quantitative estimation of the data. They imply accomplishment of characterization procedures, including sensor-detected effects corrections, such as offset and dark current corrections, spectral and geometric corrections, etc.

Measurement quality is the toughest problem in imaging spectrometry. Practical instruments which are used are always non-ideal and optical measurements are only approximated. Consequently, interpretation of obtained data is somewhat undetermined and is often dependent on the adopted assumption about the measured object [1]. Therefore, characterization procedures are carried out in parallel with the main instrument development to allow an efficient trade-off between the instrument's complexity and the system's performance, leaving correct interpretation of obtained data [3, 4]. It is strongly recommended that the instrument's development be attended by characterization process, since characterization methods are critically dependent on the instrument's design and construction, and performance requirements [5].

2. Dark current characterization

Characterization procedures start in parallel with the major instrument's development with planning and implementing methods for laboratory characterization and foreseen methods for on-board characterization.

The "dark current" term comes from the fact that this current is not relevant to sensor-surface-incident radiation. It is caused by thermo-generated electrons in silicon CCD structures, a process observed equally well in complete darkness. Some of the charge will collect in the sensor potential holes where useful-signal image-related electrons are collected. At the detector output, dark-current-generated electrons appear, identical to signal-generated electrons, so dark current appears as noise in the image.

At given temperature and sensor operating condition, dark current is relatively constant for each pixel and it appears as fixed signal offset. On the other hand, dark current varies spatially across the array. By capturing a series of images in complete darkness and averaging a pixel-to-pixel representation of the average dark current can be obtained at given temperature (Fig.1). Subtracting this reference dark image from subsequently captured real images partially eliminates the influence of the dark current (Fig.2). This is so the called dark current correction.

Unfortunately, dark current influences not to be completely eliminated. Except for the relatively constant component Uccij, dark current has a second randomly varying component ΔUcij, which is approximated as the square root [6] of the dark current, collected in the pixel (Fig.2).

Another complicating fact is that dark current will change when changing the sensor's operation mode, such as integration time, shift rate (Fig.1, 3). The size of the charge packet Q_p collected on a definite element is proportional to the integration time t, when the photo generated charges fill only partly the potential well within the integration period of the luminous flux Φ:

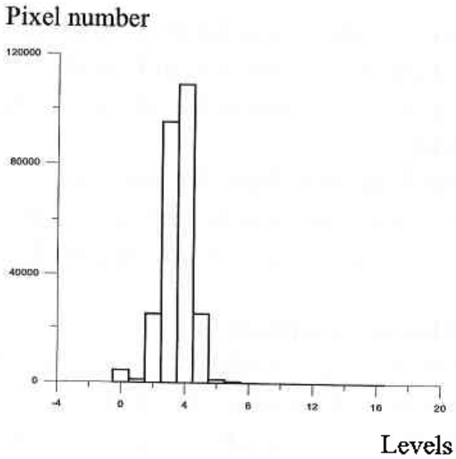


Fig. 1 Distribution of dark current levels for imaging spectrometer operating condition at integrated time $t_i = 80ms$.

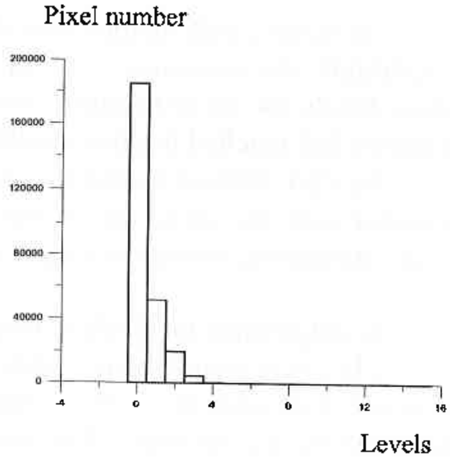


Fig. 2 Distribution of dark current levels after dark current correction, integrated time $t_i = 80ms$.

$$Q_p = q\Phi T_{tr}\eta t[1-\exp(-a\chi)/(1+aL_n)], \qquad (4),$$

where: a is the absorption coefficient of the material, T_{tr} – the transmission coefficient of the multi-layer structure, η - the quantum yield of the photo-emissive effect, χ - the depletion layer width, L_n – the diffusion length.

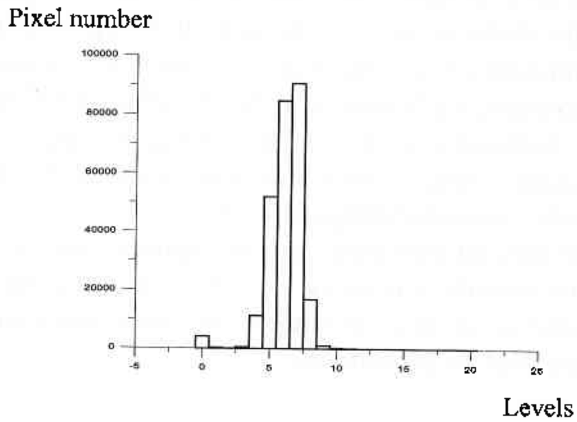


Fig. 3 Distribution of dark current levels for imaging spectrometer operating condition at integrated time $t_i = 100ms$.

Therefore, with change of operation mode, noise levels also change. To calibrate the instrument for these variations, one should store dark current levels for each operation mode and these should not be valid until the sensor had reached thermal equilibrium.

As dark current increases twice with temperature increase of 8°C, it decreases with the same rate when the sensor is cooled. For that reason, sensor cooling and operation temperature stabilization [7, 8] are required.

3. Algorithm for dark current characterization

The measurements are made in laboratory conditions; they aim to determine dark current levels' variation for each pixel of the sensor array. These laboratory-obtained data are stored for reference with on-board obtained data. In operation mode, during nominal observation, offset correction is performed by subtracting the dark level component from the signal. Dark current correction coefficients are obtained by closing the shutter, dark current levels Ucij are given by the detector response and are stored for further processing. The processing involves calculation of the average dark current level for each pixel in image and storage data for implementation of the characterization algorithms. These procedures must be performed for each possible sensor operation mode. The process of dark current characterization is indicated in the flow chart shown in Fig. 4.

The process of dark current characterization - capturing images, subtracting, storage (Fig.4) takes time and computational power, but in the corrected images, the dark current's effect is partially eliminated and quality is dramatically improved (Fig.5, 6). For example, in a system with 8-bit (256 levels) quantization, each level can hold 1/256 of full-well capacity. Each pixel has a dark-current-caused amounting to approximately 6.21 levels. Following dark current correction, dark current is reduced to 0.4 levels, as shown in the corrected image (Fig.5b).

It should be noticed that dark current characterization is only a part of a complex characterization process typical of an imaging spectrometer and it can be regarded as an integral component of the following radiometric and spectral characterization procedures.

4. Conclusions

1. The dark current characterization procedures, carried out as indicated in the proposed algorithm, result in an essential decrease of dark current levels in the corrected spectral images.

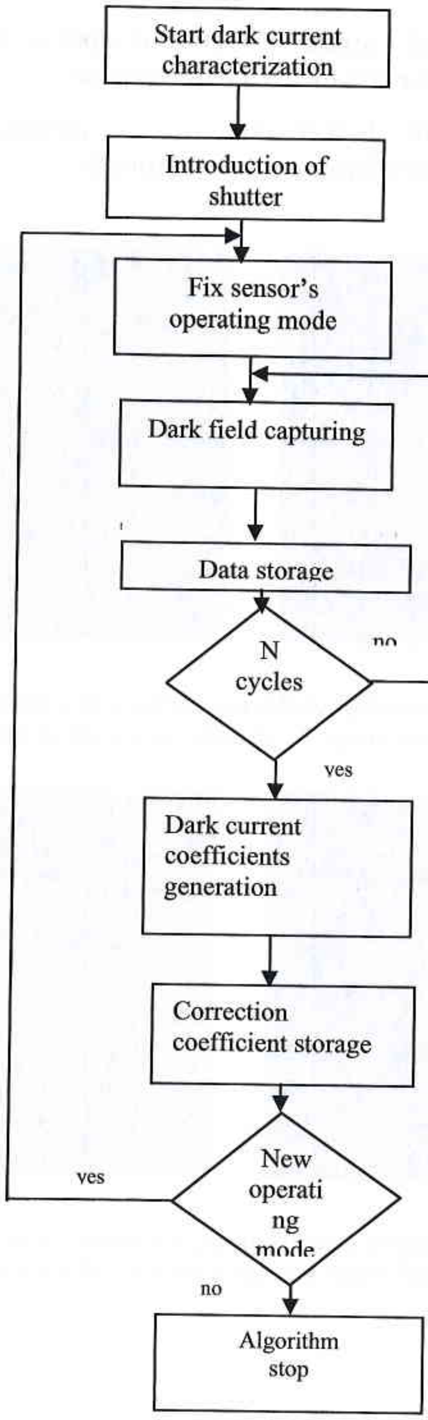
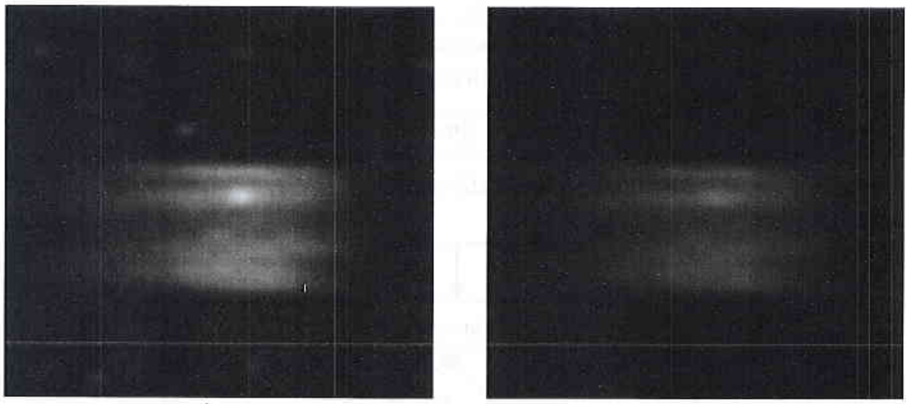


Fig. 4 Dark current characterization flow chart

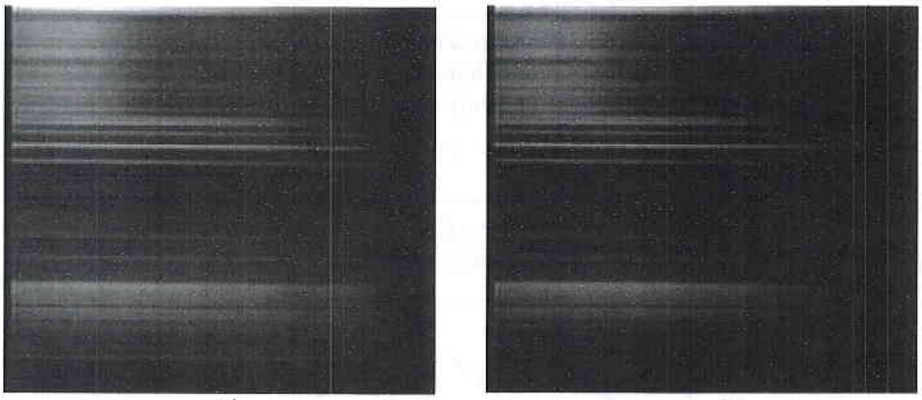
2. The foreseen dark current correction in operation mode results in improvement of the instrument's metric characteristics.

3. The dark current characterization is an inseparable part of the spectral instrument's overall characterization process.



a/ b/

Fig. 5 Laboratory obtained spectral images (fragments), spectral band 550nm,
a – original image, б – dark current corrected image.



a/ b/

Fig. 6 Spectral images of natural objects, in spectral region 450 – 650nm,
a – original image, б – dark current corrected image.

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АЛГОРИТЪМ ЗА ХАРАКТЕРИЗАЦИЯ НА ТЪМНИННИЯ ТОК НА ВИДЕОСПЕКТРОМЕТРИЧЕН МОДУЛ

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Резюме

В работата са представени част от резултатите, получени през времето на провеждане на лабораторни изследвания и тестове на модел на видеоспектрометър за дистанционни изследвания. Това са преди всичко резултати свързани с характеризационния процес при изграждане на прибора и по специално отнасящи се до характеризацията на тъмнинния ток. Описани са основните характеризационни процедури, предложен е алгоритъм за характеризация на тъмниния ток и са показани получените резултати.