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Wide Spectral Band Telescope for Remote Sensing Optical Surveilance with Remotely Piloted Aircraft

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Abstract

As an emerging field, remote sensing relays on remote aircraft system. This article discusses the emerging technology of Remotely Piloted Aircraft (RPA) based aerial remote sensing concept featuring a spectral sensing geo-referencing aerial imagery, precisely hyperspectral imaging spectrometer with diffraction resolution, light-capable and wide light spectrum (at least 0.4 – 2.5 μm range) telescope. Review of telescope and Remotely Piloted Aircraft carrier parameters are made. The detail study for the technical aspect of RPA is considered to make whole platform compatible with its need to meet the best resolution and results. This technology could be used in various fields like environment monitoring, agriculture, natural disaster survey, resource exploitation and much more that will be considered under its application.
KEY WORDS: *Remotely Piloted Aircraft (RPA), Remote Sensing Optical Surveillance (RSOS), Multispectral, Hyperspectral imaging, wide spectral band Telescope, Spectrometer*.

1. Introduction

This article discusses the emerging technology of RPA based aerial remote sensing concept featuring a recent appearance of on-board multispectral and hyperspectral imaging systems, e.g. [1, 3-6]. Both systems, particularly, hyperspectral images will find many different applications in resource management, agriculture, mineral exploration, environmental monitoring and many others applications. For hyperspectral imaging on RPA, firstly the engineering solutions to design of small dimensions light-capable telescopic system mated with hyperspectral camera (appropriate spectrometer with video sensor) must be made and secondly, the effective use of hyperspectral images requires an understanding of the nature and limitations of the data and of various strategies for processing and interpreting it, e.g. [2]. The RPA carrier parameters must meet as hyperspectral imager device certain dimensions and weight as well as ensuring its operation: aiming the object and tracking its relative movement. The hyperspectral imager device optical system (telescope) must provide sufficient illumination for the spectrometer's optical spectral channel's band.

2. Remote Sensing Optical Surveillance Directions

This article discusses the emerging technology of RPA based aerial remote sensing concept featuring a recent appearance of The RPA together with satellite platforms are more used RSOS in different earth and other sciences and applications directions and differs with applied on-board sensors and measurement technologies:

1. The simplest – the RPA optical video surveillance hardware and related technologies have mass applications.

2. More complex direction for aerial platforms – earth science and application as Land Management national organizations, includes more sophisticated RPA hardware and result analyses software (for RPA and satellite data acquisition) for different data: for technologies from 30 m till some cm resolution. This direction includes:

– Survey (photogrammetric) RPA systems as advanced system for cost and time saving.

– In-depth survey on RSOS instruments - which might be suitable for RPA payloads, particularly distinguishing between visible-band, near-infrared, multispectral, hyperspectral, thermal imagers, laser scanners (Lidars) and synthetic aperture radar.

Multispectral and hyperspectral imagers deal with:

Visible-band, near-infrared and multi-spectral cameras for photogrammetric and remote sensing community which have benefited from professional markets' designs for remote sensing instruments with high resolution (supplied with field cameras up to more than 50 Mpix now).

The simplest RSOS use spectra band (0.5-1.1/1.6 μm) divided into 6 – 8 discrete bands for multispectral band imaging.

A Hyperspectral camera deals with imaging narrow spectral bands over a continuous spectral range, producing the spectra of all pixels in the scene. Hyperspectral devices extract more detailed information than multispectral sensors because an entire spectrum is acquired at each pixel. Hyperspectral devices (spectrometers) is used in spectra band 0.4-2.5 μm and divided more than 250 sub-spectra bands, e.g. [2,8].

The hyperspectral spectrometer development parameters will be discussed below.

3. Telescopic System

The hyperspectral spectrometer development objectives for RPA firstly is associated with suitable telescope system design:

It must be with diffraction resolution, light-capable and wide light spectrum (at least 0.4 – 2.5 μm range) telescope and other complementary optical elements formatting with following spectrometer.

The imaging spectrometers with limited spectra range appropriate to use on RPA are obtainable in the market.

The optical telescope together with other optics (with included spectrometer) must be placed in direction stabilized gimbaled mount and must meet the currently used fixed-wing or rotary-wing RPA basic parameters:

1. Payload: not more than 10 kg (telescope with spectrometer in gimbaled tracking mount and related equipment including electronics system).
2. Telescope in gimbaled mount size: mot more than 150 × 150 × 150 mm.
3. Electric power: not more than 20W.

The telescope for imaging spectrometer was designed with its own special developed software (not published) and tested with ATMOS software [7], manufactured and tested with the following parameters:

Input aperture: 85 mm.
Focal length: 145 mm.
Aperture ratio: 1.93.
Field of view: 4º.**(**image height: 10.2 mm).
Spectra band: 0.4 - 2.5 μm.
Calculated optical resolution: see Fig. 1, Fig. 2

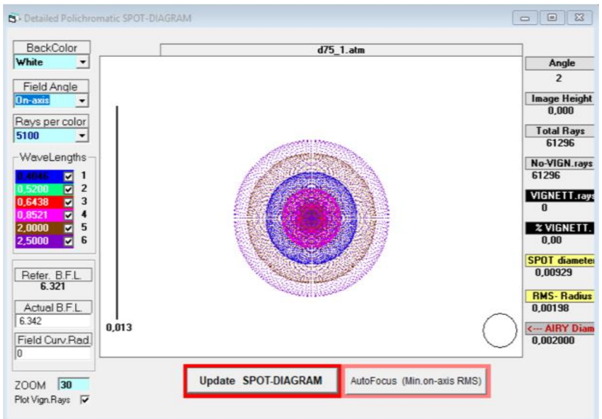

Fig. 1 Polychromatic Spot-Diagram. On-axis. Spot-diameter: <10 μm (at spectra band 0.4 - 2.5 μm).

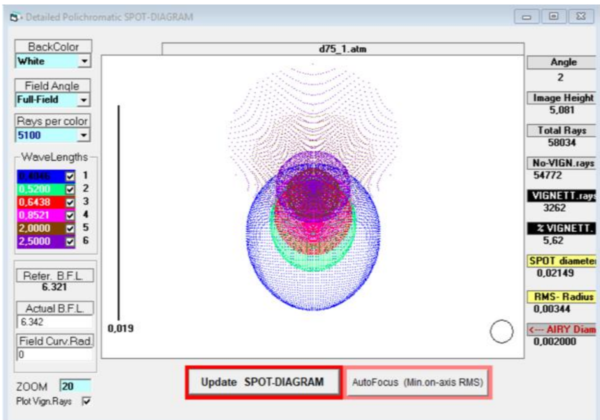

Fig. 2 Polychromatic Spot-Diagram. Full-Field. Spot-diameter on the edge of the field (4º): <22 μm (at spectra band 0.4 - 2.5 μm)

The telescope includes spectra dividing element sending firstly the visual spectra (VIS) image to visual camera focal-plane array (FPA) fixing incoming picture at the RPA flight. Secondly – sending full spectra image to spectrometer input. From the incoming VIS spectra picture analysis with the RPA flight height measurements, the data for spectrometer data analysis are acquired. The hyperspectral spectrometer measured field of view (FOV) and resolution in visual and infrared ((IR) spectra is shown in Table 1.

Table 1

Linear FOW and resolution depending of flight height

Flight height (m)	Linear FOW (m)	Theoretical linear resolution in object field (VIS) (cm)	Theoretical linear resolution in object field (SWIR and IR) (cm)
250	17.5	1.37	3.77
500	35	2.75	7.5
1000	70	5.5	15
2000	140	11	30
4000	280	22	60

4. Spectrometer

The imaging spectrometers appropriate to use on RPA are obtainable in the market, mostly with insufficient optical telescopic system. They must be completed with suitable diffraction resolution, light-capable and wide light spectrum (at least 0.4 – 2.5 μm) telescope and other optics. In this case the new spectroscope development suited for RPA fixed-wing or rotary- wing carrier is supposed (see Fig. 3). The hyperspectral spectrometer is especially designed spatial scanning device, in which each two-dimensional (2-D) FPA sensor output represents a spectrometer full slit spectrum (x, λ). Hyperspectral imaging (HSI) devices for spatial scanning obtain slit spectra by projecting a strip of the scene onto a slit and dispersing the slit image with a prism and having the image analysed per lines. With this line-scan system, the spatial dimension is collected through RPA platform movement. This requires stabilized gimbal mount and accurate pointing information to 'reconstruct' the image. To acquire the full spectra range image the 3 different spectrum dependent FPA sensors (detectors) are used for spectra ranges VIS: 0.4 – 0.9 µm, SWIR: 0.9 – 1.7 µm and IR: 1.7 – 2.5 µm) at the same time. The spectrometer has especially designed spectra calibration system.

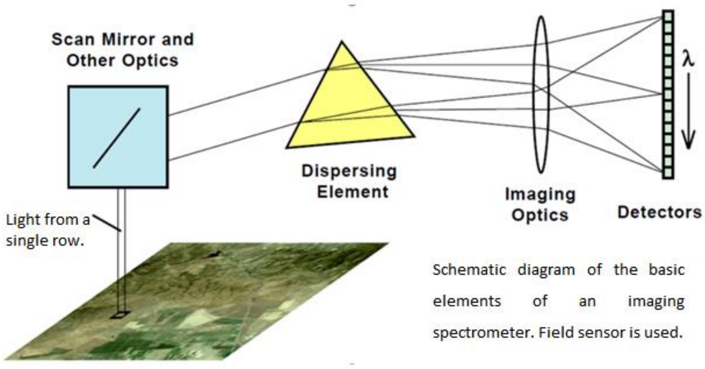

Fig. 3 Imaging spectrometer

The appropriate capacity images video data storage system used to collect synchronized incoming picture at the RPA flight, separate spectrum dependent field sensors acquired images and other RPA flight data for making post processing spectrometer data analysis.

Image analysis

Additionally for the stringent positioning, it requires that the system is designed using high quality navigation systems and using navigation-grade inertial measurement units (IMU) and of geodetic Global Positioning System (GPS) receivers.

1. Hyperspectral imaging, like other spectral imaging, it also collects and processes information from across the measured spectrum obtained for each pixel in the image of a scene, with the purpose of finding objects, identifying materials, or detecting processes.
2. The image analysis is completely dependent on the type of used Hyperspectral imaging sensor and its calibration parameters and controls, including all optics (incl. telescope optical parameters).

In this case market software is usable.

5. Remotely Piloted Aircraft for Remote Sensing

In this project the fixed-wing RPA is supposed to use. On our view would be suitable small RPA fully equipped with control and navigation systems and specialized stabilized gimbal system for telescope with spectrometer, e.g. Penguin B platform [9] or alike. This highly depends on the pre-flight operation and processing of data obtained after the flight operation.

6. Conclusion

In article are discussed the improvements in RPA carrier hyperspectral spectrometer optical system which significantly improves spectrometer sensitivity, improving the acquisition of hyperspectral data in low light conditions and shortly described selected and evaluated hyperspectral spectrometer and RPA requirements.

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