Hyperspectral monitoring AOTF-based apparatus

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Abstract. The apparatus for hyperspectral imaging in visible range is described. The rugged and compact design makes it suitable for unmanned aerial vehicles. The system is capable both for recording the entire spectral-spatial data ("hypercube") and for selective grabbing the spectral images at characteristic wavelengths. This selective mode provides real-time extracting the most valuable information from the monitoring scene and reduces requirements for operation speed and data storage capacity of processing subsystem. The technical characteristics and basic features of the hyperspectral apparatus are presented and discussed.

1. Background

Hyperspectral (HS) monitoring becomes more and more attractive technique for various fundamental and practical applications. And, as usual, new scientific tasks requires new instruments for their solution. Spectral tunable systems are now widely spread for environment monitoring, soiles classification, foliage taxation, security missions and other applications. The HS analysis is based on the relationships between energy structure of the substances and their spectral characteristics. This approach makes possible the identification of composition complex objects and its structure detection. The spectral-spatial "hypercube" $I(x,y,\lambda)$ is filled with a series of images detected by the HS instruments [1-10].

Hyperspectral imaging is helpful in investigations of land and water surfaces, for cartography, for searching deposits of mineral resources, for inspection of humidity status of the soil (extra saltiness, overwetting), status of the biocenoses, etc. A variety of applications require local monitoring of water basins, in particular, lakes and rivers, as well as sea coastal zone: bays, estuaries, offshore aquatories. Another highly important applications concern the agriculture (vegetation index, crop dynamics, pest activity, etc.).

2. UAV platform for HS monitoring

Unmanned aerial vehicles (UAVs) are an extremely promising and widely used mobile platform for remote sensing. The UAV platforms fill the gap between ground-based instruments, which are usually attached to agriculture technique and other vehicles. UAVs provide complex of properties. They are ideally applicable to the monitoring of the Earth's surface at a given point at the specified moment. Their capabilities could not be achieved even the entire group of satellites. Modern UAVs enable real-time information transferring from on-board equipment to the control center or its continuous recording on internal storage media. Such systems, unlike satellite instruments, are designed for personal use and for solving a variety of specialized tasks. Therefore, for such systems, the specific characteristics such as flexibility and prompt retuning are particularly important. Disposition at a drone enables HS systems to perform a wide range of new functions. In this configuration, the volume of collected HS data and the particular procedure of their registration can be specified by the user depending on the task.

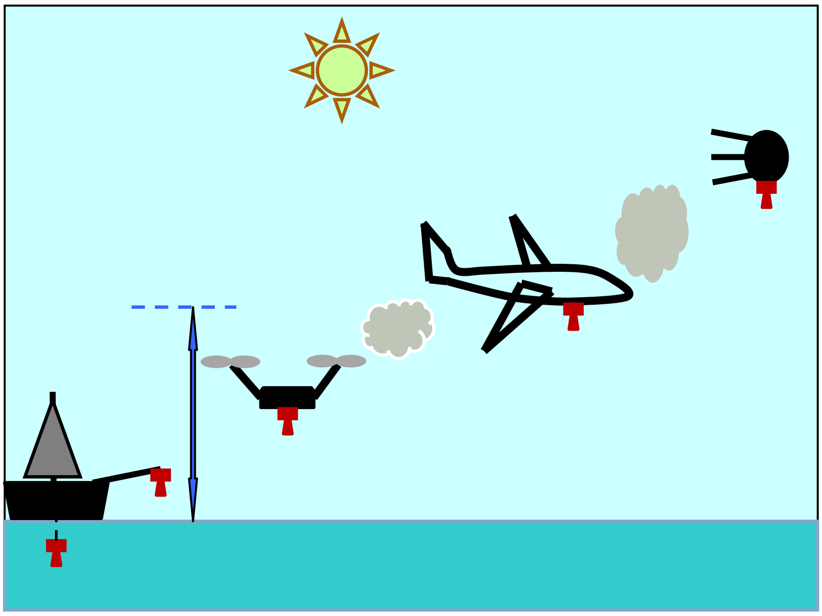

Figure 1. Earth remote sensing levels (from left to right): ground-level mobile platforms (boats, cars); low-flying platforms (UAV, helicopters); high-altitude platforms (airplanes), out-of-atmosphere platforms (satellites. spaceships).

The capabilities for the spectral information analysis significantly depend on the technical specification of the equipment, recording procedures, data processing algorithms, the volume of *a priori* information about the inspected objects, and other factors. The development of optimal analysis algorithms is a specific and complex task. With respect to UAV-based instruments, it is complicated by a number of limitations. The on-board radio modules of modern UAVs include a command receiver, as well as a service information transmitter, which permit to control flight modes and information collection remotely. Satellite navigation receivers (GPS or GLONASS) are in use to determine the coordinates, speed, flight altitude and other parameters of the UAV movement. The angles of pitch, yaw and roll are determined using on-board gyroscopes and accelerometers. This provides a fairly accurate georeferencing the recorded data and facilitates its processing. Further progress in the field of aviation HS equipment is associated with the development of autonomous small-size spectral devices capable to not only collecting spatially-spectral data, but also on-board real-time analysis of that data.

The main approaches to express-analysis are related to the objects classification and recognition by their spectral characteristics. It requires a variety of operating modes, in particular, automatic regular calibration "on board", the possibility of selecting the most informative spectral intervals that differ for different tasks. The creation of such devices will significantly reduce the recorded and processed data volume and decrease the time of recognition of HS system.

3. Hyperspectral system

The hyperspectral system was assembled in form of the prototype according to the previously described scheme [2]. The spectral-detection channel is presented in fig.2, while some important elements (single-board computer, portable electrical accumulator, radiofrequency (RF) computer-controlled generator and amplifier) are not presented for simplicity. The second (colour, RGB) channel has not accomplished at this stage of the project.

Preliminary testing [12] has demonstrated the ability to solve a wide group of scientific problems: low-aberration imaging [13-14] at any wavelength of the spectral range, spectrum and spectral characteristics detectability, and complex spectral-spatial identification.

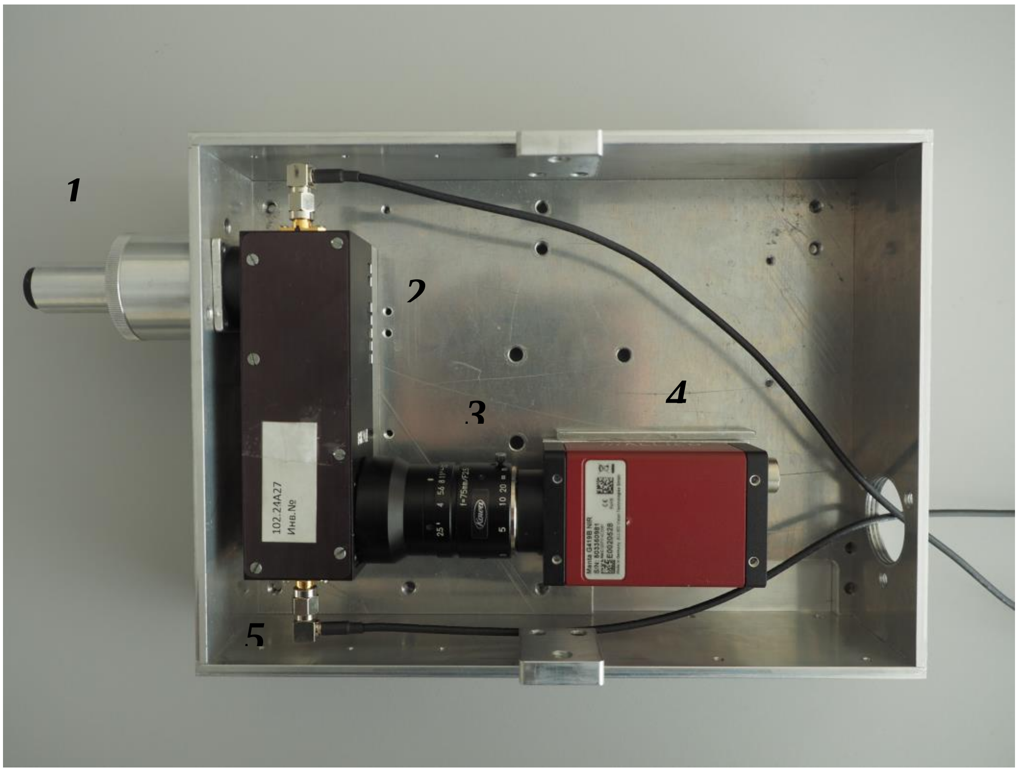

Figure 2. AOTF-based hyperspectral prototype device (internal view): 1 – input lenses; 2 double-AOTF [11] monochromatization module; 3 – output adjustable lenses; 4 – monochrome camera; 5 – RF control cables for each AOTF.

4. Conclusion

Thus, the described hyperspectrometer based on tandem aberration-compensated AOTF can be efficient tool for UAV platform as it provides flexible control, variability of detection techniques, high quality of images, their integrity (no need to reconstruct images), satisfactory sizes, weight and power consumption.

Such combination of features makes possible implementation of UAV-platform monitoring instrument with HS capabilities and new features. This system can demonstrate adaptive behavior [15] as the next-target choice is dependent on detected spectral information. The described hyperspectral device is capable to optimize the detection procedure using random-spectral-access technique and fragmentary spectral registration approach [16] and also can efficiently form and correct the flight route.

5. References

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