«Modul» Experiment

CONCEPT OF A MULTICHANNEL SYSTEM INSTALLED AT THE ISS FOR STUDY OF THE EARTH'S SURFACE AND ATMOSPHERE

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The concept of a multichannel system for the synchronized observations in the IR, sub-mm and mm wavelengths is developed to carry out investigations of the Earth's surface, atmosphere and ionosphere. The system envisages both scanning the atmosphere up and down from 15 up to 120 km per orbit and long view pointing towards an astronomical object.

The multichannel system will be connected with the Cassegrain type telescope and scanning system. The optical axis of the telescope will be oriented to the velocity vector. The mirrors will be made of a lightweight metal. The field of vision of the scanning mirror will be equal to 60°; the micro scanning mode will be also possible. The rotation system will provide 270°-slowing in the plane, which is perpendicular to the axis of the telescope. The fast scanning system will ensure stereoscopy observations and integration of signals from various points of the Earth's surface. The rotation system will also provide telescope orientation for atmospheric and space research, and will make pointing available on the ground stations for communication experiments [1]. We are planning to make four instrumental modules, assuming their modification for other tasks. The experiment pursues the following objectives.

Study of the Earth's surface

- Scanning the Earth's surface in the visible and near IR range by photometer and spectrophotometer with the resolution of 15 — 20 m to carry out water control, land and surface temperature measurements, fire and environmental monitoring, estimation of agricultural crop, as well as gas-field and oil-field prognostication.

Study of the Earth's atmosphere and ionosphere

- Measuring the temperature of the atmosphere to construct the distribution of the atmospheric gravity waves connected with the processes on the Earth's surface.
- Measuring the content of CO and CO_2 molecules in the atmosphere for estimation of the «hothouse» effect.
- Measuring the stratospheric ozone to study the «ozone hole» region and its influence on the processes in the ionosphere.
- Studying the mechanisms which provide coupling between the upper and lower atmosphere; studying the influence of the processes on the ground and in the lower atmosphere on the processes in the upper atmosphere and ionosphere.
- Investigation of the influence of turbulent transport and corpuscular radiation on the processes in the atmosphere and ionosphere.

Astronomy

- Detailed study of the physics and chemistry of comets, planets, bright stars, interstellar molecular clouds, namely the following classes of objects will be targets for observations:

— Comets: water outgassing, size of active regions, density of molecules in short-period and long-period comets.
— Planets: seasonal variations in the atmospheres of planets-giants.
— Detection of protostars: dynamics of circum-

stellar envelopes and interstellar extinction.

— Giant molecular clouds and nearby dark clouds: molecular distributions in comparison with those in the envelopes of stars.

To meet these objectives, the following instrumental basis will be developed.

Telescope

The diameter of prime mirror is equal to 400 mm with the f/D ratio of 15. The scale level in the focal plane will be equal to 1 mm = 35 arcsec with the equivalent focus of the telescope of 6000 mm. The actual field of vision of the telescope will be about 1°. Depending on the change of the orbit altitude of the ISS from 300 km to 450 km, the viewing spot on the Earth's surface will change from 5.2 km to 7.8 km in diameter. Use of 256 element 1D array of detectors in the focal plane will provide the surface resolution of 20 — 30 m in the IR band with subsequent improvement by the factor of 2 with the use of 512 element array. The visual CCD or CMOS camera with the guide small telescope will be used for trace recognition. Cooling of detectors in the focal plane of the telescope is envisaged to provide a sufficient sensitivity. Cryo-cooler will be used to cool the IR and sub-mm detectors and mixer of mm-band to the temperature of 70—90 K. Only the thermoelectric coolers can be used to cool the detectors for short wave IR band to the temperature of 200 K.

The optical system configuration [2]

The optical system configuration is shown in Fig. 4. The four optical channels are separated by dichroic elements. One of the variants of dichroic elements is the photolitography grating performed on the substrate.

IR channel.

We intend to use the following devices in the IR channel:

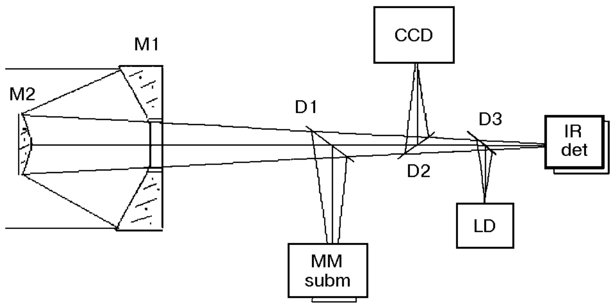

Figure 4. The schematic of optical channels: M1, M2 — mirrors of the telescope; D1, D2, D3 — dichroic elements; MM — millimeter channel; SUBMM — sub-millimeter channel; IR — infrared channel; LD — laser diode

— photometer-grating spectrophotometer for the spectral range of 1 — 2.5 μm with the spectral resolutions of 3 cm^{-1} in the spectrophotometer mode;

— photometer for the spectral range of 2.5 — 16 μm. HgCdTe 1D array with cooling to 77—100 K will be also used.

— spectrophotometer for the spectral range of 16 — 60 μm with scanning grating and 2×2 element YBaCuO superconducting bolometers at the temperature of 77 K;

— 256 or 512 element InGaAs 1D arrays for the spectral range of 1 — 2.5 μm with cooling to 77 — 200 K by the closed-cycle cooler and thermoelectric battery. With the field of vision of the telescope of 1° and the scanning surface width of 5 — 7.8 km, it will provide the surface resolution of up to 10 — 20 m.

Sub-mm channel

In the sub-mm channel we are planning to use a spectrophotometer for the spectral range of 60 — 120 μm with scanning grating and 2×2 element YBaCuO superconducting bolometers at the temperature of 77 K. The low temperature bolometer at the temperature of 4.2 — 30 K will be also applied. Epitaxial $YBa_2Cu_3O_{7-x}$ films with the thickness of 0.1 — 0.25 μm are formed by pulsed laser deposition technique on various substrates. However, the working points of the superconducting bolometer films are destabilised, because of the positive thermal feedback in these films. Working modes and procedures will be implemented to stabilise the working points of the superconducting bolometers, to provide a broader dynamic range, and to ensure the longer total duration for useful signals.

MM channel

The mm channel will be used for radiometer observations of the atmosphere and ionosphere in the spectral ranges of 118 — 119 GHz (O_2), 115 GHz (CO), and 96.2 — 101.7 GHz (O_3). The mm radiometer is equipped with a cooled Schottky diode mixer, phase-locked Gunn oscillator and IF amplifier. Cooling will be provided by the closed-cycle cooler to the temperature of 70 — 90 K or by the thermoelectric battery to 200 K. The HEMT transistor preamplifier allows the system temperature to be lowered to 300 K at 119 GHz. A digital autocorrelator (A-C) will be also used.

Control system software

A hybrid technology is being developed, which will be applied to perform on-board processing of the remote sensing data, algorithms and programs, as well as to pre-process results of the remote sensing in mm and IR ranges, and to apply purpose-oriented signal processors that can be incorporated into the observation system. Image processing methods based on the neural networks will be created [3].

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«Choven» Experiment

SCIENTIFIC HARDWARE AND METHODS FOR THE REMOTE MONITORING THE EARTH'S ATMOSPHERE AND SURFACE BY MILLIMETER WAVELENGTH RADIOMETRY

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Further progress of such important research fields as climatology, meteorology, and environmental monitoring largely depends on understanding the regularities of the origin and phase redistribution of atmospheric moisture.

Practically approved radiophysical methods of remote monitoring of the Earth's surface and atmospheric parameters have led to a marked improvement in the efficiency of global and regional monitoring.

At the same time, the problem of negative influence of atmospheric inhomogeneity in the cases of Earth's surface (especially of the ground) sounding, as well as negative influence of the Earth's landscape irregularities during atmosphere monitoring, has not been solved yet. At present, the satellite systems operating in the mm-wavelengths radiometric channels (Cosmos-1610, Nimbus, SSM/I, TRMM, and others) are used.

The proposed «Choven» experiment will deal with development of hardware and methods to conduct remote monitoring of the Earth's surface and atmosphere, as well as with development of new methods for data interpretation. The project pursues the following objectives:

— ensuring higher sensitivity and improving equipment configuration as compared with, e. g., the best US-Japanese counterpart satellite «TRMM», which provides the tropical zone monitoring;

— covering other latitudes with monitoring;

— obtaining information, which is currently lacking for implementation of the ideas earlier set forth by the authors with respect to development of new methods and approaches in processing the remote sounding data [1, 2].

The scientific novelty of the planned space research underlies the significance of this experiment. It is based on development of new methods and approaches capable of achieving higher accuracy in interpretation of the meteorological parameters and improved quality of the Earth's surface radio images in mm-range of wavelengths. With respect to the applied science, the novelty of the experiment lies in continuous generation of current information on water content in the atmosphere, as well as on the phase composition of cloudy moisture using the regular and new methods developed during performance of this research project. These data are necessary for obtaining new climatic, meteorological and general physics estimates.

Facility. The first stage of the experiment envisages the use of a five-band radiometric scanning system operating as a part of the measuring equipment