

## PROSPECTIVE SPACE MISSIONS WITH L-BAND MICROWAVE RADIOMETRIC SYSTEMS

Yu. Tishchenko<sup>a</sup>, V. Savorskiy<sup>a</sup>, M. Smirnov<sup>a</sup>, V. Abyazov<sup>b</sup>, A. Khaldin<sup>b</sup>

<sup>a</sup>Fryazino Department, Kotelnikov Institute of Radioengineering and Electronics, RAS, Vvedenskogo sq., 1, Fryazino, Moscow region, 141190, Russia - (savor, tishchen)@ire.rssi.ru

<sup>b</sup>Special Design Bureau of the Institute of Radioengineering and Electronics RAS, Vvedenskogo sq., 1, Fryazino, Moscow region, 141190, Russia - ahaldin@sdb.ire.rssi.ru

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#### ABSTRACT:

Prospective Russian space missions include aims directed in developing and enhancing Earth remote sensing techniques by means of microwave radiometry. New L-band (wavelength about 21 cm) microwave radiometric systems for space applications are constructed in the Special Design Bureau of the Institute of Radioengineering and Electronics RAS. Scientific programs of experiments with these instruments, which incorporate numerous proposals of Russian scientific organizations, are prepared in the Institute of Radioengineering and Electronics RAS. The main goals of scientific programs are: development of radio physical Earth remote sensing methods from space in L-band for investigation of physical events and processes in earth surface-atmosphere system; investigation of external factors (galaxy emission, ionosphere, etc.) impact into measured parameters of investigated objects; analysis of radio interference problems; development of new techniques for processing of data with different space resolution.

#### 1. INTRODUCTION

Theoretical and experimental investigations show that L-band radiometry is very prospective (optimal) for soil moisture and sea surface salinity investigations. These measurements practically not influenced by weather conditions in the atmosphere. Now one of the most important problems for L-band radiometry is the problem of radio interference (RFI). RFI may be not so important in open ocean region, but are very strong in urban areas. The second important problem consists in necessity to make relatively large antenna for reasonable spatial resolution of the instrument.

Despite this difficulties interest to investigations with use of microwave radiometers in this band is very high. One of the most powerful L-band instruments launched several months ago is European project SMOS [1]. It contains very sophisticated interferometric imaging radiometer MIRAS with synthetic aperture antenna. In USA under developments is a project SMAP with combination of microwave radiometer and scatterometer [2]. In Russia under development are simpler microwave radiometers for small satellite and for Russian segment of International Space Station (ISS) [3]. Time of SMOS and our instruments operation may overlap and it should provide the possibility to compare some results.

#### 2. SPACE L-BAND MICROWAVE RADIOMETRIC SYSTEMS

Leading scientific organization for creation of payload for two space projects with use of L-band radiometers is Kotelnikov Institute of Radioengineering and Electronics of RAS (IRE

RAS). Head design organization of these radiometric systems is Special Design Bureau of IRE RAS (SDB IRE RAS).

The first creating radiometric system PN1 consists of L-band microwave radiometer with 2 beams antenna. It is compact module and will be attached to the outer side of the small satellite (planned launching – 2010). General specification of the instrument is presented in the middle column of Table 1.

	PN1	ALRS
Main frequency, MHz	1410	1410
Bandwidth, MHz	20	20
Radiometric sensitivity, K	0,2-0,3	0,2-0,3
Polarization	linear	linear
Number of beams	2	8
FOW, km	350	50
Swath width (at orbit height 350 km), km	700	400
Power consumption, VA	≤ 60	120
Weight, kg	≤ 13	35
Size, mm		
radiometer	400x300x50	
antenna	800x510	1200x1920

Table 1. General specification of the satellite radiometric systems

Observation geometry of the small satellite system is presented in Fig. 1. Antenna of the radiometric system will be oriented for observation in nadir direction and provide spatial resolution about 350 km and swath width 700 km. In the main operational mode two beams of the system oriented across the flight direction in order to have wider swath width. In addition to this mode it may be possible to rotate the satellite so that two beams will be in a flight plane. This mode may be useful for calibration purposes and development of RFI suppression algorithms.

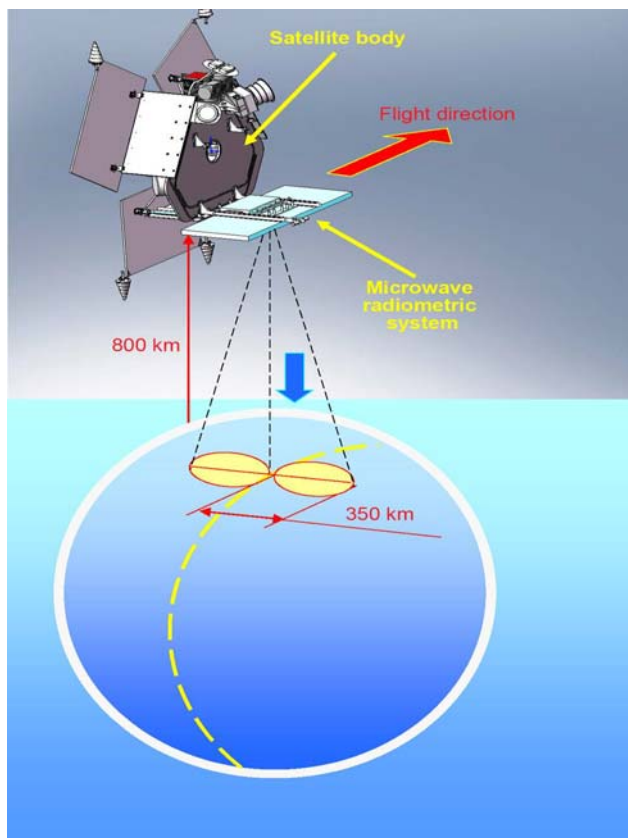


Fig.1. Observation geometry of the small satellite microwave system

Advanced L-band radiometric system (ALRS) will be installed on the module of Russian segment of International Space Station (RS ISS) (planned installation - 2010). General specification of the instrument is presented in the last column of Table 1. It is a set of radiometers with pushbroom 8 beams antenna. Each beam will have spatial resolution about 50 km. Observation geometry of the advanced microwave system is presented in Fig. 2.

Due to relatively large size of the ALRS antenna and requirements to deliver instrument in compact state through the manhole it has folding elements and will be deployed manually. General view of L-band radiometric system in compact (transport) state is shown in Fig. 3.

Now both radiometric systems are made in technological versions and are in the procedure of laboratory testing. Results of testing are in a good agreement with technical requirements.

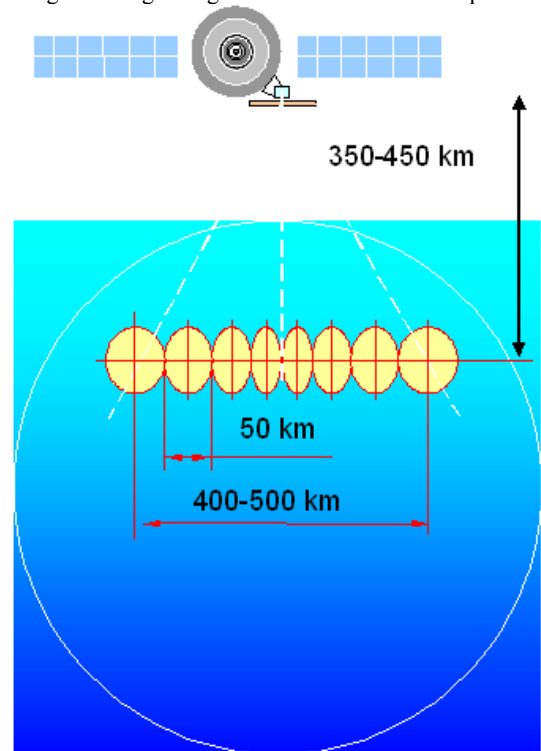


Fig.2. Observation geometry of the advanced microwave system

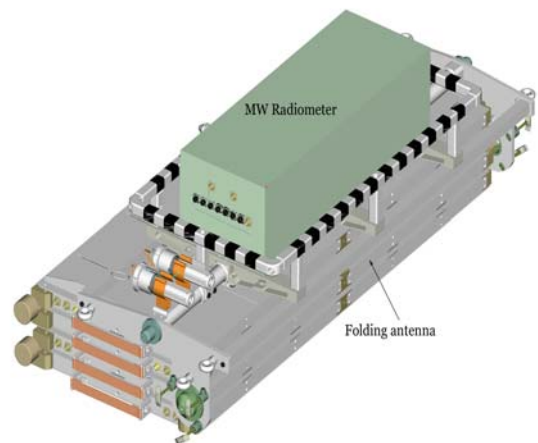


Fig.3. L-band radiometric system ALRS in compact (transport) state.

### 3. SCIENTIFIC OBJECTIVES AND GENERAL FEATURES OF THE EXPERIMENTS

Microwave radiometers despite their low spatial resolution are widely used in space remote sensing of environment. It is due to ability of microwave radiometry to get data which are impossible or at least very difficult to get by any other means. Such data are data on averaged by surface and/or depth thermodynamic temperature of physical objects, their integral

dissipative features, and information on complex dielectric permittivity (see, for example, [4-6]). Moreover these data could be received at any day time and do not depend on weather conditions.

Merits of microwave radiometers promote them to be used as one of the first instruments installed on satellites for Earth exploration. The main observed objects were both land covers with vegetation canopy and those without canopy featured with different soil moisture, ground water level, vegetation type, temperature, and soil density, as well water basins with different salinity, mineralization, and temperature. Nowadays microwave radiometers are used in synchronous measurements with optical and IR sensors. As a result the relation between microwave radiation intensity and soil water level down to 1.5-2 m depth in overmoistured and down to 3-5 m in dry regions are retrieved [5]. As well it is revealed that agriculture vegetation canopy with biomass up to 2-3 Kg/m<sup>2</sup> is semi-transparent media for decimeter wave range. So, it is possible to get estimations of soil moisture and biomass (for above part of water plants) for those levels of biomass [4,6].

Scientific programs for PN1 and ALRS radiometric systems were prepared IRE RAS on the base of proposals from Russian institutions. This work explores IRE RAS experience on developing scientific programs for such space projects as PRIRODA, OCEAN-O No.1.

The main contribution to working out of key proposals in the Scientific programs (priority directions of researches, objects of researches) have submitted the following organizations:

- Kotelnikov Institute of Radioengineering and Electronics of the Russian Academy of Sciences,
- Institute of Space Researches of the Russian Academy of Sciences,
- Shirshov Institute of Oceanology of the Russian Academy of Sciences.

The Programs are directed on the decision of problems on working out of radio physical methods of remote sensing of the Earth from space in a perspective decimeter range of electromagnetic waves for studying of the physical phenomena and processes in atmosphere-surface system; on research of influence of external factors (a galactic background, an ionosphere, etc.) on measured characteristics of investigated objects; on studying of radio interference at carrying out of researches; on development of methods of joint data processing with the different spatial resolution.

In 70 and 80th years in the IRE RAS and other organizations in the USSR and the abroad the large-scale theoretical researches of microwave radiometry possibilities of soils, vegetation and water investigations in a range of wavelengths to 30 cm, and also experimental researches from airplanes carried out. Researches have shown the possibility of estimation, in particular, of soil humidity and vegetation biomass, and also salinity of water areas by radiometric method [5-7]. At the same time, the experimental data of using of decimeter waves for working out of practical methods of estimation of soil moisture and vegetation biomass, sea salinity from space it is not enough to make conclusion about possibility of radiometric space operative observations application of soils, vegetation, water areas state in regional and global scales.

Realization of Programs will allow estimate the efficiency of microwave radiometric method for definition of soil moisture and vegetation biomass, sea salinity from space (accuracy of estimation, spatial and time variations). Necessary models and algorithms will be developed. The technique of carrying out of

corresponding space measurements, calibration and validation of experimental data is fulfilled. Data for the decision of various scientific and practical problems will be obtained:

- mapping of soil moisture (including under the forest canopy) within the regional and global scales,
- research of temperature and moisture conditions of forest-swamp systems,
- studying of vegetation biometric characteristics,
- study of water areas salinity,
- study of glacial and permafrost zones,
- study of the ocean-land-atmosphere exchange energy (in conjunction with data from other sensors),
- research of geothermal activity, estimation of border of zones and temperature regime,
- development of methods for joint processing of data with different spatial resolution.

Results can be used in areas such as agriculture, forestry, hydrology, climatology, ecology.

Programs consist of five sections and attachments. Sections of Programs cover the following objects of researches:

- research on land,
- research of ocean,
- study of the atmosphere,
- conducting of calibration measurements,
- information support of scientific programs.

Experiments on remote sensing of land, ocean and atmosphere are systematized in the first three sections. The basic directions of researches are presented.

Experiments on remote sensing of a land are systematized in the first section. The following main research directions are planned:

- study of vegetation,
- study of the hydrological situation of individual regions the Earth surface,
- study of forest-swamp systems state,
- study of seismic zones, zones of geothermal and volcanic activity,
- study of glacial and permafrost zones.

Experiments on remote sensing of ocean are systematized in the second section. The following main research directions are planned:

- development of techniques of remote definition of ocean surface layer salinity,
- research of thermal and dynamic interaction of ocean and atmosphere,
- research of ocean hydrophysical fields,
- study of ice conditions.

Experiments on remote sensing of atmosphere are systematized in the third section. The following main research directions are planned:

- influence of external factors (galactic background, ionosphere, etc.) impact into measured parameters of investigated objects,
- study of radio interference problems.

The experiments concerning to calibration measurements and Scientific programs information support are placed in separate section since these experiments provide basis for all research experiments. They are connected with development of methods and technologies of measuring equipment calibration and data validations; of methods and technologies of using of active archive of experimental researches data; of means and techniques of data processing, storage and distribution. Effective data exchange allows to expand the possibilities of researches, for example, by use of the various information from various sources.

In many cases it can be a basic condition for successful realization of planned researches at carrying out of complex space experiments.

During the programs realization it must be solved a wide range of scientific problems, part of which is an associated sub-satellite (calibration) measurements. Such measurements are needed for

- calibration of remote sensing devices, control of their working capacity in functioning, experimental data informativeness in remote control tasks,
- working out of new, improvement and check of existing geophysical parameters restoring techniques;
- development of techniques of joint interpretation of the space data received in various spectral bands and results synchronous sub-satellite measurements,
- validation of space data,
- complex studying of natural objects by use of the information received from various levels and with the different spatial resolution.

For calibration uniform sites of terrestrial and water surfaces with known radiating and geophysical parameters are selected. The sizes of these sites are defined by resolution of measuring devices. For the radio spectrum - from a few kilometers to tens and hundreds kilometers depending on the wavelength. Test sites (on which subsatellite measurements are carried out synchronously or quasynchronously with satellite observations) are chosen in different regions of the Earth for wider coverage of studied objects types. List of measured on test sites parameters, content of measurements are determined with concrete purpose of test site and experiment tasks.

In Attachments to Programs are presented:

- structure and characteristics of scientific equipment;
- levels of the space data presentation (processing),
- proposals on development of Scientific programs.

It is worthwhile to coordinate the developed Scientific programs with similar researches of existing and planned to realization in near future of russian and foreign space projects.

At the first stage of our space experiments the main goals are to develop and test new space microwave radiometric instrument in new band of electromagnetic spectrum in order to solve the following technical objectives:

- investigation of RFI situation in L-band all over the globe,
- development of in-flight calibration techniques,
- development of subpixel data processing algorithms for information simultaneously obtained from different satellites with different spatial resolutions.

During this stage we expect to select main regions with low level of RFI and made adjustments of preliminary prepared data calibration techniques.

Relatively low space resolution of the L-band radiometric systems restricts us in the list of possible applications. In the large field of view of the radiometer may be objects with quite different characteristics of emission. In this case high importance has development of algorithms for subpixel microwave data processing. During the data processing will be used simultaneous data from all available satellites with microwave and optical instruments having different space resolution.

At the second stage it is expected to concentrate more on the scientific objectives and environment investigations. Main directions are:

- soil moisture retrieval over the territories in regional and global scales,
- sea salinity estimation in open ocean,
- study of the geothermal activity regions,
- investigation of energy-exchange in the ocean-land-atmosphere system (in combination with the data of other sensors).

#### 4. CONCLUSIONS

Experiments with space L-band microwave radiometers will provide new information on key characteristics of the oceans and land surface, mostly sea salinity and soil moisture. To achieve this goal it will be required to solve several technical problems concerning calibration, removing RFI effects and etc.

Scientific program of the experiments should be coordinated with similar programs of European and USA projects.

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