PASSIVE MICROWAVE REMOTE SENSING OF SOIL, VEGETATION, AND WATERS

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INTRODUCTION

The feasibilities of methods of remote sensing in optical, infrared, and microwave bands of electromagnetic spectrum are now widely examined and some of these methods are already used for practical purposes /I-II/.

The reason for their development, improvement, and application is in the all growing number of scientific and practical problems that can be effectively solved with an aid of remote sensing. These problems are assosiated in particular with complex investigation and development of virgin regions of the Earth, investigation and effective use of natural resources, observation and control of environmental objects, investigation of the processes of interaction between ocean, land, ice, atmosphere at regional and global levels.

The authors are with the Institute of Radioengineering and Electronics where the method of microwave radiometry is mostly developed and examined. Thus paper discusses primarely the feasibility of soil, vegetation, and waters sensing with this method. The attempts are made as well to compare the effectiveness of this method with some others and estimate the advanteges of complex use of different methodsas well as complex use of remotely sensed and ground truth data for solving some problems.

I. PECULIARITIES OF MICROWAVE RADIOMETRY

Microwave radiometry is a passive method of remote sensing at radio waves. It is based on receiving natural radiation of environmental objects at millimeter, centimeter, and decimeter wavelengths. The main investigations of the sea and land surfaces usually take place in the range of 1.5-2 to 30 cm. This can be explained with those facts that radiation of the system "surface-atmosphere-space" is influenced by the atmosphere at the wavelengths shorter than 2-3 cm, and is affected by the galaxy radiation at wavelengths longer than 30 cm.

The measure of radiation at microwaves is a brightness temperature that is a product of emissivity and thermodynamic temperature within the effectively emitting layer. The sources of information are the intensity of radiation at different angles of observation and polarizations, degree of polarization, spectrum peculiarities of intensity of radiation and degree of polarization.

More than 20 years ago there took place the first aircraft experiment on microwave radiometry of land and sea at the Institute of Radioengineering and Electronics AS USSR. Then the first "radiation vs soil moisture content" dependence was examined at 3 cm wavelength. Now, after extensive investigations, theoretical and experimental conducted at the laboratories, field stations, pools, from aircraft and satellites there were worked out the effective methods of soil, vegetation, and waters sensing. This gave an opportunity to pass from fundamental relationships of Planck, Kirchhoff, Rytov to methods and procedures which have found the consumers in agriculture, irrigation, hydrology, geology. Let's discuss how good is this method.

2. APPARATUSES AND CONDITIONS OF EXPERIMENTS

Within period from 1964 till recent time the experimental investigations of radiation characteristics of land and sea surfaces under simulated and natural conditions from stationary, mobile, aircraft, and satellite platforms were conducted in general at the wavelengths of 0.8, 1.35, 2.25, 3, 3.4, 7.5, 8.5, 10, 18, 20, and 30 cm. The most extensive and representative experiments were conducted at the wavelengths of 2.25, 18, and 30 cm for nadir viewing angles of observation of 0 to 30°. Sensitivity of radiometers is about 0.1 - 0.2 K for time constant 1 sec. Thermostabilization of high-frequency sets gave the opportunity to conduct measurements for air temperature ranged from -40 to +50°. Radiometers that now are under construction will operate at the wavelengths of 2, 6, 21, and 42 cm.

3. PROBLEMS THAT CAN BE SOLVED WITH METHOD OF MICROWAVE RADIOMETRY

It has been shown theoretically and in experiments that retreival procedures worked out at the IRE AS USSR are feasible for determining soil moisture content, the depth of shallow water tables, biomass of some types of agricultural canopies, salinity of waters by means of microwave radiometric measurements at certain wavelengths within a range from 2 to 30 cm /2, 3, 7, 8/.

3-1 The indices of effectiveness

Method gives the information about

- soil moisture content (volumetric content of free water) within nearsurface layer of about 20 to 30 cm thick with an accuracy of about 0.05 g/cm^3 (or 5% of volumetric content);
- the depth of shallow water tables down to 2 - 3 m with an accuracy of about 30 - 50 cm;
- biomass of agricultural canopies with an accuracy of about 20%;

-water surface temperature within a layer of about I-2 cm thick with an accuracy of about 0.5-2°C within a range from 0 to 30°C;

-water surface salinity within a layer of about I-2 cm thick with an accuracy of about 0.5-2 ppt within a range from 0-2 to 40 ppt.

3-2 Productivity of these parameters mapping

The indices of productivity are as follows

-when mapping the soil moisture and biomass of vegetation data with a pixel of about I00mxI00m (spatial resolution is about I hectare) the productivity is about I000 hectars per hour;

-when mapping the data of shallow water tables, temperature and salinity of waters with a pixel of about I kmxI km the productivity is about I0000 hectares per hour.

3-3 Examples of operational use of microwave rsdiometry

Since I979 for the first time in national and world practice there were organized in the USSR special aircraft services on supplying consumers in the Ministries of Land Reclamation (Irrigation), Agriculture, Hydrometeorology the data of soil moisture, water seepage from canals, quality of moistening in irrigated fields, salinity and in general the degree of mineralization of water surface in the internal waters.

4. SOME PERSPECTIVE AREAS OF DEVELOPMENT OF METHODS OF REMOTE SENSING WITH APPLICATION OF MICROWAVE RADIOMETRY

4-I Relative calibration

Good results gives the method of calibration based on training procedure according to which one puts the scale of measured radiometric signals into correspondence with the scale of geophysical parameters that vary, influence the signal. This simplifys much the retreival procedure and increase an accuracy of these parameters determination.

4-2 Complex use of radiometric data, apriori information about the object, and in situ data

Method of microwave radiometry gives in general the estimates of soil moisture content under the vegetation without any a priori information about canopy. But when using a priori knowledge about the type of canopy and expert estimates of its biomass with an accuracy of about 30% the accuracy of radiometric estimates of soil moisture increases I.5-2 times.

The accuracy of the depth of shallow waters determination increases I.5-2 times when using the a priori information about the types of soil-climatic zones where the measurements take place.

The accuracy of total mineralization of water increases by I0-30% when using the a priori information about the composition of salts in water.

Complex use of remotely sensed microwave radiometric data of moisture content and the a priori information about the type of soil namely the data of wilting poit and field capacity gives an opportunity to obtain the soil moisture estimates down to I m.

4-3 Some results of complex use of remotely sensed data obtained with different methods

Complex use of microwave radiometric and active radar data gives an opportunity to obtain the estimates of soil moisture moisture content and the degree of ground surface roughness. For certain roughness of a ground surface the microwave radiometric data of soil moisture obtained along limited numbers of aircraft track may be successfully used for calibration of spatial "picture" of radar responce. This procedure increases an accuracy and productivity of soil moisture survey by remote sensors.

Complex use of microwave radiometric and near infrared canals of remote sensing gives the possibility to conduct a classification of some natural objects, such for example as bare ground and soil with vegetation, fields with sugar-beet and winter wheat.

Complex use of microwave and infrared data gives an opportunity to obtain the estimates of the temperature profile in soil.

4-4 Newest approach

One of the newest approach in remote sensing is in the exposing the generalized "radiation vs geophysical parameters" dependences and their use in the investigations of the Earth at regional and global levels. We mean the exposure of such electromagnetic bands along spectrum and such parameters which would be able to characterize not one or limited number of physical parameters of observed object but give the generalized information about the state of the object, for example about the heat and moisture content in soil and vegetation ("dryness index"/2/,"stress index" /II/).

CONCLUSION

Microwave radiometry is one of the effective method of remote sensing the land and sea surface. It gives useful information about soil moisture content, the depth of shallow water tables, biomass of vegetation, temperature and salinity of open water. These data can be successfully used for solving many scientific and practical problems.