# SOME RESULTS OF TESTING AND APPLICATION OF MICROWAVE REMOTE SENSING METHODS FOR ESTIMATION OF GROUNDS AND WATERS STATE

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## ABSTRACT

Institute of Radioengineering and Electronics (IRE) Russian Academy of Sciences (RAS) and Institute of Geoinformatics, Ltd (IGI) together with organizations in different regions of former USSR and abroad had conducted the number of experiments for estimating the Earth surface geophysical parameters by means of remote sensing methods at different wavelength ranges. Experiments includes testing of equipment and software along the special test lines for estimation of method accuracy in different conditions with the simultaneous ground measurements and thematic mapping of some geophysical parameters from the boards of aeroplanes and helicopters in regions, selected by customers..
IRE had developed algorithms and together with IGI elaborated software for estimating a surface soil moisture, depth to a shallow water table, vegetation biomass, water mineralization and temperature variations using the of remote sensing multichannel measurements data. IGI had elaborated and manufactured microwave devices (MCW radiometers) for all mentioned measurements and elaborated methods and software for passive microwave remote sensing data processing in the presence of some kinds of radiointerference
In presented paper are given some results of Remote Sensing method application for determination of a number of geophysical parameters, including results of comparison microwave remote sensing and contact data along the flight lines, conducted in Republic Belarus jointly by specialists of IGI Ltd. and Scientific Research Centre "ECOMIR" (Academy of Sciences of Belarus Republic) and Hydrometeorological Centre of Belarus Republic, and examples of thematic mapping of some regions in Belorussia and Southern Bavaria, conducted by IGI Ltd. separately and together with TOPOGRAMM GmbH, Weilheim, Germany respectively.

## INTRODUCTION.

Remote sensing of ground and water state gives the real possibility of environment monitoring. Passive means played it's own important role in solving of ecological and economy problems. The main characteristics of remote sensing methods are their accuracy, required time for the measurements, data processing and interpretation, validation, compatibility with other remote and contact sensors, number of determined geophysical parameters.
In that case passive microwave, infrared and optical devices, installed on the aircraft board gives possibility to obtain quantitative estimations of the environment state (Shutko, 1986; Liberman, 1994).
Some results of testing and application of remote sensing methods, peculiarities of GPS system using, accuracy, and other problems of earth survey are discussed in presented paper. Experiment principles, used equipment are described.

## EQUIPMENT. EXPERIMENTS ORGANISATION PRINCIPLE.

For measurements portable and light microwave radiometers on wavelengths 2.25, 6, 21, 27 cm and two channel spectrometers at spectral window 500 - 700 nm were used. The infrared radiometer works in waveband 2 - 20 mkm with the number of filters. The helicopter Mi-2 and aeroplane D 228 were used as installation platforms. Main characteristics of radiometers are given in Table 1.
The examples of used equipment are given on Figures 1 and 2.
Antennas on decimetre waves were made as plane microstrip structures, for centimetre radiometers were used horns. Spatial resolution on microwaves was about 35 , in visible waverange - about 6 degrees.
The information from remote sensors was recorded in digital form on floppy disk using IBM PC, installed on the board of the aeroplane and helicopter too. The example of registration system is presented on Figure 3.
All antennas were located in the shafts of aeroplane

and out of doors of helicopter and were nadir looking. Sensors were located in the shafts.

Table 1. Main characteristics of Remote Sensors

| | |
|---|---|
| Microwave Radiometers | |
| Operating Range, K | 10 - 350 |
| Sensitivity, K | < 0.1 |
| Integration Time, S | 0.5 |
| Output Signal (Analogue Form), V | +5.0..-5.0 |
| Supply Voltage (Direct Current), V | +27 (+7, -4) |
| Power Supply, VA | 30 |
| Weight, Kg | <6 |
| Heating Duration After Switching, Min. | 45 |
| Environmental Conditions: | |
| - Air Temperature, C<br>- Air Humidity (20 ), % | +10.. +45<br>< 80 |
| Infrared radiometers | |
| Operating Range, K | 10 - 350 |
| Sensitivity, K | < 0.1 |
| Integration Time, S | 1 |

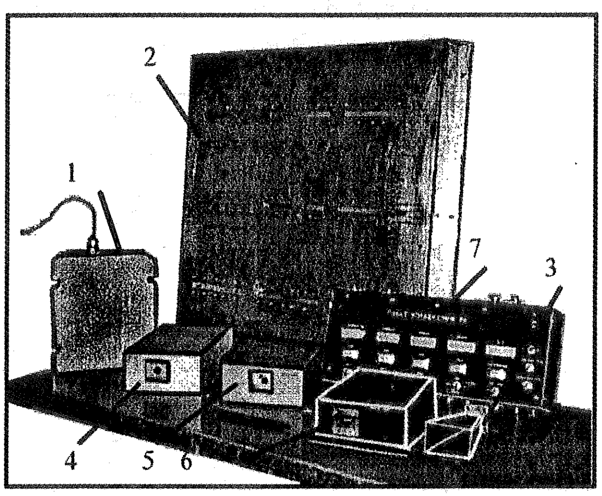


Figure 1. Passive Microwave Radiometers, Antennas and Control Desk, Used During Experiments. 1, 2, 3 - antennas on 6, 21/27 and 2.25 cm; 4, 5, 6 - radiometers on the mentioned waveranges. 7 - control desk.

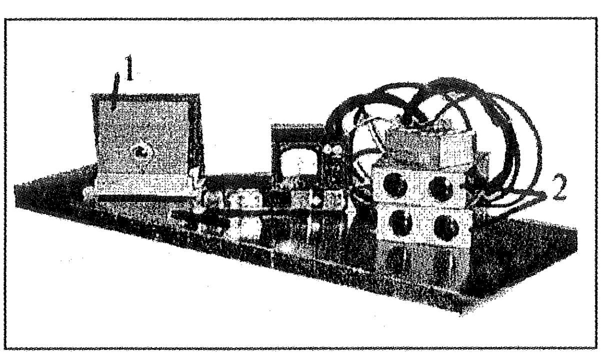


Figure 2. Optical and Infrared devices, Used During Experiments. 1 - Infrared Radiometer; 2 - Two - channel optical spectrometers.

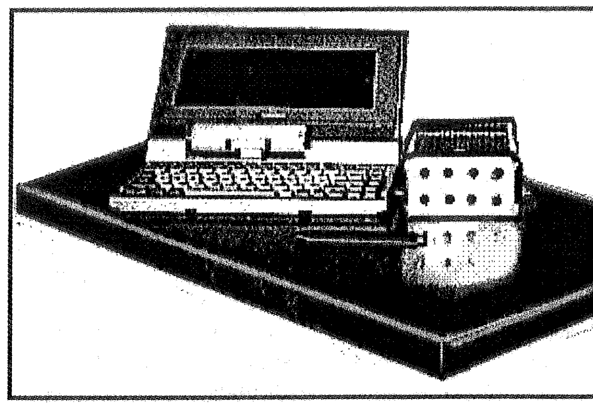

Figure 3. The Example of Registration System, Used During Experiments.

The testing experiments was conducted in summer and autumn and includes several flights along the test line in the opposite directions on the 100 m height. 45 tested regions were characterised by different soil types, soil moisture), different types of vegetation (grasses, beet, barley) in the presence of biomass variations. The main characteristics of test regions are given in Table 2.

Table 2. Main characteristics of test regions

| Biomass, kg/m2 | Bulk density, g/cm3 | Wilting point, % | Field capacity % | Water content, % |
|---|---|---|---|---|
| 0-5.72 | 1.12-1.74 | 0.48 -5.5 | 11 -18 | 5 -20 |

The samples of soil moisture for the comparing were taken from 6 levels (0-5, 10, 20, 30, 50, 100 cm) in a special order, which gave possibility to take into account spatial resolutions of remote sensors.
Due to trace type of radiometers and spectrometers the mapping cycle includes measurements along flight lines and mathematical interpolation between the traces in the laboratory after landing. The aeroplane location was checked by GPS 100 and video camera.
The examples of airplane location variations during thematic mapping, obtained using GPS, are presented on Figure 4.

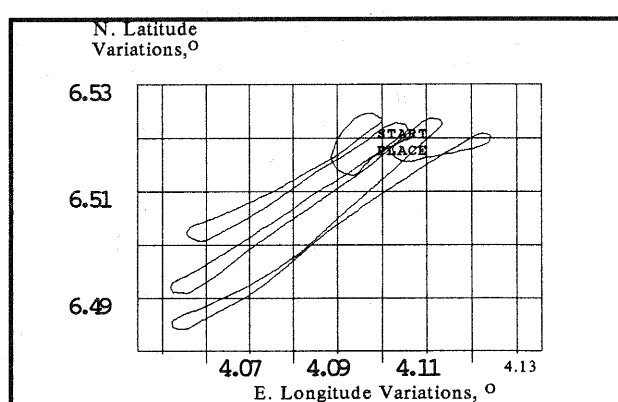


Figure 4. Airplane location variations, obtained with GPS, during thematic mapping.

All flights were conducted from 300 m height, which corresponds to spatial resolution about 70% to flight height (H) for microwave and infrared radiometers and 20% to H - for spectrometers.

## RESULTS AND DISCUSSION.

Application of relatively narrow band (about 7% mean value of frequency) and tuned radiometers accompanied with special software of microwave data filtration gives the possibility to obtain usable data on decimetre wavelengths in spite of radio frequency interference problems, which makes possible passive microwave radiometry application in the regions with high level of industry and communication systems development.

The analysis of remote sensing and contact data comparison confirm the accuracy of remote sensing soil moisture equipment and software application. The error value is about 2 - 8 % in dependence of vegetation biomass (Figure 5). Remote sensing estimations were compered with general water content in 1 m layer too. The accuracy was about 50 - 80 mm in dependence of vegetation biomass (Figure 6).

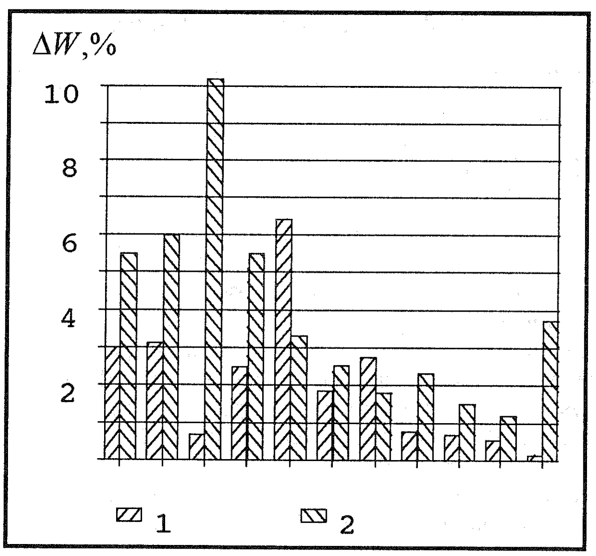


Figure 5. The results of comparison between remote sensing estimations of surface soil moisture and contact data .; 1 - difference between mean values of Remote Sensing and contact data; 2 - difference between maximum and minimum values of contact data Belorussia test site.

The state of aquatory of lakes Worthsee, Ammersee and Pilsensee (Bavaria) , agricultural fields at Minsk region (Belorussia) and the Northern and Southern parts of Ammersee lake, a number of regions in Northern Alps was analysed by means of remote sensing. Some natural objects were studied two times during slow drying. One of the problem to study was estimation of space distribution of the water pollution intensity, where variations of chlorophyll "A" concentration were the indices of it. The example of chlorofill “A” remote sensing determination on the aquatory of Ammersee lake (Bavaria, Germany) is presented on Figure 7.

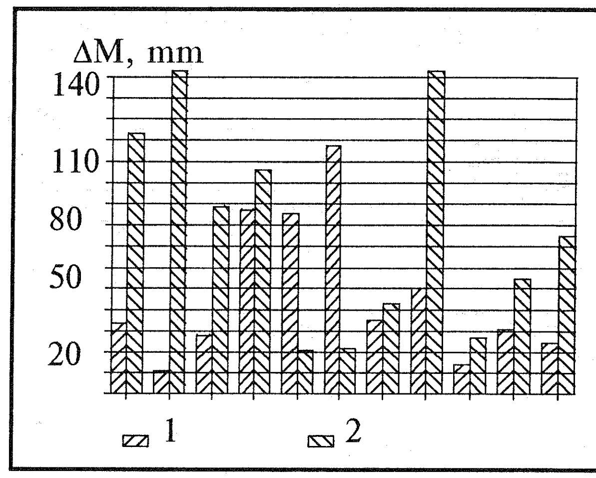


Figure 6. The results of comparison between remote sensing estimations of water content in 1 m layer and contact data. 1 - difference between mean values of Remote Sensing and contact data; 2 - difference between maximum and minimum values of contact data. Belorussia test site.

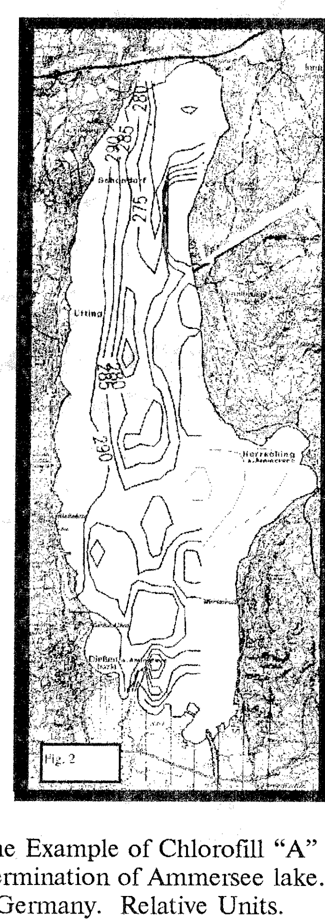

Figure 7. The Example of Chlorofill “A” Remote Sensing Determination of Ammersee lake. Bavaria, Germany. Relative Units.

Due to special algorithm, realised in spectrometers by Dr. A. Gitelson and his colleagues the output signal variations are proportional chlorophyll "A" concentration variations. For exact estimations it's necessary to measure chlorophyll concentration in two

- three regions of Ammersee lake (best of all in regions with minimum and maximum values in relative units) and using simplest formula to calculate values of chlorophyll concentration and in any other tested region of the lake.

The obtained results shows, that some regions with abnormally high chlorophyll "A" concentration are clearly selected. These regions are related first of all to west and south-west shores of the lake.

The results presented are derived with the data of microwave radiometric measurements at decimetre wavelength range which exposes the information about upper layer of 20 cm thick The example of soil moisture map of agricultural fields on Northern part of Ammersee lake is given on Figure 8.

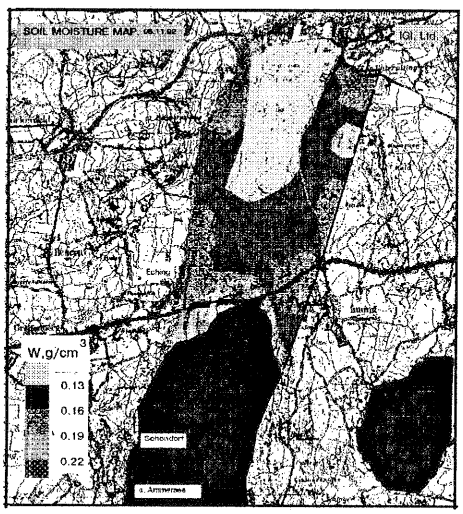


Figure 8. The Example Of Upper Layer (0 - 20 Cm) Soil Moisture Map Of Ammersee Lake Northern Region (Bavaria, Germany), Obtained Using Passive Microwave Remote Sensing Data.

The day after day measurements in the same region gave the possibility to analyse the soils upper layer drying process. The analysis of soil moisture distribution in upper layer (0 - 5 cm), obtained by centimetre radiometers data shows, that all obtained peculiarities are remained for this case at whole. The only distinction consists in more low background value of water content as during 24 hours interval divided the previous and these measurements. The results of joint remote sensing data and soil type map analysis shows, that there is a good correlation between soil moisture map and soil type map at all. To our mind this correlation is based on different drying speed of different soil types after raining.

## CONCLUSION.

The results of experiments confirmed, that:

- microwave radiometry method can be effectively used in for solving different problems, connected with environmental study, connected with determination of water content in soils, some indices of water surface pollution, etc.
- modern passive microwave systems in decimetre wave range and special software give the possibility to operate in the regions with high density of industry and communication systems.
- GPS application gives possibility to obtain more valid remote sensing data spatial distribution in comparison with measurements on the base of only of pilot experience or videocamera.

For example on Figure 9 and Figure 10 are given thematic maps, obtained with the help of GPS (Figure 9) and using only pilot information about aeroplane location (Figure 10).

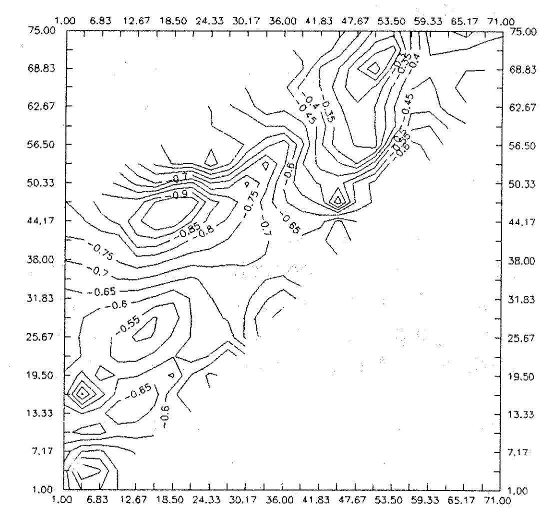

Figure 9. Thematic map, obtained by means of passive microwave remote sensing method using GPS

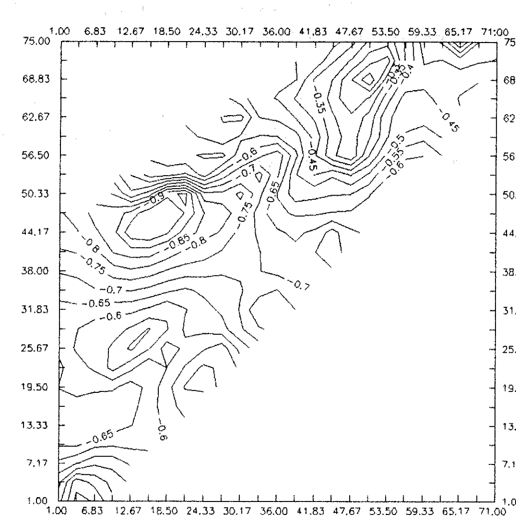

Figure 10. Thematic map, obtained by means of passive microwave remote sensing method using only pilot information.

- Passive microwave remote sensing method is effective mean of environment study. In the same time it gives more objective general estimations of ground state, because contact data variations may differs very much from pixel to pixel and its possible to be wrong during estimations of water sources.

Nearest future projects will be connected with joint application of passive microwave radiometer means with devices working in visible and infrared waveranges, in particularly during aeroplane and satellite measurements.

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