THE GIMS-BASED RESEARCH REMOTE SENSING PLATFORMS

Prof. Eng. **Vladimir F. KRAPIVIN** PhD[1], Prof. Eng. **Anatolji M. SHUTKO** PhD[1], Prof. Eng. **Costică NITU** PhD[2], Assoc. Prof. Eng. **Anda Sabena DOBRESCU** PhD[2]

[1]V.A. Kotelnikov's Institute of Radioengineering and Electronics, Russian Academy of Sciences, Moscow
[2] University "POLITEHNICA" of Bucharest, Romania

REZUMAT. În această lucrare sunt prezentate serii de platforme de cercetare de teledetecție pentru a fi utilizate întru rezolvarea unor sarcini diferite, de mediu, inclusiv diagnosticul umidității solului. Unii parametri ai acestor platforme sunt cunoscuți. Sunt prezentate de aseamenea caracteristicile specifice de monitorizare de la distanță.

Cuvinte cheie: proiectate tehnologie GIMS, teledetecție, umiditatea solului, mediu

ABSTRACT. In this paper, series of research remote sensing platforms are discussed to be used for solution of different environmental tasks including the soil moisture diagnosis. Some parameters of these platforms are given. Specific features of remote monitoring are discussed.

Keywords: GIMS-technology, remote sensing, soil moisture, environment

1. INTRODUCTION

Solution of specific environmental tasks requires the optimization of instrumental and algorithmic means. It can be realized by means of the GIMS-technology methods [1]. Ratio between experimental and theoretical methods in this case is defined by the complexity of environmental system that to be studied. Cumulative experience of the GIMS application is based on the solution of national problems in many countries where different remote sensing platform were created. Historically this experience was started in 1980 with equipping of flying laboratories based on bi-plane AN-2, twin-engine plane IL-14, 4-engine plane IL-18, helicopters MI-2, MI-8 and Ka-26. During the ensuing years, set of these majority carriers were widen.

One of effective multi-frequency polarimetric synthetic aperture radar system was created in the 90s by the Russian Corporation "Vega" for surface and subsurface sensing .It is airborne IMARC SAR system principal image of which is detailed described by Krapivin and Shutko [1]. This Corporation created radiometer system "Radius" operating at the wavelengths of 0.8 cm, 2 cm, 5.5 cm, 21 cm and 43 cm. Main features of the IMARC SAR complex are given in Table 1.

The IMARC is a four-wavelength polarimetric airborne SAR system designed at Radio-engineering Corporation "Vega"[1-3]. The basic technical characteristics of this radar are given in Table 1. Radar system operates at wavelengths: X (3.9 cm), L (23 cm), P (68 cm), and VHF (2.54 m); polarizations in all bands: VV, HH, VH, and HV; spatial resolution is around 12±8 m; maximum swath is 24 km. The carrier of this system was a twin-turbine jet airplane TU-134A and other planes. The main IMARC SAR mission goals were to map the characteristics of Earth covers (including soil hydrological regimes), to map the ground terrain in a presence of vegetation with eliminating of the influence of vegetation and, to produce elevation models, to detect areas with on-ground and underground irregularities, etc. [3].

Airborne SAR system IMARC can use for solution the following tasks:

- surface sensing of ocean, ice and vegetation;
- subsurface sensing of scattering objects and deep layers.

Multi-frequency polarimetric SAR gives new possibilities for operative remote sensing of sea, soil, vegetation, ice cover and other Earth surfaces. Algorithms of deep layer-by-layer remote sensing that are used give possibility to solve narrow set of environmental problems.

It is well-known that the larger the wavelength is, the higher is the influence of deeper soil layers. This fact allows the development of methods of thick layer deep sensing using multi-frequency radar systems. For subsurface sensing the use of long waves of P and VHF bands is required.

Table 1. The IMARC SAR complex parameters.

Parameter	Value			
Frequency	X	L	P	VHF
Wavelength, cm	3.9	23	68	254
Polarization	VV, HH, VH, HV			
Resolution, m	4-6	8-10	10-15	15-20
Antennas: gain, dB	30	14-17	14-17	9-11
Width in azimuth, deg	18	24	24	40
Width in elevation, deg	24	24	24	60

2. DETERMINATION OF SOIL MOISTURE PROFILE

Information about soil properties (soil moisture) profiles can be received from the analysis of measurements of scattering at different wavelengths. The influence of soil moisture profile into backscattering cross section it is necessary to develop the models of reflection from the layers situated at different depth. Solution of the inverse problem can be obtained set at the measurement of backscatter at several wavelengths and at different polarization modes. To have complete information about soil moisture profile it is necessary to solve of the problem by images interpretation in broad band of wavelengths including meter band where attenuation in soil and vegetation is comparably low.

The results of multi-band radar survey obtained with the help of 4-bands airborne SAR IMARC (Radio-engineering Corporation "Vega") illustrate the possibility of measuring of hydrological soil regimes and water lenses allocation in Kara-Kum desert. Lenses of underground water at the depth of 50-70 m were detected. Results were validated by control well-boring. We can see at radar images:

1) dry river-Uzboy bed;
2) sand dunes of 6-15 m height;
3) underground water lenses;
4) transmission facilities.

Application of the GIMS-technology depends on the complexity of environmental tasks solution of which is to be realized during restricted time period with given precision. One of effective instrument for the GIMS-technology using was synthesized by private Dutch\Holland Company "Miramap" was founded at the European Space Incubator initiative from the ESA Technology Transfer & Promotion (TTP) office. The TTP office is contributing to the capitalization of space-based technology and know-how for the benefit of Europe's economy and science. The innovation of microwave radiometer (MR) mapping company (Miramap) was nominated for the Holland Innovation Price in 2005 and was quoted in several newspapers and magazines such as the Dutch Financial Times.

The Miramap instrument consists of three microwave sensors in X-band, C-band and L-band that are all GNSS integrated. The X-band and C-band sensor makes a conical scan at constant incidence angle over a wide swath, while the L-band sensor makes a twin-beam oscillating scan (Figure 1 and Tables 2, 3). The small instrument sizes and weights enable use of a low-cost light aircraft as the observing platform, providing decision makers with a new affordable tool. The platform on which these instruments are flown is a reliable and safe twin Aero Commander [1,2]. The aircraft is specially modified to simultaneously carry a range of other than microwave instruments, such as (digital) photogrammetric cameras, scanners, thermal infrared and multi-spectral sensors. The capability to measure such a comprehensive range of remotely sensed parameters from a single low-cost airborne platform is unique worldwide.

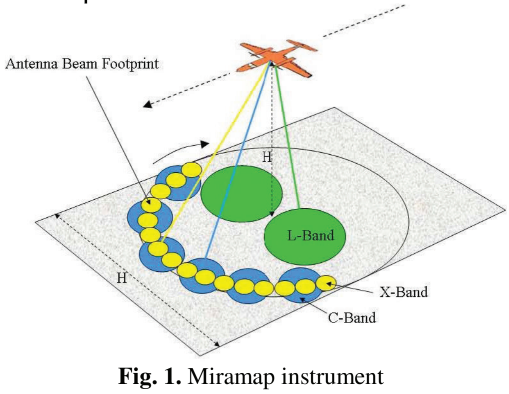

Fig. 1. Miramap instrument

Table 2. Miramap microwave sensor specifications.

Parameter/Band	X-band	C-band	L-band
Frequency (GHz)	15.2	5.5	1.4
Wavelength (cm)	2.0	5.5	21
Pixels/Scan	16	6	2
Incidence Angle (°)	30	30	15
Beam Width (°)	3.5	5	25
Polarization	H	H	H
Sensitivity (K/s)	0.15	0.2	1
Absolute Accuracy (K)	±5	±5	±5

Table 3. Microwave Radiometer Mapping Company (Miramap, Noordwijk, the Netherlands): Sensor specification.

Sensor	Type	Wavelength	Project specs	Use
Digital Photo Camera	Rollei AIC 50 mm lens	Visible 0,4-0,7 micron	10 cm GSD subpixel precision	Detailed visible interpretation
Lidar scanner	Optech Altimeter	SW infrared 1064 nm	2 cm GSD 0,1 m precision	Elevation model
Passive microwave scanner	Radius (IREE-Vega design)	Microwave 2, 5, 21 cm	5 m GSD 0,15 K	(Sub) surface detection of wet and dry areas
Thermal camera	Flir Systems	LW infrared 7,5-13 micron	3 m GSD 0.1 °C	Surface temperature

With whole set of sensor shown in Tables 2 and 3, company Miramap provides the customers exactly with the parameters and environmental conditions including:

• surface soil moisture,

• underground moistening,

• depth to a shallow water table (down to 2 meters in humid areas and down to 3-5 meters in arid/dry areas),

• located on the surface and shallowly buried metal objects of a reasonable size under the conditions of dry ground,

• contours of water seepage through hydro-technical constructions (levees, dams, destroyed drainage systems, different kinds of leaks),

• biomass of vegetation above a water surface or wet ground,

• increase in temperature in land, forested and volcano areas,

• changes in salinity/mineralization and temperature of a water surface,

• water surface pollution, oil slicks on a water surface,

• on-ground snow melting,

• ice on a water surface and on the roads, runways.

Some indices of the effectiveness of the GIMS-technology realized in framework of Miramap's flying research laboratory are the following:

1) Soil moisture content

• operating range is 0.02-0.5 g/cm3

• maximum absolute error is:

- when vegetation biomass is less than 2 kg/m² - 0.05 g/cm3;
- when vegetation biomass is greater than 2 kg/m² - 0.07 g/cm3.

2) Depth to a shallow water table

• operating range is:

- for humid or swampy areas - 0.2–2 m;
- for dry arid areas, deserts - 0.2 – 5 m;

• maximum absolute error is 0.3 - 0.6 m.

3) Plant biomass (above wet soil or water surface):

• operating range is 0–3 kg/m²;

• maximum absolute error is 0.2 kg/m².

4) Salt and pollutant concentration of water areas (off-shore zones, lakes):

• operating range is 1–300 ppt;

• maximum absolute error is 1–5 ppt;

• relative error is 0.5 ppt.

Large-scale investigations on the creation of microwave research carrying platforms were realized by Microwave Remote Sensing Division (MRSD) in 2002 through 2005 within the NASA Center for Hydrology, Soil Climatology and Remote Sensing (HSCaRS) at Alabama Agricultural and Mechanical University (AAMU). This Division was capable of performing microwave radiometric data interpretation and conducting studies in field conditions, from mobile platform and unmanned helicopter.

The antennas, radiometers, data collection system and an embedded Global Positioning System (GPS) receiver were mounted on the manned "Rover" type mobile platform and unmanned helicopter platform "Microwave Autonomous Copter System" (MACS) for measuring the soil-plant system radiation. All radiometers were mounted on a folding mounting panel to observe horizontally polarized radiation when folding the panel between the nadir through zenith looking angle. The GPS information was used to register the microwave reading to a common coordinate system of the study area. All data was stored on a 256 MB memory card. The data capture rate was set to 1 measurement per second in each of the radiometric channels and GPS readings.

The manned "Rover" type mobile platform is a modified "Gator" utility vehicle. This two-seater vehicle has a 286 cc, air-cooled, 4-cycle gasoline engine. Its towing capacity is 500 lb (226 kg) with a top speed of 20 mph (32 km/h). The instrument platform (or mounting frame) for the radiometers and other instruments was assembled at AAMU research station. The aluminium folding panel of 1.5m x 1.5m connecting all system components was designed so that the incidence angle from 0° (nadir) to 180° (sky) could be easily obtainable. The radiometers were mounted with the antennas viewing off to the right hand side of the platform at an incidence angle of 10°. The radiometer "Rover" shuttled back and forth in a north-south direction at a speed of 2-5 mph. using the developed remote sensing system data obtained from a height of 2 m provided the spatial resolution of 1.4 m of land area.

The unmanned helicopter platform MACS was equipped with a 6 cm radiometer (incidence angle 5°) mounted on the nose of the AutoCopterTM onto a stabilized gimbal with pan/tilt interface which attenuates vibrations. The MACS is a modified AutoCopterTM, a small unmanned helicopter platform that can fly autonomously (fly a pre-programmed flight path) or semi-autonomously (with an operator directing the manoeuvres). This is a product of Neural-Robotics, Inc. (NRI) of Huntsville, AL.

The unmanned helicopter advantage is its patented flight control system consisting of multiple neural network modules working together. The result is an autonomous helicopter that adapts to changing conditions and provides an extremely stable platform for hundreds of applications. The AutoCopterTM is 2.18 m in length (from tip of tail rotor to tip of main rotor) and weighs approximately 13.6 kg. It carries a payload of up to 6.8 kg. Basic avionics consist of a PC/104 computer, altitude and heading reference system (AHRS), GPS receiver (WAAS-compatible), downward pointing range finder (ultrasonic sensor), barometric pressure sensor, and heading-hold gyro. The standard transmitter is used as the "ground station."

The Ground Control Station (GCS) with a flight planning program "WayPlanner" was used with the AutoCoperTM. This is a self-contained Windows-based application that unlocks the power of fully autonomous flight. The program enables mission planning in 2D using stored satellite images. Flight plans were uploaded to the AutoCopterTM via data link enabling the aircraft to takeoff, climb, fly its programmed route, and land fully autonomously. The programmed flight consisted of an autonomous launch with 16 waypoints, a climb to 30 meters, followed by a transition to forward flight at a velocity of 2 m/s and auto-landing.

During flight the aircraft has the ability to state data (aircraft altitude, speed, and other parameters in real time on the GCS screen in 2D and 3D. While maintaining airspeed, altitude and heading, 8 flight lines were flown at a distance of ~ 500 m at 30 m intervals. The time it took the helicopter to fly from waypoint to waypoint (north-south direction) was ~ 4.5 minutes totalling ~ 40 minutes of flight time. Because the aircraft flew below 152 meters it was exempt from FAA regulations. Using the developed remote sensing system, data obtained from an altitude of 30 m provided the spatial resolution of 20 m of land area.

5. CONCLUSIONS

This paper presented the platforms for determination of different environment parameters. For example, the results of multi-band radar survey obtained with the help of 4-bands airborne SAR IMARC (Radio-engineering Corporation "Vega") illustrate the possibility of measuring of hydrological soil regimes and water lenses allocation in Kara-Kum desert. Lenses of underground water at the depth of 50-70 m were detected.

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About the authors

PhD Prof. Eng. **Vladimir F. KRAPIVIN** PhD
V.A. Kotelnikov's Institute of Radioengineering and Electronics, Russian Academy of Sciences, Moscow
email: vfk@ms.ire.rssi.ru

V. Krapivin was educated at the Moscow State University as a mathematician. He received his PhD in geophysics from the Moscow Institute of Oceanology in 1973. He became Professor of Radiophysics in 1987 and Head of the Applied Mathematics Department at the Moscow Institute of Radioengineering and Electronics in 1972. He was appointed Grand Professor in 2003 at the World University for Development of Science, Education and Society. He is a full member of the Russian Academy of Natural Sciences and Balkan Academy of Sciences, New Culture and Sustainable Development. He has specialized in investigating global environmental change by the application of modelling technology.

Mechanical Engineer of the University Transilvania from Brasov, the Managerial Industrial Program with Welding Especiality and PhD in residual stresses and strains modelling and technology optimisation. He worked at the Industrial Tractors Design and Research Institute at ICPATT Brasov to havy and mediun Bulldozers prototips design and other Earth Moving Machineries prototipes and series products. From 1988 he work at Transilvania University at Materials Science and Engineering Faculty and from 2010 he work in the area of Civile Engineering at Transilvania University. He publish monographis in the area of Optimization Technology and Transport

Prof. Eng. **Costică NITU**, PhD
University "POLITEHNICA" of Bucharest, Romania
email: cnitu_ubp2001@yahoo.com

Costică Nitu is full professor in Automatic control and System modelling at the System engineering and Automation Department He participated in a mixed university-enterprise research team, as team leader for human operator interfaces, with two research institutes to design and to implement in the automation industry, for the first time in Romania, the distributed digital control system with microprocessors. His actual courses are System modelling in ecology, Distributed Control Systems and Distributed information systems. He is also involved in the research projects for environment protection, development of software and hardware for distributed systems.

Assoc. Prof. Eng. **Anda Sabena DOBRESCU** PhD
University "POLITEHNICA" of Bucharest, Romania
email:sabda23@yahoo.com

Graduated at the University "POLITEHNICA" of Buchares, Automatic Control and Computer ScienceFaculty. Her main areas of interest are design and software architectures and distributed systems. She has acquired a big experience while working as computer software engineer (contract based) for various customers in Romania and Belgium in domains ranging from low level programming language, to the highest, including Assembly, Java, C++, C#, T-SQL, PL/SQL.