AEROSPACE AND GROUND BASED GEORADARS

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Bulgarian and foreign scientific materials have been analyzed concerning using of radars by the meter range with aerocosmic base for solving the problems of ecological and nature-resourse monitoring. A brief overview of the methodics is made related to the georadar sonding of surface objects and assessment of supplies of biomass of wood ecosystems. A list of tasks for georadar sonding is presented as well as some requirements to the range of georadars, conditions of photography and precision of geographical bond of the data.

Keywords: georadars, satellite systems, space radiolocators

1. INTRODUCTION

In scientific-technical literature the term „georadar" (from English "Ground Penetrating Radar – GPR" or "Subsurface Interface Radar – SIR") is usually used in regard to radiolocational sensors on ground portable platforms or can be transfered manually [1-2]. These are the modern devices of subsurface sonding designed for detecting the abnormalities in the Earth layers. They are used for preliminary geophysical exploration of archeological objects. Their mechanism of work consists of radiating powerful electromangetic impulses which frequency varies from several tens of MHz up to several GHz which reflect during the transition from a substance with a certain permittivity into a substance with another permittivity. The registration of reflected signals helps for creation of 2D and 3D image of objects located under the ground or under vegetation.

It is advisable the term „radar" to be used for the terrestrial sensors as well as for the devices with airily and cosmic base since they are designed for the same purpose.

In the resent years the data users of the remote sonding on the Earth began to focus their attention on the information that comes from the aerocosmic radars from the meter range. This fact is related to the changing of priorities and interests of agricultural branches and the administrative organs in different level that are concentrated on solving the global and regional problems of the energy and ecological safety. For their putting in practice would be in assistance the operating data for the condition of the biosphere components (soil and vegetation layer, sea ice, peat, ever frozen zones, etc.), which are delivered by the board aerocosmic radars for subsurface sonding.

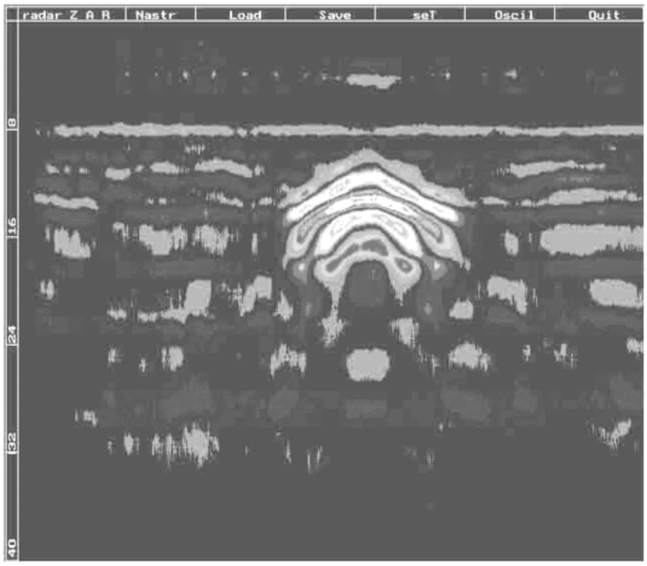


Fig. 1. Picture of terrestrial georadar

Aerocosmic georadar sonding is a relatively new method for remote observation. Currently, this method is used in the systems of agricultural and ecological monitoring and it can be used in more systems.

The aim of this article is to analyze Bulgarian and foreign scientific materials related to the problems of georadar sonding in order to give more detailed information to the specialists in the field of remote sonding. The details include data about the current state and perspectives of georadar methods and means, their capacity in finding and studying terrestrial and underground objects.

2. CONTEMPORARY STATE OF GEORADAR'S SONDINGS

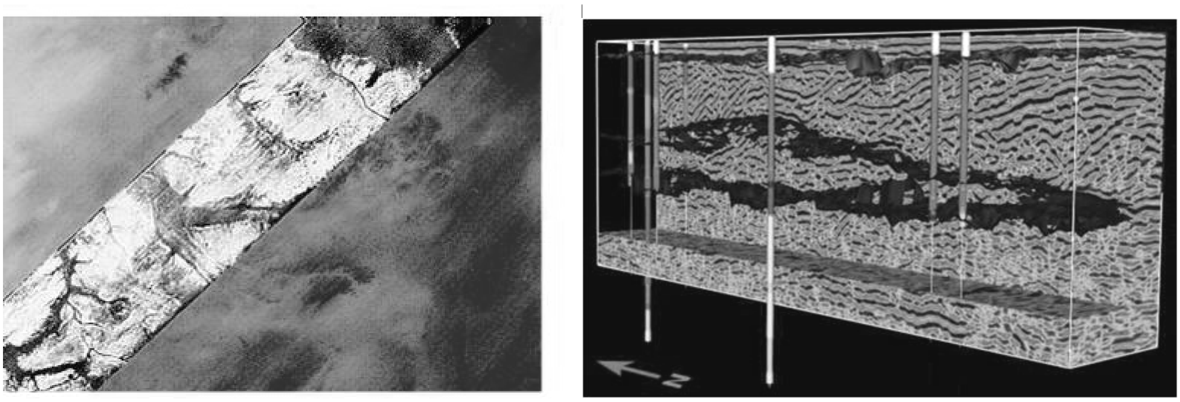
Aerocosmic georadars are a relatively new tool for Earth exploration. The method for underground radiolocation sonding from airplanes and helicopetrs was invented in the 1960^{-es} in Canada and in the early 1970^{-es} was widely used. That method uses radiation in nadir in supershort impulses towards the surface [1]. The radars on the board of the airplane/helicopter, which were used for this method were designed to evaluate the ice/snow thickness on the lake surface where heavy planes were landing.

There were experiments in the USA in the early 1980^{-es} evaluating the usage of board radars with synthesized equipment (PCA) on the board of an airplane for underground geophysicsal explorations [3].

In the Institute for civil aviation in Rizh in the former USSR were organized and conducted experiments using radars with transmiters of supershort sonding video-impulses. These experiments were carried out under the supervision of Prof. Finkelstein in the 1960^{-es}.

In the late 1980^{-es} and the early 1990^{-es}, Prof. Kalmykov and his co-workers at the Institute for Radiophysics and Electronics of the Ukrainian Academy of Sciences in Harkov organized successful flight testings of the decimetre and metre range. They used quasipermanent signal with linear frequency modulation. The results of these tests showed the real possibilities of the radars to find underground pipelines (at a depth of 6 meters) and to determine the level of underground waters.

Finally, starting in the mid 1990^{-es} untill now in the USA and Sweden designed and tested georadars for airplanes and helicopters. They are constructed on the base of PCA and they use sonding signals and constant radiating with step-manipulation of the frequency. This method ensures harmonization of the frequency spectrum of the sonding signal with the spectral properties of the antennas [3].



a. b.

Fig. 2.a LANDSAT-TM L-range padar reveal pale archeological phenomenon in the north desert of Sudan covered with a few meters of sand; 2.b georadar estimations of underground vesicles and levels.

Table 1 shows the charasteristics of the most perspective georadars in metre range with aerocosmic base, which are installed on helicopters (a), airplanes (b), and space (k) devices [4-10].

MIMOSA – unfocused radar made by EKA. Its main purpose is nadir sonding of Arctic ice. It can be also used for sonding of wood ecosystems.

IMARK – four-diapason airplane PCA mabe by specialists in Russia. It is multifunctional: it obtains a wide range of application. The long-wave range is successfully used for detecting of above-the-ground parts of highway pipelines in the oil-sourse regions. It is also very effective for detecting the level of undeground waters.

№	Radar	Wave length, m	Polos of scope, km	Horozontal, m	Vertical, m	Made by
1	**MIMOSA (k)**	1.0	40-50	1-10x10	10	EKA
2	**IMARK (c)**	2.24	24	15-25	15	Russia
3	**MARS (c)**	1.8	30-60	50-100	40-90	Ukraine
4	**CARABAS (c)**	5.0	0.7	3.0x3.0	3.0	Sweden
5	**MkV (в)**	1.0	0.5	1	1	USA

Table 1. Characteristics of board radars with aerocosmic base

MARS – four-diapason airplane PCA. Its characteristics are similar to these of IMARK.

CARABAS – airplane PCA. Its main purpose is finding objects in woods or any kind of vegetation. Its function in urban environment is: management of the condition of wood ecosystems, to guard the environment and to preserve all protected areas.

MkV – helicopter PCA designed to locate targets hidden in vegetation or positioned underground (blindages, minefields, arms depts etc.).

3. Possibilities of Aerocosmic Georadar's Sonding

From methodological point of view the most important characteristics for georadar sonding from aerocosmic platforms are:

- determination of the maximum depth for detecting objects under the ground or under certain amount of vegetation;
- evaluation of the potential accuracy of measurment the depth of the location of objects;
- option of the maximum quantity of horizontal space of georadar;
- formulation of requrements for the accuracy of bonding the results of the sonding.

The methodic for calculation of the maxumum depth of sonding is presented in [1, 3], that is why only the final formula is shown here:

(1) $$h_{max\lambda} = \frac{q}{4\pi\{\ln(4G\sigma_\lambda|F_{\text{пр}}|^4) - \ln[G\sigma_0 S_{n\lambda} N + (4\pi)^3 R_\lambda^4]\}}$$

where $h_{max\lambda} = \frac{h_{max}}{\lambda}$ is maximum depth of sonding standardized to the wavelength. The possibility of the radar ΔR equals the upper boundary frequency f_B multiplicationed to the respectively wave length -λ_k. Then $V = f_0 \lambda_k$ and the possiblitiy of georadar could be explained by λ_k and $\frac{\Delta F}{f_B}$ as following:

(2) $$\Delta R = \frac{V}{2\Delta F} = \frac{F_B \lambda_k}{2\Delta F} = \frac{\lambda_k}{2(\frac{\Delta F}{f_0})}$$

The standardization ΔR of λ_k, when including the quantity $\Delta R_x = \frac{\Delta R}{\lambda_k}$ could explain the quantity of the possibility in wavelength

(3) $$\Delta R\_\lambda = 1/2(\Delta F/f\_B) = 1/2(1/(\Delta F/f\_c) + 0{,}5)$$

It is a well-known fact that waves of optic range diffuse primarily from the tree crowns rather than their stalks and their other lower parts. The electromagnetic waves of santimeter and decimeter range go in depth of the tree crown and get diffused by the leaves, needles and brunches and at the same time the waves of meter range are diffused by the tree stalks and the ground. This enables the structure of tree trunks hidden by the tree crown to be seen.

The mechanism of reciprocal action of meter range electromagnetic waves with tree stalks and the ground surface is analogous to the process of their reflection by angle reflectors. This insures high level of the efficiency signal. The relative effective surface of reflection of wood for sonding by meter range of waves is connected to the relative volume of softwood by the formula [2, 3]:

$$\sigma \approx \frac{1}{3|F|^2 \Sigma V_i^2}, \quad i = 1,2,\ldots N \qquad (4)$$

Helicopters' and airplanes' georadars allow 2D and 3D pictures to be made of ground surface characteristics. The usage of radio-locational interferometers – working with „hard" and „soft" base – ensure the sterescopic and volumetric georadar images.

The differense between PCA and impulse radars with nadis sonding is their high ability in horizontal (in the range of 1 m for MkV radars) and the wide polos of scope (up to 60 km for MARS PCA). However, when working in slope these radars esnusre lesser depth (compared to the terrestrial georadars) for sonding and are designed to find objects underneath leaves, superficially located pipelines, oil leaks of damaged oilpipelines, and also for determination of softwood supplies in forests [1-2].

Concerning the usage of georadars with cosmic base: there are less results in that field compared to those of the georadars with airplane base. There are two reasons for that. Firstly, there are much more expenses for their design and secondly, there is need for detecting the influence of ionosphere on the characteristis of echo-signal – amplitude and phase. Currently, the European Cosmic Agency is designing the cosmic radar MIMOSA taking into account all that characteristics [3].

4. Conclusions

4.1 Aerocosmic georadars of meter range are perspective means for global and regoinal ecological monitoring of the state and condition of underground objects and underground environment. Currently, the board air based radars successfully deal with detection of water and oil levels, evaluation of supplies of softwood in forest ecosystems, they also allow control over highway oilpipelines and gasepipelines.

4.2 The resent design and put into space orbit of ИСЗ will allow the invention of hierarchic system for global and regional ecological and nature-resourse monitoring. These devices have georadars with meter range and obtain higher tactical and technical characteristics than MIMOSA. They will include means for air and terrestrial georadar sonding.

4.3 Maximum effectiveness of function of such system can ensure of stable development of certain regions and countries as well as of world society.

5. References

[1] Канащенков А. И., Ведешин Л. А., *Исследование земли из космоса*, 2004, №3, стр. 88-96

[2] Франкельштейн М. И., Мендельсон В. А., Кутев В.А., *Радиолокация слоистых земных покровов*, М., Сов. Радио, 1977, стр. 176

[3] Herique A., Kofman W., Bailer P., Phalippou L., A *Spaceborne Ground Penetrating Radar*: MIMOSA CEOS SAR Worshop, ESA-CNES Toulouse, 26-29 October, 1999, p. 6