PETROV AND HIS LABORATORY "PLANETARY RADAR SYSTEMS"

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Abstract. **Some book fragments of the former 127 laboratory Kotelnikov FIRE RAS scientific researchers are presented. They include information about Petrov G.M. - the laboratory head, the solar system planet radar works in the 60-80s last century by Petrov and his colleagues, Venus surface atlas and so on.**

Keywords: **planetary radar, astronomical units, mapping**

UDC 621.396.967; 621.396.962

Bibliography - 3 references *Received 10.09.2018*

RENSIT, 2018, 10(2):175-192 **DOI: 10.17725/rensit.2018.10.175**

PETROV GENNADY MIKHAILOVICH (1.06.1924-2.12.2008) is a specialist in radio engineering and radar astronomy, Ph.D. Phys.-Math., laureate of the Lenin Prize, head of the laboratory of the Institute of Radioengineering and Electronics of the USSR Academy of Sciences. Member of the Great Patriotic War from 1942. In 1955 he graduated from the Radio Engineering Department of the Moscow Power Engineering Institute and began working at the Institute of Radioengineering and Electronics of USSR Academy of Sciences; since 1972 - Head of the Laboratory of Planetary Radar Systems. Since 1968 he defended his Ph.D. thesis on the specialty "Radio Astronomy".

GM Petrov is one of the leading specialists in the field of radar research of planets, the author of more than 90 publications. Under his leadership a large complex of planetary radar equipment was created. His thesis is devoted to the definition of an astronomical unit based on the results of radar observations of Venus, Mars and Mercury, performed in the Soviet Union in 1961-1964. The team led by GM. The extensive program of radar observations of planets and radiophysical studies in space with the help of automatic interplanetary stations "Mars-4, -5, -6", "Venera-9, -10, -11, -12" and an artificial moon satellite "Luna" -22 ".

G.M. Petrov was awarded the Order of the Badge of Honor, the Medal for Military Merit and five more medals.

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Gennady Mikhailovich was born June 1, 1924 in the village Dorogorskoe Mezensky district of the Arkhangelsk region. In 1940 he entered the technical school. Since October 1941 - on the construction of fortifications near Moscow - he rebuilt the destroyed buildings in Moscow. He was drafted into the Red Army in August 1942, a cadet in the school of the anti-aircraft artillery regiment in Moscow, and from November 7, 1942, to the end of the war, as part of the 130th Independent Air Defense Armored Trains, where he fought in the South, West and South-fronts, from Kalach at Stalingrad to Peremyshl in Poland. His battle path, he began gunner guns and finished commanding guns.

In 1955, after graduating from the MEI radio department, a young engineer Petrov was sent to the Institute of Radioengineering and Electronics of USSR Academy of Sciences, where he worked for almost half a century, from 1956 to 2004. At first he dealt with the problems of noise immunity of radars and the development of a technique for trajectory measurements of the first Earth satellites.

But the main business of G.M. Petrov became radar astronomy. With his direct and largely determining participation, the first domestic planetary radar was created. This unique instrument worked in the decimeter (39 cm) radio wave band and used two eight-mirror antennas of the Center for Remote Space Communications in the Crimea near Evpatoria. One of the antennas was transmitting, the second - the receiving room.

Very much then it was necessary to create for the first time. Gennady Mikhailovich developed and created a software-temporary device, the so-called "chronizer", for this radar. The range of time was previously unseen - up to 10 thousand seconds - after all, the delay of echo signals from the planets was tens of minutes. At the same time, the instrumental measurement error should be no worse than 1 microsecond. But then everything was done on antediluvian radio tubes and each trigger required a separate lamp.

An even more unique device is the first parallel digital spectrum analyzer. He, for decades ahead of his time, was developed by Petrov and created under his leadership.

The point is that the radar transmitter sends continuous coherent signals with periodic frequency modulation. The signals reflected from the planet have a ruled and extremely narrow spectrum, and therefore the optimal harmonic filter is precisely the parallel harmonic analyzer.

It was in the mid-1960s. The analyzer had 15 parallel channels with a frequency resolution of 0.25 to 16 Hz. It was made in the size of half a room on finger lamps, double triodes 6N3P (total 600 lamps), consumed several kW.

With the help of this first planetary radar, planets of the terrestrial group were successfully investigated, unique high-precision measurements were obtained, on the basis of which the Astronomical unit was radically refined. It was these measurements that made it possible to "get" to Venus to our first interplanetary stations.

From the TASS report of April 22, 1964: "For the radar studies of the planets Venus, Mars and Mercury, the Lenin Prize was awarded to the Director of the IRE of the USSR Academy of Sciences, the head of the work, Academician VA Kotelnikov, the staff of the same institute, VM Dubrovin, MD Kislik , VA Morozov, GM Petrov, ON Rzhige, AA Shakhovsky, the head of the laboratory GNII MOD of the USSR VP Minashin.

A detailed analysis of the long-term series of radar astrometry made it possible to create a highly accurate theory of planetary motion.

In 1982, G.M. Petrov as a member of the team of authors for the series of works "Creation of a single relativistic theory of motion of inner planets" was awarded the State Prize of the USSR.

The fundamental contribution of Gennady Mikhailovich Petrov to the national and world science was the active participation already as the head of the laboratory of the Institute of the Far East of the Russian Academy of Sciences "Planetary Radar Systems" created by him in 1982-1984 in the pioneering experiment on radar mapping of the planet Venus, which was carried out with the help of artificial satellites "Venus-15 "and" Venus-16 ". He made a significant contribution to the creation of the world's first "Atlas of the planet Venus".

Having already left the position of the head of the laboratory for health reasons, Gennady Mikhailovich continued to work fruitfully at the FIRE of the Russian Academy of Sciences. To him went for the qualified help and consultations, for wise advice and memories

THE BIRTH OF A LABORATORY 127

The 127 laboratory of the "Planetary Radar Systems" were born in 1972 from the group of 127. All information about the employees of the laboratory. 127 was in the famous barn book, which was mastered by G.M. Petrov. In this book there are records of more than 80 people who worked at one time in 127 laboratory. A general photo of the laboratory staff was preserved, made in 1975 on the stage of the Institute's assembly hall.

In this photo - the bottom row (from left to right): L.N. Samoznayev, N.V. Rodionova,

L.V. Vyshlova, V.Z. Sukhoverkhova, Yu.N. Aleksandrov, V.M. Dubrovin, G.M. Petrov, V.M. Smolyaninov, E.G. Nazarenko, L.V. Abramova (mater. responsible), V.I. Kaevitser, I.V. Turusina; average row: A.C. Vyshlov, A.S. Maksimov, B.I. Kuznetsov, E.A. Razumny, A.I. Sidorenko, Yu.V. Feofanov, N.A. Savich, P.V. Chernov, V.E. Zimov, V.K. Golovkov, V.A. Samovol; upper row: A.B. Kalinin, V.A. Ivanov, A.L. Zaitsev, A.F. Khasyanov, M.V. Sorochinsky, S.M. Baraboshkin, M.V. Labutin, V.I. Churkin.

PETROV'S GROUP

The main directions of work of Petrov's group, are told by Dr.Sc. V.I. Kaevitser and Dr.Sc. A.I. Zakharov.

Radar studies of planets in IRE RAS

Radar studies of planets in the IRE RAS were started in 1960 on the initiative of the director of the Institute, Academician VA. Kotelnikov. The use of radar methods in space research, which is the essence of radar astronomy, provides new opportunities for studying the celestial bodies of the solar system, new information on their position, motion, rotation parameters, dimensions, physical properties of surface rocks, and much more. The increased practical interest in the development of radar methods in the interest of studying the planets in the early 1960s, among other things, was caused by the need to ensure the navigation of spacecraft during the planned interplanetary flights.

Optical observations of planets and the Sun, which measure the angular position of objects on the celestial sphere, were conducted in the world for two hundred years. On the basis of these observations, quite advanced theories of planetary motion were constructed, but the accuracy of the forecast of their position was insufficient for the high requirements of astronautics. The point is that the accuracy of measuring the angular position in optical observations does not exceed a tenths share of cornersecond and is determined, in the main, by random deviations of the beam in the Earth's atmosphere. Because of this, for example, the error in measuring the position of the planet Venus in the picture plane at the moment of its closest proximity to the Earth is 40 km. The distance to the planet is measured indirectly, by measuring the position of the planet in different parts of its orbit, and may have an error of tens of thousands of kilometers. This is completely inadequate for interplanetary flights, since the diameter of any of the terrestrial planets does not exceed 12.000 km.

Unlike indirect optical methods, the radar methods give direct measurements of distance based on the time of passage of the radio signal to the planet and back. In addition, the value of the Doppler frequency shift of the reflected signal makes it possible to estimate the radial velocity of the reflecting object, and the Doppler frequency band is the rotation speed around the axis. Modern radar facilities allow you to measure the range to the planets of the Earth Group with an accuracy of several hundred meters, and the speed - a few centimeters per second. From radar measurements of distance and speed, it is possible to determine the position of planets in space with an accuracy several orders of magnitude higher than on the basis of optical observations of their angular position.

The first experiments on the radiolocation of celestial bodies were carried out shortly after the war in the US and Hungary by military radars. It turned out that with their help it is possible to reach only to the Moon, since by the level of the reflected signal this satellite of the Earth is comparable to the plane for them. To locate more distant objects like Venus, it was required to improve the radar parameters. For example, increase the radiated power in 10 million times, because the power of the reflected signal coming to the radar is inversely proportional to the fourth power of the distance to the reflecting object.

The possibility of radiolocation of the planets of the Solar System appeared in the world only by the beginning of the 1960s due to the creation of antennas with a larger area, more powerful transmitters and sensitive receivers, as well as to improved methods for separating signals from a interferences.

It was decided to conduct radar studies of the planets in the Soviet Union on the basis of the complex of receiving and transmitting antennas ADU-1000 of the receiving complex "Pluton" of the Center for Long-Range Space Communications in Yevpatoria, which was created for communication with interplanetary ships. Thanks to the use of ready-made nodes and solutions, two receiving and one transmitting antenna complexes were created in a short time.

Antenna systems of these complexes consist of 8 duralumin parabolic antennas with a diameter of 16 m attached in the form of a grid to the hull of a diesel submarine attached to the farm of the railway bridge, which, in turn, rests on a support-turning device from the gun turret of the main caliber of the battleship (see Fig. 16, Article 2 of this issue).

Built in just one year, these antennas provided deep space exploration in the Soviet Union until the late 1970s, when the RT-70 system with a 70-meter antenna was put into operation (Fig. 2, article 2 of this issue).

About the first radar contacts with Venus abroad was reported back in 1958, but later it was established that the received signal turned out to be noise radiation. Reliable recording of the signal reflected by Venus was made in early 1961 at the time of the lower connection almost simultaneously in the USA, the Soviet Union and England, when the distance to the planet was about 40 million km.

The domestic radar in USSR operated at a frequency of 768 MHz, the power flux density was 250 MW per steradian, so that into the entire visible surface of Venus hit 15 watts. The emitted signal had the form of telegraphic parcels and pauses lasting 128 or 64 msec (amplitude modulation). A signal was also used in the form of alternating telegraphic parcels at two frequencies, offset by 420 kHz, each with a duration of 64 msec (frequency modulation). The frequencies of the carrier signal and its manipulation were corrected for displacement due to the Doppler effect caused by a change in the distance between the Earth and Venus, as well as the rotation of the Earth. The transmission was conducted by sessions during the time the signal passed to the planet and back. Session management was conducted with the help of a specially developed high-precision chroniser. To ensure the possibility of detailed analysis of radar data with a revision of various processing algorithms, magnetic recording of the received signal was realized. The analysis of the echo signal was carried out using an analyzer, which was a line of filters.

As a result of a series of observations from April 18 to 26, 1961, measurements were made of the distance to Venus, which made it possible to significantly clarify the value of the astronomical unit (the distance from the Earth to the Sun). Accurate knowledge of the astronomical unit - the distance from the Earth to the Sun - is important because in astronomy through this unit all other distances are determined. If before the radar observations the most significant was the value of the astronomical unit of 149527000 ± 10.000 km, obtained from optical observations of the small planet Eros, after the first radar observations it turned out that it is equal to 149599300 ± 2000 km, which is 73 thousand km more than was thought in astronomy.

In June 1962, after upgrading the equipment of the complex, which consisted of using a more sensitive receiving apparatus (a paramagnetic amplifier was used on a ruby crystal with helium-cooled at the input of the receiver, which increased the sensitivity at 6 times), for the first time in the world the radiolocation of Mercury was conducted. The emitted signal consisted of alternating parcels at two frequencies, differing by 62.5 Hz. The duration of the parcels and pauses at each frequency was 1024 msec. Estimates of the astronomical unit, based on measurements of the distance to Mercury, were in good agreement with the estimates obtained at the radiolocation of Venus. Due to the calibration of the sensitivity of the receiving equipment over the radiation of the extraterrestrial radio source Cassiopeia A, the reflection coefficient of the Mercury surface was measured equal to 3-7%. Similar measurements in the US were conducted a year later.

In the fall of 1962, the radiolocation of Venus was repeated. In these works, for the first time, a signal with periodic linear frequency modulation was used to measure the distance to the planet (in the US in subsequent years a signal with phase-code manipulation was used). Besides corrections were made to the modulation parameters to compensate for the frequency variation due to the Doppler effect caused by the motion of Venus and the Earth. Thanks to the improvement of equipment and methods of signal generation and processing, measurements of the distance to the planet, obtained in each separate session, had an error of less than 15 km. The reflection coefficient of Venus was equal to 12-18%, and along the broadening the spectrum of the reflected signal it was found that Venus rotates around its axis in the opposite direction compared to the Earth and at a very low speed: one revolution for 200-300 days. In optical observations, this could not be done because of the opaque, powerful cloud cover of the planet. The increase in the radar potential in these studies made it possible to conduct an amusing experiment on radiotelegraph communication using Venus as a repeater. The words "MIR", "USSR", "LENIN" were transmitted by the radio telegraph code in the direction of Venus. After a total distance of 85 million km, the signal was received on the Earth (see the fragment of the signal recording in Fig. 2).

In the first half of February, 1963, at the moment of confrontation, the first radar-tracking of Mars was made. The general parameters of the radar were the same as in the radar sessions of Mercury, and a signal was also used in the form

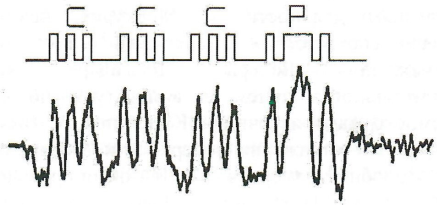

Fig. 2. *The word "USSR", transmitted by the telegraph code and reflected from Venus on November 24, 1962.*

of alternating rectangular pulses with different frequencies. The reflected signal was reliably detected in 48 sessions on the night of 7 to 8 February and from 8 to 9 February. The reflection coefficient in various parts of Mars was less than that of Venus, but at times reached 15%.

In September-October of the same year, thanks to a further increase in radar sensitivity, it was possible to obtain reflections from Jupiter at a time when it was located at a distance of 600 million km from the Earth. The reflected signal was so weak that for its detection it was necessary to carry out the accumulation of energy for 20 hours. The reflection coefficient was 10%. At the same time conducted in the US attempts to radar Jupiter did not yield any results.

Pioneer work on the radiolocation of the planets was highly appreciated - a group of staff of the IRE RAS, headed by Academician V.A. Kotelnikov received the Lenin Prize in 1964 (VM Dubrovin, VA Morozov, GM Petrov, OI RyzhA, AM Shakhovskoy).

In January-February 1966, the radar observations of Venus, jointly with the British Jodrell-Bank Observatory, were conducted. Monochromatic signal emitted from Evpatoria after being reflected from Venus was received by a large radio telescope in England. The signals recorded on the magnetic tape were digitized and analyzed at the FIRE. Due to the spresd of the transmission and reception points, the accumulation time of the signal was increased and the potential of such a radar system was improved. The data processed on a computer in the IRE made it possible to reveal anomalies of the reflective properties of the surface, to precise the orientation of the rotation axis of the planet and the period of its rotation.

Radar observations of planets in the IRE of the Russian Academy of Sciences were regularly held in the following years. Further improvement of the parameters of the equipment and improvement of the processing methods led to an increase in the sensitivity of the planetary radar by an average of 70 times. This made it possible, for example, to increase the accuracy of measurements of the distance to Venus from 1000 km in 1961 to 0.3

km in 1978, and its radial velocity from 40 cm/s in 1961 to 0.8 cm/s in 1978.

In 1978 a unique radio telescope RT-70 with a mirror diameter of 70 meters, one of the largest in the world, was built in Evpatoria. The new antenna, more powerful transmitters and low-noise receivers increased the potential of the planetary radar by 50 times, which further enhanced the capabilities of radar observations. With the help of this radar, observations of Mercury, Venus and Mars were carried out in February-April 1980 on large areas of the orbit of these planets: 139° of the arc of the orbit in the region of the lower compound for Mercury, 82° of the arc of the orbit in the region of maximum elongation for Venus and 29° of the arc of the orbit in the area of confrontation for Mars. The long-term radar observations of 1980 made it possible to obtain detailed profiles of the surface heights at the subscore point and to clarify the available data on the relief of the planets.

Accumulation of the actual measuring material in the time interval from 1961 to 1980 made it possible to start creating a new theory of planetary motion. The unified relativistic theory of the motion of the planets Earth, Venus, Mars and Mercury, created by the IRE RAS in collaboration with a number of other organizations on the basis of domestic and foreign radar and optical measuring material, made it possible to predict their relative position 50-100 times more accurately than the forecast on the classical theory of motion planets. The deviations of the measured distances from the planets from their calculated motion, calculated according to a unified theory, do not exceed the values: for Venus, 0.9 km in 1970-1980; for Mars - 2.5 km for 1967-1980; Mercury - 2.0 km in 1980.

Per a series of works on the creation of a unified relativistic theory of planetary motion, a group of Soviet scientists in 1982 was awarded the USSR State Prize. Among the rewarded are the staff members of the IRE RAS: Academician V.A. Kotelnikov and head of the laboratory of radar research of the planets of the FIRE, G.M. Petrov.

The high accuracy of the created theory of planetary motion made radar observations unnecessary for a certain period of time. As a result of the social and economic transformations that followed soon in society and the related problems with financing, this period dragged on to the present day. New domestic plans for the exploration of outer space lead now to the need to resume radar observations of the planets and to refine the parameters of their motion.

Radar mapping of the northern hemisphere of the planet Venus with spacecraft Venus-15 and Venus-16

Radar studies of planets from the Earth are limited in detail of the measurements and the area of the planet under study. Surface heights profiles are measured along the trajectory of the displacement of the sublocator point along the surface of the planet. The same trajectory, as a rule, limits the measurement profile of the reflective characteristics of the surface. The most successful experiment on mapping the planet Venus from Earth was conducted from Arecibo (Puerto Rico), using a unique radar with a mirror diameter of 300 m. In this experiment, using radio waves, it was possible to slightly open the cloud veil of Venus and see its surface. A radar image of a small area on the surface of Venus was constructed (see the fragment of image of the region of the Maxwell mountains with a resolution of about 10 km in **Fig. 3**).In this figure with a lighter background a system of ridges of the Maxwell mountains is shown, that have an increased reflection coefficient against the background of more radio-dark, smooth lava plains. The double ring structure on the right side of the mountain range is Cleopatra's Patera, 100 km in diameter.

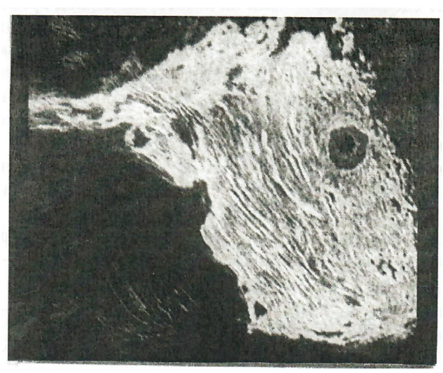

Fig. 3. *Radar image of the Maxwell Mountains region obtained by the radar in Arecibo.*

By 1980, the most detailed map of the surface of Venus was a map of the heights of the planet in the range from 60° S up to 75° N, built with the help of an altimeter of the American spacecraft Pioneer-Venus. Despite a relatively large step of measurements on the surface of ~ 50-150 km, this map reveals details of a continental scale - Ishtar's Land, Aphrodite's Land, Beta Area, etc. Smaller details - ridges, rift valleys, impact craters were not visible. Meanwhile, the absence of such details did not allow us to judge the age of the surface of the planet, about the geological activity of Venus.

In order to obtain a more detailed and important information for geologists, an experiment was conducted in the Soviet Union on radar mapping of this planet from the spacecraft Venera-15 and Venera-16, performed in 1983-1984 by soviet scientists. This work is deservedly a world-class achievement. For the first time in the world, from the spacecraft a detailed radar survey of the planet's surface was carried out, closed by a dense atmosphere, inaccessible to observations in the optical range. The area of the surveyed territory located north of 30° N is 115 million km^2, which is a quarter of the entire surface of Venus and only one-third less than the terrestrial land area.

The successful carrying out of the experiment became possible thanks to the close cooperation of domestic organizations, such as the Research Center named after G.N. Babakin (artificial satellites of the "Venera" series, satellite control during the experiment), OKB MEI (onboard radar system), NII KP (development of a radio link, receiving information at the Center for Remote Space Communications in Crimea), Keldysh IPM (trajectory measurements processing), Central Research Institute of Geodesy, Aerial Photography and Cartography (mathematical foundations of cartographic support, preparation of maps), Vernadsky GEOKHI (geological and morphological analysis). The idea of carrying out the experiment and its scientific and methodological basis was developed at the IRE. A computer center was set up in the Fryazino branch of the IRE RAS, all processing of the received material was carried out and digital maps of Venus were created. It should be noted that all the equipment used in

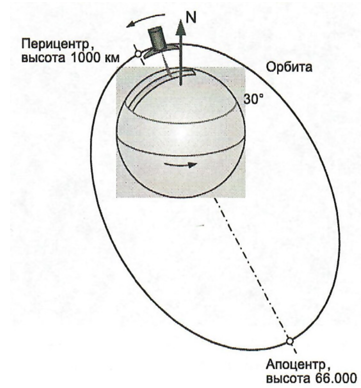

Fig. 4. *Survey scheme of the polar region of Venus from the spacecrafts Venus-15/16.*

the work in space and on Earth was created in the Soviet Union.

A synthetic aperture radar with a viewing angle of 10°, mounted on a spacecraft, provided a survey of a strip image of the surface during the movement with a spatial resolution of 1-2 km. The radio altimeter-profilograph made measurements of the surface heights in the nadir. The measurement scheme is shown in **Fig. 4**. The spacecraft, which is in an elliptical orbit with a period of revolution of one day, conducted a survey of the band of the radar image of a surface 150 km wide and 7000 km long in the vicinity of the pericentre of the orbit. In the area of the apocenter, the received information was transmitted by radio to Earth. It should be noted that the radio telescope RT-70 in Yevpatoria was used as the receiving device for information on the Earth. During the time between successive surveys, Venus rotated relative to the plane of the orbit of the apparatus, which ensured the growth of the removed region. The use of complex sounding signals and the aperture synthesizing method gave a relatively high spatial resolution in the images.

The achieved resolution of 1-2 km was sufficient for the discovery of all the main geological structures characteristic only of Venus (tesserae, arachnoids, crowns, lava plains and domes, etc.), and conducting a sufficiently detailed geological and morphological analysis. More than 100 impact craters measuring from 8 to 146 km were found, the density of their location along the planet made it possible to estimate the age of the surrounding surface. An onboard radio altimeter developed by the OKB MEI measured the heights

Fig. 5. *An example of a radar image of the Maxwell mountains region.*

of the relief with an accuracy of about 30 m in height, and a topographic map of the investigated territory was constructed from them.

In **Fig. 5** shows an example of an image on the junction area of the Lakshmi plateau (lava plain on the lower left) and the Maxwell mountains with the 100-kilometer Cleopatra's patera (top right). At the center of this unusual patera (kilometer of depth), located on the eastern slope of Maxwell's mountains, a second dip of 1 km deep is clearly visible (see combined surface image and heights profile in **Fig. 6**). According to geologists, the internal failure is not the result of a meteorite impact, but the result of a collapse of the bottom of the pater. In the middle of the image in Fig. 6 there is also the highest point of the surface on Venus - a peak 11.5 km high above the middle sphere, which is higher than the highest mountain peak on Earth.

As a result of the experiment, not only the first detailed surface maps were obtained, but the main forms of the geological structure of Venus

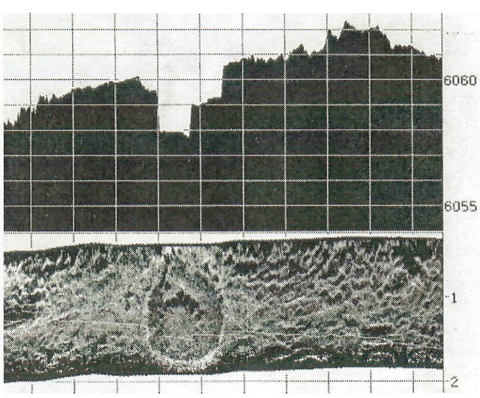

Fig. 6. *Fragment of the image band and heights profile Cleopatra's patera. The white line in the image shows the position of the height measurement track.*

were also revealed. It was established that the neighboring planet, close to the Earth in size and remoteness from the Sun, lives its geological life. For example, it does not have such an important mechanism for the formation and renewal of the earth's crust as plate tectonics, and the processes of erosion of the surface are extremely slow, which keeps the details of the relief unchanged for millions of years.

The results of radar mapping of Venus received in the Soviet Union were widely analyzed by the world scientific community and were used in the preparation of the US space experiment "Magellan" on global radar mapping of the surface of Venus, conducted 8 years after our experiment. Despite the globality of the radar images obtained by "Magellan" and an order of magnitude greater spatial resolution, the main geological discoveries on Venus were made according to the data of the Soviet apparatus Venera-15 and Venera-16.

For the work on radar mapping of Venus in 1985, the young employees of the FIRE RAS were awarded the Lenin Komsomol Prize (Zakharov A.I., Zimov V.E., Sinilo V.P., Shubin V.A.). The main ideologists and performers of the FIRE RAS were awarded in 1986 with the Lenin Prize (Alexandrov Yu.N., Sidorenko A.I.) and State Prizes in 1986 (Rzhiga ON), in 1989 (Zagorodni S.F., Zakharov A.I., Krymov A.A.).

Remote sounding of the seabed by sonar systems with complex sounding signals

The experience of radar studies of planets in IRE RAS has allowed to create a new direction of work - remote mapping of extended objects with the help of high-energy probing signals and digital methods of echo-signals coherent processing. The digital methods of synthesizing and signal processing used in the location of the Earth and planets were proposed at the end of the seventies at the FIRE RAS to create a new generation of sonar systems for seabed surface mapping. The problem of distance studies of the seabed and bottom sediments by remote methods is related to the fact that only acoustic waves propagate in water with low attenuation. In this case, the lower the frequency of oscillations, the less attenuation.

The second feature is the propagation velocity of about 1500 m/sec, which along the propagation path can vary within a few percent. And the third problem is the preservation of the coherence of the sounding signal during propagation and scattering by inhomogeneities. In this regard, the methods of radio vision, developed in the radio range, can not be used directly in an acoustic vision, additional research and technical developments are required.

The first acoustic systems - side-scan sonar, echo sounders and profilographs, developed in the 1960s, emitted tone impulse messages in the frequency range 3-500 kHz. In this case, at low frequencies, the systems provided large (several km) of sounding distances, but with a low resolution along distance because of the narrow band of the acoustic radiators - about 10% of the radiated frequency. High-frequency systems allow obtaining a high resolution up to 5 cm, but at distances up to 50-100 m. Increasing the action range of the sonar systems by increasing the radiated power is limited by cavitation on the surface of the radiator. The contradiction is removed by using complex sounding signals with a large base and correlation processing of echoes. However, the implementation of this method implies preservation of the coherence of the signal during propagation and scattering, which was negatively perceived by marine acoustics at the beginning of our work.

These were the years of discovery on the ocean floor of rich stocks of precious metal ores. The task of estimating ore reserves of ferromanganese nodules (FMN) was supposed to be solved by sonar on the power of reflected acoustic signals. For these purposes, the Shirshov Institute of Oceanology developed a side-scan sonar (SSS) of the action range of 6 kHz, using the traditional in those years tonal impulse, but the limited energy potential provided a range of up to 6 km. Since the deposits of iron manganese ores are located at depths of more than 5000 m, the efficiency of the device tested on the second voyage of the R/V "Akademik Keldysh" turned out to be low, comparable with the echo sounding measured. However, it was possible to confirm a significant increase in the level of echoes during scattering from ore sites on the bottom surface.

By this time, at the FIRE RAS under the direction of Kaevitser V.I. an experimental sample of a side-scan sonar with linear frequency modulation (LFM) of a sounding signal was created and tested in cooperation with Research and Design Institute (RDI) "Oceangeophysics" in Gelendzhik. The results of the work made it possible to modernize the long-range sonar IO RAN in a short time, increasing its energy potential by more than 100 times due to the use of the chirp signal and digital correlation processing of echoes. The device was tested on the fourth voyage of the R/V "Akademik Keldysh" in the Pacific Ocean and the sixth voyage in the Indian Ocean. The experimental sonar had a survey on one side, while at a depth of 5-7 km a 12-15 km mapping strip with a detail of about 5 m was provided. As a result, a technique was developed for detecting and measuring the productivity of the fields of FMN.

The conducted experiments confirmed the important advantages of our developments in comparison with traditional sonars using tonal sounding impulses. This increase in energy potential and resolution, increasing noise immunity and associated electrical and acoustic compatibility of various devices, increasing the ability to automate the sonar systems for various purposes.

In order to create an industrial long-range SSS, in FIRE RAS in the mid-1980s a laboratory was created, which on the task of Mingeo USSR developed and, together with the RDI "Oceangeophysics", created a towed side-scan sonar for the long-range "Okean-D", operating in the frequency range 10 kHz and providing a shooting strip for the acoustic image of the seabed at depths of up to 6 km in the 30 km band. The device was released in a small series and was widely used for exploration of ore formations on the seabed at Scientific Production Association "Yuzhmorgeologiya". The works carried out at the FIRE RAS were supported by the Main Navigation and Oceanography Directorate (GUNIO MO USSR) and the State Committee for Science and Technology of the USSR (Minnauka).

As a result, several hydroacoustic systems were developed and tested at the FIRE RAS on new principles using long-duration probing signals with intrapulse modulation and a correlation system for digital processing of echoes. These include: on-board sonar complexes of the surface survey of the topography and the bottom of the seabed - AGKPS-200 (80 kHz) and Coral-300 (80-240 kHz), towed by AGKPS-1500 (30 kHz) and AGKPS-5000 (12 kHz), high-frequency sonar "Kedr" (400 kHz, onboard and towed variants), profilographs (5-15 kHz, onboard or towed, the latter in a single module with "Kedr"). All systems use digital methods of signal generation and processing, LFM probing signals (corresponding correlation processing, coordinated and the calibration of the received signal, and in AGKPS-200/1500/5000 and "Coral"-300 and phase processing.) The complex AGKPS-1500 during the tests made it possible to detect the sunken submarine "Kursk", to determine the exact coordinates of the bow and stern parts. The systems are built according to the modular principle and, during operation, can be combined in various combinations. The navigation data comes in complexes from any satellite receiv-indicator and digital sensors for determining the spatial position. Abroad, such developments appeared only in the mid-1990s.

At present, acoustic sonar systems of coherent sounding have become the main instrument for remote measurements of the seabed relief and the structure of bottom sediments. For simultaneous measurements of the relief and obtaining of acoustic images of the bottom surface, two main, to some extent competing, class of systems have been formed: interferometric side-scan sonar and multi-beam echo sounders. If one survey sonar usually contains one antenna per board, interferometric SSS - two, three, then multi-beam echosounders are a more complex complex consisting of a much larger number of receiving elements of the order of 100 and higher. Low-frequency acoustic profilographs are used to study the subsurface structure of the seabed. This, as a rule, single-channel systems, providing continuous profiling of the soil along the route of the vessel.

The location methods of lateral survey are based on the sequential formation of data about the seabed during the movement of the vessel (**Fig. 7**).

The pulse radiated by the transmitting antenna is sequentially reflected from the individual elements of the bottom at different ranges. Reflected echoes are received by one or more receiving antennas. A cycle consisting of transmission and reception forms one implementation (one horizontal row of the acoustic image). The set of sequential realizations formed during the movement of the vessel contains information on the reflective characteristics of the seabed in the survey band and represents an acoustic image of the bottom - an analog of the optical and radar images. Such images are intended for visualization and classification of objects. The survey band is determined by the directivity pattern of the receiving elements, the energy characteristics, the shape of the seabed relief, is usually set in the depths H_0 "below itself" and is 4-10 H_0. The use of antennas with narrow directional patterns in the lateral direction provides a certain two-dimensionality of measurements in the plane of the side-view. The seabed is considered as a spatial medium with a backscattering coefficient that depends on the distance L and the angle θ between the vertical and the direction of arrival in the lateral survey plane R = R (L, θ).

The processing task is to estimate the reflection coefficient $R(u,\tau)$ from the set of measurements

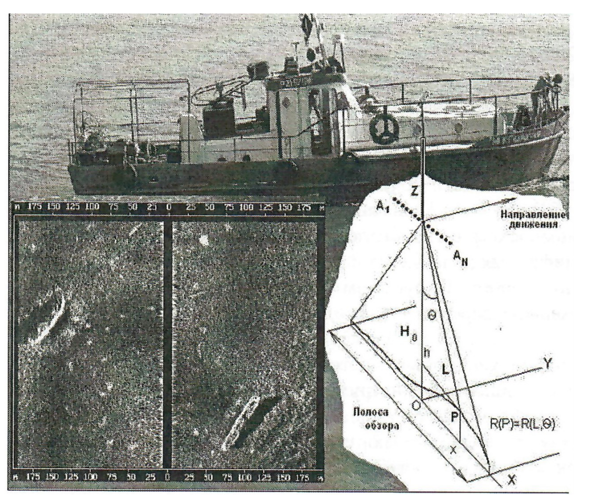

Fig. 7. *The geometry of the side scan and a fragment of the resulting acoustic image of the bottom with wrecks.*

$Z_n(t)$ and the subsequent determination of the seabed parameters. Depending on the number of receiving antennas in different systems, various methods for estimating the reflection coefficient R and the parameters of the seabed are used, as well as various restrictions on the assumed shape of the seabed relief.

The dependence of the reflection coefficient modulus R on the distance is the basis for constructing maps of the acoustic image of the bottom. The absence of angular selectivity in single-channel survey SSS is not an obstacle when using this class of systems to study relatively flat areas of the seabed, search for small objects, details of relief such as furrows, trenches, and stones. Usually the survey SSS is a single-channel sonar on the right and left sides, with independent transmit-receive antennas having a narrow (about 1°) directional pattern along the carrier line and, as a rule, a digital system for the formation, processing and recording of signals. The type of radiated pulses are tonal and chirp sending. Operating frequencies from 10 to 500 kHz. In the tonal mode, the pulse duration is a fraction of milliseconds, in the LFM mode it reaches several seconds.

Interferometric methods are used to calculate the depths in the survey strip. For analysis of the bottom relief in the survey strip, interferometric SSS complex includes additional receiving channels with a set of antennas in the vertical plane. Signal processing in interferometric SSS is based on the calculation of the arrival angle and is performed by measuring the phase Ψ of the complex-conjugate product of a pair of samples of two channels (an interferometer).

One of the single-channel instruments, where chirp signals are widely used to increase the energy potential, are acoustic linear profilographs. The long experience of using a low-frequency profiler with chirp sounding signals, developed at the IRE RAS, confirmed its high operational capabilities and allowed to reveal some features of the interpretation of the results obtained. The working frequency of the profilograph is 5 kHz, the frequency band is about 4 kHz, the radiated power is about 3 kW. The profilograph includes: a nine-element antenna

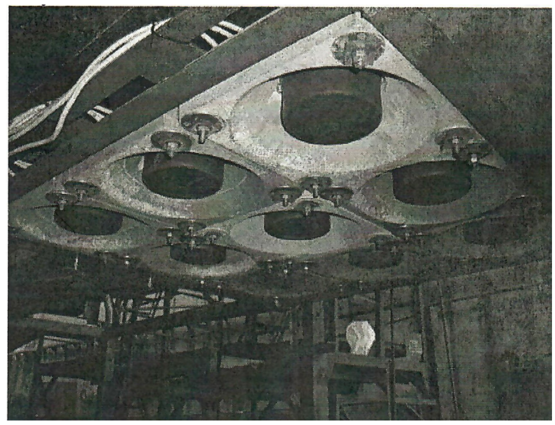

Fig. 8. *Acoustic antenna echo sounder profilograph.*

system (**Fig. 8**), an electronic system for generating sounding parcels (a digital synthesizer), a power emitter, and an input interface for information in the PC. The device contains a digital system for collecting, displaying and processing data. It is designed for examining the bottom relief and bottom sediments at depths from 20 m to 3000 m. Data collection programs provide coherent input of echo signals, input of navigation information from GPS sensors and the spatial position of the vessel, display of information in real time and archiving of the received data.

In **Fig. 9** shows a fragment of profiling the seabed in the ice conditions of the Chukchi Sea. The depth is about 70 meters. The result of the profiling shows the high noise immunity of the device, which made it possible to realize a high resolution of bottom sediments. The above fragment is also interesting in that a hollow is clearly visible, filled with sediments. This kind could well have been the bed of the ancient river after the descent of the land and the onset of the sea. High energy potential with the use of chirp sounding

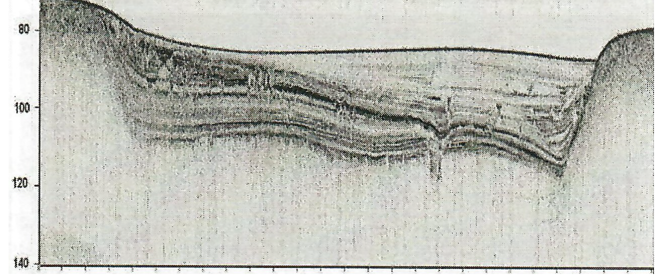

Fig. 9. *A fragment of the profiling of the seabed in the Chukchi Sea.*

signals allows the profiling of bottom sediments at large depths of the sea. In **Fig. 10** shows the result of profiling from a ship in the Sea of Japan at depths ranging from 1200 m to 1.400 m. The area is characterized by a changing terrain with a thick layer of plastic deposits. The first reflection corresponds to the depth and is confirmed by the results of the measurement by single-beam and multi-beam echo sounders. The horizontal distance is the distance traveled in meters, and the vertical axis is the depth in meters. As can be seen in the figure, the profiling depth is 100 and more meters, the nature of the deposits on the slopes has a layered structure characteristic of silty clays. In the hollow, the profile of the profilogram is more uniform in depth, which is characteristic of sandy loam.

Long-term research of IRE RAS staff in the development and application of new methods of synthesis and signal processing for the solution of location problems is widely used at present in remote sensing of the Earth from space, as well as other scientific and technical applications.

From a brochure by Ryzhga Oleg Nikolayevich [2].

As the scientific leader of the space experiment on radar mapping of the planet Venus, the author remembers the stages of the creation of the unique space complex "Venus-15" and "Venus-16". This was an example of the creative cooperation of industrial enterprises and scientific institutions. The work was conducted by an interdepartmental team, under the leadership of the Vice President of the Academy of Sciences of the USSR, Academician V.A. Kotelnikov, where everyone did their work. The Academy of Sciences developed a methodology for the experiment and carried out data processing. The OKB MEI of the Ministry of Higher Education developed the radar system equipment, and the cooperation of industrial enterprises created the spacecraft and ensured its management.

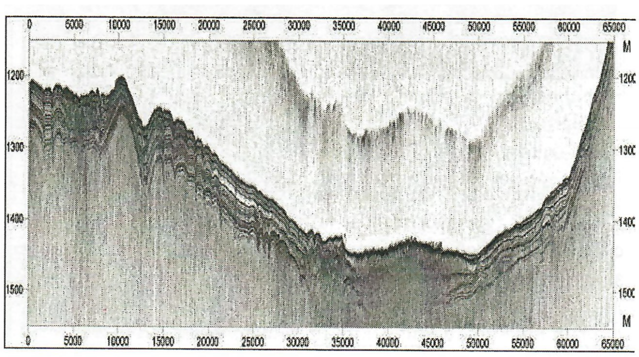

Fig. 10. *Fragment profiling the seabed in the Japan Sea.*

The idea of the experiment arose in the IRE of USSR Academy of Sciences in the autumn of 1972. It was directly developed by Yu.N. Alexandrov, G.M. Petrov and the author. In November 1975, the author reported the idea of the experiment to the President of the USSR Academy of Sciences, Academician M.V. Keldysh. Shortly thereafter, an experiment on radar mapping of Venus was included in the program of space research. The design of the radar system equipment was undertaken by the OKB MEI (director A.F. Bogomolov). In OKB MEI was such a man G.A. Sokolov, who immediately imbued with the task and set the goal of his life to carry out the experiment. Through him, a connection was made between the IRE of USSR Academy of Sciences and the OKB MEI. He enjoyed great authority, and everything that we agreed with him was put into practice.

The equipment, including antennas, was first tested autonomously at the OKB MEI Medvezhye Ozera polygon. This responsible work carried out guided by GA. Podoprigora. Then, during the year preceding the flight, tests were carried out together with data transmission equipment to the Earth and processing equipment. Signals reproducing reflections from point targets were fed to the input of the radar system receivers. Test equipment, developed under the leadership of M.N. Meshkov, allowed to automatically change the level of signals, their lag and the frequency by a certain program. Magnetic tapes with the recording of signals that passed through the receiving and recording equipment of the radar system were transmitted for processing and analysis at the IRE. These tests made it possible to identify 2-3 serious defects, after the elimination of which the equipment worked impeccably. Great work in the organization of tests was enclosed by V.G. Timonin.

To test the operation of the radar in conjunction with the new radio link, the tests were continued in flight. The information recorded in advance on the Earth on magnetic storage devices was reproduced. The transmitter of the radar was switched on, its antennas were alternately direct to Earth, and the power of the sounding signal, its frequency and the modulation structure were measured on the Medvezhye Ozera poligon. Slowly rotating the device according to the program, we checked the shape of the directivity diagram.

Among IRE of USSR Academy of Sciences staff engaged in radar observations of planets in the Center for Long-Distance Space Communication, it has become a tradition to create with your own hands complex equipment for fundamental research. Thus, a set of equipment was developed for processing radar information of the Venera-15 and Venus-16 spacecraft and a package of mathematical programs was developed. In the creation of the Center and in the organization of information processing, showed great perseverance his head A.I. Sidorenko.

The development of a processor for accelerated execution of the Fourier transform on the reflected signals was started at the IRE of USSR Academy of Sciences under the direction of Yu.N. Alexandrov. Then this work was carried to the Institute of Electronic Control Machines of the Ministry of Instrument Engineering, where the technical manager was B.Ya. Feldman, and the scientific leadership was carried out by Yu.N. Alexandrov. A specialized Fourier processor (SPF-SM), developed specifically for the processing of reflected signals during the survey of Venus using Venera-15 and Venera-16 spacecraft, is currently produced by the industry for research and economic purposes.

The methodology, algorithms and programs of information processing were created entirely in IRE of USSR Academy of Sciences. For a year and a half before the experiment began, it turned out that programs written in the standard Fortran language work too slowly. For example, it turned out that one of the 6 main programs for processing information received in one shooting session (the program for building a radar image strip) requires 26 hours of computer time. Since it is impossible to make the machine faster, it was necessary to apply "small tricks", such as the switch to the language of assembler, the use of integer arithmetic, the decomposition of complex functions into finite series, interpolation. All, taken together, reduced the counting time by about 10 times.

Mathematical programs were supposed to provide complete processing of incoming information, including the construction of radar images and the measurement of the high-altitude relief of the surface of Venus. In addition to the speed of the calculations, they were required to be self-dependent in making decisions in case of distortions of information. During the processing, the characteristic values of the parameters of the reflected signals, such as power, frequency, delay, were to be calculated in order to promptly judge the operation of the radar and the processing progress. The complexity of programs is judged by the number of elementary operations into which the program falls. Some programs had up to 4000 such operations, and their total number in all programs reached 50.000!

In May 1983, several months before the start of the experiment for various reasons several people from the FIRE staff, who were preparing algorithms and programs, were dismissed. In the situation that emerged, when those who had been taught "little tricks" for several years were lost, no one could help. There was only one way out - to work more intensively, with maximum dedication. Some worked during their holidays, on weekends. In the last two months all worked from 8 am to 8 pm, but no more to regain strength.

As a result, all major programs were debugged to the time of the receipt of magnetic tapes with the recording of the information of the first shooting session. Now we were at the last stage of a long chain, which began with the creation of a radar and a spacecraft. From our work depended on how successfully the work of many thousands of people participating in the experiment would end. This was the main stimulus in the work.

An experiment of such complexity was carried out for the first time, and when in early June 1983 spacecraft was started toward Venus, there were many fears in its success. Will the equipment work? Will the atmosphere of Venus to distort the image? Do we correctly understand how radio waves are reflected by surface of Venus? After all, after the first low-quality radar images obtained in the US, some thought that Venus is as smooth as a billiard ball, and thereat there's nothing to radiolocate!

And then came the landmark days. On October 16, 1983, the Venera-15 spacecraft made the first radar survey of the planet Venus. On October 18, magnetic tapes with the recording of the information of the first shooting session by an early train were delivered to Moscow by E.P. Molotov, who led the development of reception equipment and noise-resistant registration of spacecraft information. On October 20, about 15 h, a fragment of the first image of the surface of Venus appeared on the display screen (**Fig. 11**). Everything worked perfectly.

When the regular daily shooting of Venus began, the backlog in processing began to grow. Then in late 1983 it was decided to switch to two-shift work, including Saturday and Sunday. All the employees involved in the processing were divided into 3 brigades. One of them worked during the day, the other in the evening, and the third on these days rested. In the creation of a complex set

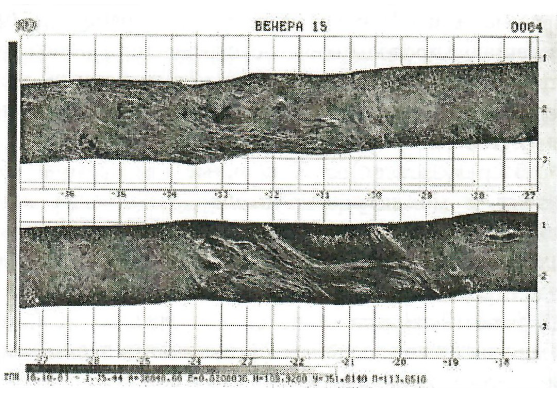

Fig. 11. *Part of the strip of the image of the surface of Venus, obtained in the first session of shooting on October 16, 1983 with the Venera-15 apparatus. Horizontally plotted in degrees orbital longitude, measured from the pericenter of the orbit, the orbital latitude, measured from the plane of the orbit, is plotted vertically. The spacecraft moved from left to right, its route passed above the band. Regular displacements of the strip relative to the orbital plane are associated with a change in the height of the apparatus moving in a highly elongated elliptical orbit, irregular - caused by local relief.*

of programs, the development of the equipment of the Center and the processing of information, a large role belonged to young researchers A.I. Zakharov, V.E. Zimov, A.P. Krivtsov, I.L. Kucheryavenkova, N.V. Rodionova, V.P. Sinilo and V.A. Shubin.

Every week, 100-150 photographs with images and profiles of the surface heights of Venus were transmitted to the GEOKHI AS of the USSR and Central Research Institute of Geodesy, Aerial Photography and Cartography (CNIIGAIK). To speed up the issue of maps, it was decided to build maps using digital methods using the equipment of the Center. By the middle of 1987 all 27 maps for Venus territory in four variants were constructed. They were transmitted (on magnetic tapes) to CNIIGAIK for preparation to the publication. Two maps of them were published in a small print run in 1986. In November 1987, A.A. Krymov and O.S. Shamparova completed the construction of a complete map of Venus surface, which included all the material obtained with the help of spacecraft "Venus-15" and "Venus-16".

The nomenclature of details of the surface of Venus for published maps was approved by the XIX General Assembly of the International Astronomical Union, held in November 1985 in Delhi. In the preparation of the nomenclature took part Soviet specialists A.T. Bazilevsky, G.A. Bourba, M.Ya. Marov, Yu.S. Tyuflin, etc. The nomenclature contains over 250 items. It is widely represented by Russian women's names, women's names of the peoples of the USSR and the socialist countries. On the maps of Venus, we meet the names of famous women scientists, poetesses, actresses, public figures. So, on the first published map "Plateau Lakshmi" we see the craters of the name of Ekaterina Dashkova, Anna Akhmatova, Polina Osipenko, Eugénie Cotton. The publication of maps of Venus continued in 1987.

The results of radar survey of Venus with the help of spacecraft "Venus-15" and "Venus-16" aroused great interest not only in the Soviet Union. At preparing to repeat the radar studies of Venus from the orbit of an artificial satellite on the project "Magellan", American scientists asked the Academy of Sciences of the USSR to transmit the materials of the radar survey of Venus. Transmission of magnetic tapes with images and elevation profiles of Venus' surface is carried out regularly through the "Intercosmos" council. In turn, we received all the data from the radar survey of Venus with the help of the Pioneer-Venus spacecraft, as well as detailed maps of Mars, based on the results of television surveys using the Mariner 9 and Viking spacecraft.

The flight of the spacecraft "Venus-15" and "Venus-16" opened a new era in the study of this planet. In an address by the General Secretary of the CPSU Central Committee, M.S. Gorbachev to members of the congress delegation of the Nobel Peace Prize laureates in November 1985, this experiment was put on a par with the launch of the first satellite, the first manned space flight and landing on the moon, the landing of automatic stations on Venus and Mars. The map of Venus was called great magnificent!

SMOLYANINOV'S GROUP

The main theme of the Smolyaninov Vyacheslav Mikhailovich's group was the interference-stability transmission and reception of signals in various environments.

Currently, there is an intensive development of various digital data transmission systems. All systems use wireless channels for data transmission, in which the interferences of different physical nature acts on the transmitted signal. This leads to the fact that the received data with a high probability will contain errors. At the same time, for many practical applications only a very small fraction of the errors in the discrete data being processed are allowed. As a result, the problem arises of ensuring the reliable transmission of digital information through channels with noises.

The most important contribution to the solution of this problem is made by the interference-stability coding theory. On its basis, methods of error protection are developed, based on the use of interference-stability codes. The use of these codes makes it possible to obtain the energy gain of the coding, which characterizes the degree of possible reduction in transmission power when encoding as compared with the absence of coding, if the reliability of the transmission in both cases is the same. This gain can be used to improve the parameters and characteristics of many important properties of data transmission systems, for example, to reduce the size of very expensive antennas, increase the communication range, increase the data transfer rate, reduce the required transmitter power, etc

The development of noise-immune encoding has been going on for half a century. If at first it relied on algebraic methods, later it was replaced by the methods of majority coding and, as a more efficient, exhaustive algorithm of Viterbi. The disadvantage of the latter is the exponential increase in complexity for long codes. The next stage was cascade codes based on convolutional codes and Reed-Solomon codes. Cascade codes provided higher noise immunity characteristics with less decoding complexity, but were far from theoretically possible limits (Shannon's theorem for channels).

The turbo codes, discovered in 1993, made it possible to almost completely use the capacity of digital communication channels. They approached codes with speeds close to the bandwidth of the channels, which is especially important nowadays with increasing communication range.

SAVICH'S GROUP

The main direction of the Savich group's work is connected with the study of the ionospheres of the planets of Venus and Mars.

Detection of the nocturnal ionosphere of Mars [3]

During the passage of the Mars-4 station near the planet Mars on 10.2.1974, the atmosphere of the planet was radarized by two coherent monochromatic signals in a decimeter ($\lambda \approx 32$ cm) and centimeter ($\lambda \approx 8$ cm) wavelength bands with a frequency ratio of 4 , which were emitted from the station and were received on Earth.

The problem consisted in detecting a plasma over the surface of Mars unenlightened by the Sun and determining the profile of the electron concentration in the nocturnal ionosphere. At the ground receiving point, each signal was separately received and processed simultaneously by two independent systems of a dispersion interferometer. Both treatment systems produced identical results. According to the data obtained, under the assumption of the spherical symmetry of the ionosphere, the altitude distribution profile of the electron concentration in the night ionosphere of Mars was calculated (**Fig. 12**). The graph clearly shows the main ionization maximum at an altitude of about 110 km above the surface with a particle concentration of $N_m \approx 4.6 \cdot 10^3$ cm^{-3} and a half-thickness of the layer of the order of 35 km. The measurement error in the region of the maximum is of the order of 5%.

Multiple single-frequency transmission of the night ionosphere of Mars was carried out using the Mariner 9 station. However, the measurement errors inherent in the single-frequency method in the incoherent mode when the on-board transmitter is operating from the quartz generator do not allow us to detect the nocturnal ionosphere of Mars without a priori information.

Measurements of two-frequency radio luminosity allowed obtaining a reliable distribution of electron concentration in the night ionosphere of Mars and determining its main characteristics: the height of the main maximum and the value of the electron concentration.

Investigation of the ionosphere of Venus by the method of two-frequency radio transmission using Venus-9, 10.

Before the flight of spacecraft to Venus, information about its atmosphere was limited, mainly, to ground and radio-astronomical observations. The

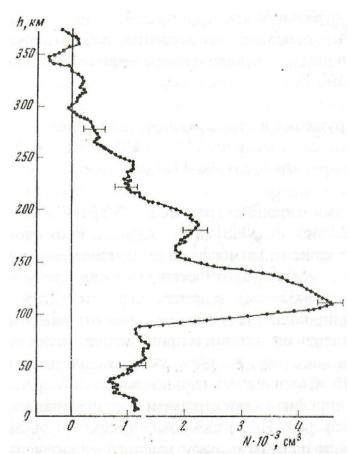

Fig. 12. *The distribution of electron concentration in height in the night ionosphere of Mars.*

estimation of Venus ionospheric parameters was based on analogies with the terrestrial and had a hypothetical character.

The first experimental data on the parameters of the Venus ionosphere were obtained by the radiophysical method during the passage of the "Mariner-5" apparatus in 1967. Two-frequency radiolocation was carried out on the "Earth-to-space" communication request line by two coherent signals of 49.8 MHz and 423.3 MHz, and the results of measurements of the reduced Doppler frequency difference, as well as the signal amplitudes, brought the first information on the electron concentration $N(h)$ distribution in the daytime and the nocturnal ionosphere of Venus. The main conclusions of this work are: 1. The daytime ionosphere has a main ionization maximum at an altitude of ~ 140 km with a particle concentration $N_m \sim 5.5 \cdot 10^5$ cm^{-3} and a secondary maximumat ~130 km with $N_m \sim 2 \cdot 10^5$ cm^{-3}. 2. The night ionosphere has a main ionization maximum at an altitude of ~ 142 km with $N_m \sim 2 \cdot 10^4$ cm^{-3}.

In 1974, during the flight of the Mariner-10 apparatus near Venus, a two-frequency radio sounding of the day and night ionosphere of Venus was again carried out, but at higher frequencies (~ 2295 MHz and ~ 8415 MHz) via the Earth-to-space communication line. As a result, it was shown that: 1) The daytime ionosphere has a principal ionization maximum $N_m \sim 3 \cdot 10^5$ cm^{-3} at an altitude of ~ 145 km. 2) The night ionosphere has two ionization maxima.

To clarify the structure of the day and night ionosphere of Venus, systematic experimental data were needed on the altitude profiles of the electron concentration, which could be obtained with the help of a long-lived satellite of the planet. Therefore, when creating satellites "Venera-9, 10", it was envisaged to perform a multiple radio sounding of the ionosphere and the atmosphere of Venus by the method of a dispersion interferometer.

In October 1975 of the automatic interplanetary stations "Venus-9" and "Venus-10" in the orbits of artificial satellites of Venus opened for the first time the possibilities for carrying out a multiple two-frequency radio sounding of the atmosphere of Venus. At both stations, in addition to a standard transmitter of a decimeter (32 cm) range, a coherent centimeter radio transmitter (8 cm) designed and manufactured at the Special Design Office (SKB) IRE of USSR Academy of Sciences, was setting. As a result, during the period from 24.10.76 to 7.12.76, 22 sessions of radio transmission of the night and 13-day ionosphere of Venus were successfully carried out using the dispersion interferometer.

It is established that in the night ionosphere of Venus, as a rule, the altitude distribution of ionization has two maxima (16 cases) and very rarely one (2 cases). The electron concentration in the upper maximum of the night ionosphere of Venus lies within $N_m \sim(2.9\pm16.0)\cdot10^3$ cm^{-3}, and its height in most cases is ~140±5 km. The lower maximum of the concentration has the parameters $N_m \sim(1.8\pm11.2)\cdot10^3$ cm^{-3} and a height of 120±13 km. It was shown for the first time that the electron concentration distribution in the Venus night ionosphere is characterized by considerable in times variability both in the density of ionized layers and in the shape of the profile.

In the daytime ionosphere of Venus (zenith angles from 10° to 87°), the electron concentration at the main maximum, located at altitudes 140±166 km, lies within $N_m \sim(1.25\pm4.4)\cdot10^5$ cm^{-3}. In addition, the existence of a lower ionized layer with a maximum concentration of $N_m\sim(4.6\pm13)\cdot10^4$ cm^{-3} at altitudes of 125±138 km and an additional upper layer at altitudes of 180±210 km, which is observed at low zenith angles of the Sun at zenith angles ≥74°.

MAKSIMOV'S GROUP

One of the directions of the work of the staff of Maximov Alexander Stepanovich was the creation and research of semiconductor analogues of inductance. The fact is that in devices that work well at low frequencies, when tuning them to infra-low frequencies, a number of specific features begin to appear: an increase in noise, a decrease in the Q-factor of reactive elements, an increase in the dimensions and weight. The problem of reducing the dimensions and weight of reactive elements for infra-low frequencies is particularly acute both in microminiaturization of equipment and in the creation of super-powerful reactive elements.

The IRE of USSR Academy of Sciences proposed new principles for the creation of miniature elements with a large equivalent inductance ($10^3 \div 10^6$ H) and, accordingly, with a large time constant when using both thin-film and solid-state technology. The principle of operation of these devices is based on the phenomena of capture and release of charge carriers by slow surface states. It has been shown that the use of solid-state technology to create inductive elements is more promising. On the basis of *p-n-* and *p-n-p-n-* germanium and silicon structures with a specially treated surface, the possibility of their reproducible production, the stability of the parameters in time, and practical implementation in a number of radio engineering devices was demonstrated.

CONCLUSION

In conclusion, we list of all workers of the 127 laboratory, who worked in it at one time or another and who made their contribution to glory and pride of the Institute of Radioengineering and Electronics of Russian Academy of Sciences: Abramova L.V., Azarov V.V., Aleksandrov Yu.N., Baraboshkin S.M., Belitsky M.R., Berezina S.I., Burkov V.D., Vasiliev M.B., Vyshlov A.S., Vyshlova L.V., Gavrik A.L., Gatilova M., Gerasimov S.V., Golovkov V.K., Dolotov S.A., Dubrovin V.M., Zaitsev A.L., Zaitseva O.S., Zakharov A.I., Zimov V.E., Zyablov A.B., Ivanov V.A., Kaevitser A.V., Kaevitser V.I., Kalinin A.V., Kovtun V.V., Kopnina T.F., Koroleva T.S., Krivtsov A.P., Krylov G.A., Krymov A.A., Kuznetsov A.A., Kuznetsov B.I., Kuznetsov O.O., Kuznetsova L.V., Kukushkin A.S., Kucheryavenkova I.L., Kushchenko E.F., Labutin M.V., Maksimov A.S., Margachev V.V., Metelskaya Z.T., Moiseenko V.Yu., Nazarenko E.G., Nazarov L.E., Nekrasov A.Ya., Pervushin S.A., Perfilova N.I., Petrov G.M., Prokofiev I.V., Prokuronov V.V., Razumnyi E.A., Rzhiga O.N., Rodionova N.V., Romanova G.V., Ryabova N.V., Savich N.A., Salnikov V.P., Samovol V.A., Samoznayev L.N., Semaev V.N., Semiletnikov V.V., Sidorenko A.I., Sinilo V.P., Sknarya A.V., Smolyaninov V.M., Sorokin V.K., Sorochinsky M.V., Suhoverhova V.Z., Turusin I.V., Feofanov Yu.V., Khasyanov A.F., Khlebnikov M.N., Tsarfin D.L., Chalikov S.F., Chelyshev N., Chernov P.V., Churkin V.I. Shatalova L.I., Shubin V.A., Shumilova L.V., Yurkova V.I.

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