

Scientific session of the Division of Physical Sciences of the Russian Academy of Sciences, in commemoration of Academician Vladimir Aleksandrovich Kotel'nikov (22 February 2006)

The scientific session of the Division of Physical Sciences of the Russian Academy of Sciences (RAS), devoted to the memory of Academician Vladimir Aleksandrovich Kotel'nikov, was held on February 22, 2006 in the conference hall of the P N Lebedev Physics Institute, RAS. The following reports were presented at the session:

(1) **Gulyaev Yu V** (Institute of Radioengineering and Electronics, RAS) “Vladimir Aleksandrovich Kotel'nikov (Opening address)”;

(2) **Kotel'nikova N V** “Vladimir Aleksandrovich Kotel'nikov: the life's journey of a scientist”;

(3) **Armand N A** (Institute of Radioengineering and Electronics, RAS) “V A Kotel'nikov and his role in the development of radiophysics and radio engineering”;

(4) **Sachkov V N** (Academy of Cryptography of the Russian Federation) “V A Kotel'nikov and encrypted communications in our country”;

(5) **Molotov S N** (Institute of Solid State Physics, RAS, Chernogolovka, Moscow region; Academy of Cryptography of the Russian Federation; M V Lomonosov Moscow State University Department of Computational Mathematics and Cybernetics) “Quantum cryptography and V A Kotel'nikov's one-time key and sampling theorems”;

(6) **Chertok B E** (Russian Space Corporation ‘Energiya’) “V A Kotel'nikov and his role in the development of space radio electronics in our country”;

(7) **Pobedonostsev K A** (Special Design Bureau of the Moscow Power Engineering Institute) “V A Kotel'nikov as outstanding engineer and his role in the coming of age of the Special Design Bureau of the Moscow Power Engineering Institute”.

An abridge version of the first six reports is given below.



Vladimir Aleksandrovich Kotel'nikov
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Vladimir Aleksandrovich Kotel'nikov (Opening address)

Yu V Gulyaev

It is a year ago that Academician Vladimir Aleksandrovich Kotel'nikov, an outstanding scientist in radio engineering, radiophysics, and informatics, passed away. His name is inseparable from an entire era in the development of these

crucially important fields of science and technology, beginning with communication systems and computers and ending with large-scale studies of space. The Kotel'nikov (sampling) theorem is ‘engraved into the alphabet’ of the education of any engineer in the fields of communications and informatics; the theory of potential noise immunity elaborated by Kotel'nikov lies at the foundation of all modern communications systems, radar, radionavigation, and remote control. His work in radar astronomy rightfully belongs to the science and technology hall of fame.

I was exceptionally lucky in being able to work with Vladimir Aleksandrovich for more than 45 years. Allow me to briefly outline the main events in the life of this illustrious person.

Kotel'nikov, a brilliant scientist, graduated from the Moscow Power Engineering Institute (MEI in Russ. abbr.) in 1930, having majored as a radio engineer, and began his

career as an engineer at the Communications Research Institute of the Red Army, then enrolled as a postgraduate at MEI (1931). After graduation (1933) he moved to the Research Institute of the People's Commissariat of Communications. The data communication facilities at the time were quite crude and the problem of noise resistance in wired communication systems demanded that a drastic solution be rapidly found. In the initial phase of his research career, Kotel'nikov searched to improve the efficiency of the communication facilities. In 1933, he wrote and published a fundamental work "On the transmission capacity of 'ether' and wire in electric communications", in which he formulated for the first time the theorem (known in radio engineering as the Kotel'nikov theorem, or sampling theorem) on exact representation of a function with a band-limited spectrum by a set of its readings taken at separately selected points. It is important to stress here that later this theorem formed the basis of digital processing and transmission of signals and of the creation of digital computers, and is widely used to analyze a number of phenomena in radiophysics and optics. Kotel'nikov was the first to realize the profound importance of the technological consequences implied by this theorem and in fact imparted a profound physical meaning to it.

During the Great Patriotic war (1941–1945), Kotel'nikov designed specialized communication equipment and was twice awarded the State Prize for this work (in 1943 and 1946). In 1947, he submitted and defended his doctoral dissertation in which he presented the theory of potential noise immunity and established for the first time the threshold constraints on the sensitivity of radio receivers imposed by noise, and also the theoretical foundations of extracting useful signals from background noise. His monograph *The Theory of Potential Noise Immunity* became widely known and was published both in this country and abroad. The theory of noise immunity still remains one of the main tools the world over for designing communication radar and remote control systems, as well as other radio engineering facilities. These achievements in their totality brought Kotel'nikov world renown.

Kotel'nikov's election to full membership in the USSR Academy of Sciences and his appointment to the post of Director of the Institute of Radioengineering and Electronics (IRE) of the RAS started a new phase in which his talents as an outstanding scientist, science organizer, and science manager of a large research body could manifest their brilliance. He directed all his energy and talent at searching for interesting and promising approaches to solving various scientific problems and to formulating and advancing fundamental research: in long-distance tropospheric propagation of ultrashort radiowaves, in waveguide communication systems, in extracting weak signals from background noise, in processing and transmission of information, and in the generation, amplification, and reception of signals in the centimetric and decimetric wave bands. He put great organizational effort into incorporating into the Institute the best and most talented distinguished physicists, together with the groups that crystallized around them.

Today we can only marvel at Kotel'nikov's sagacity and intuition, which we see in his formulation of new fundamental challenges to current-day radio electronics. For instance, it was under his guidance and with his close participation that progress was achieved in the following fields: moving into new radio-frequency bands (millimetric, submillimetric, optical, and ultralow-frequency wave bands); statistical

radiophysics; remote sounding of the atmosphere and of terrestrial and planetary surfaces; that new avenues of research were created: planetary radar and radar investigation of planets using space probes, and work on waveguide and fiberglass broadband communication systems was pioneered. [Detailed results of these studies can be found in the review paper by V A Kotel'nikov and K I Palatov: "Radioengineering and electronics research at the IRE of the USSR Academy of Sciences from 1953 to 1978", in *Problems in Contemporary Radioengineering and Electronics* (Ed. by V A Kotel'nikov) (1980).] Kotel'nikov actively supported investigations into the theoretical foundations of microelectronics, optoelectronics, superconducting electronics, semiconductor electronics, acoustoelectronics, magneto-electronics, crystal physics, and the automatization of scientific research; he paid special attention to these programs. His contribution to each of these fields did not stop with science management — he always took a very active part in solving the most difficult problems. As Chairman of the Interkosmos Board for many years, he was a permanent science supervisor of many programs on radar investigation of planets in the Solar system and deep space. Numerous results of this research served as a basis for designing various radio devices and systems by factories and plants of the former Ministries of Radio Industry, Electronic Industry, Electrotechnical Industry, Defense Industry, and Communication Facilities Industry, as well as by factories and plants of the Ministry of Communications and some others.

Owing to the efforts of Kotel'nikov and his students and colleagues, the relative accuracy of measuring distances in radar astronomy was improved to 10^{-8} of the quantity measured. Consequently, we know the size of the Solar system much better now and deeper understand the factors influencing the trajectories of planets. On Kotel'nikov's initiative, the antenna and transmitter of the Long-Range Cosmic Communications Center were used for planetary radar, which made it possible to receive weak reflected signals from Venus, Mercury, Mars, and Jupiter, as well as signals reflected by Halley's Comet and some of the larger asteroids.

Kotel'nikov actively supported the program of interplanetary flights of space vehicles. Together with his colleagues, he pioneered in improving the accuracy of the astronomical unit, which was necessary to achieve the required accuracy of control over space vehicles. After the completion of a number of fundamental research projects (1984–1992), the cartography of the northern part of the planet Venus was carried out, above 30° north latitude, for the first time ever, over an area of about 115 mln km² at a resolution of about 1–2 km, using automatic interplanetary stations 'Venera-15' and 'Venera-16', while the atmosphere and ionosphere of Venus were also studied in the framework of the 'Vega' program. The accuracy of the relativistic theory of planetary motion was investigated and a program to study solar wind, near-terrestrial space, and the terrestrial surface was started using space probes and round-the-earth satellites.

The election of Kotel'nikov as Honorary Member of the International Institute of Electrical and Electronics Engineers (IEEE), member of the International Union of Radio Science, member of the academies of sciences of Poland, Czechoslovakia, Mongolia, Bulgaria, and Germany (former GDR) is evidence of the international recognition of his scientific standing.

For his outstanding services to the progress of radio engineering, electronics, and radio astronomy of the mother-

land, as well as for scoring big successes in training new generations of scientists and for his personal achievements, Kotel'nikov was twice awarded the title of a Hero of Socialist Labor, received the Badge of Honor, two Orders of the Red Banner of Labor, six Orders of Lenin, the Order of the October Revolution, the Order of Honor, the Second Class Order of Merit for the Fatherland, and numerous medals. On his 95th birthday he received the Russian Federation First Class Order of Merit for the Fatherland.

He was also awarded, jointly with his corps of co-workers, two State Prizes and one Lenin Prize.

In 1993, the International Institute of Electrical and Electronics Engineers awarded Vladimir Aleksandrovich Kotel'nikov with the Hernand and Sosthenes Behn Prize from the IEEE "for fundamental contribution to communication theory and practice, and pioneering research and leadership in radar astronomy," and with the Alexander Graham Bell Medal "for fundamental contribution to signal theory" in 2000. The Eduard Rhein Foundation (ERF, Germany) awarded in 1999 Kotel'nikov with the Eduard Rhein Basic Research Prize for the first theoretically exact formulation of the sampling theory. Kotel'nikov's tremendous creative contribution to fundamental studies of communications theory and radar investigations of planets was marked in 1974 by the A S Popov Gold Medal of the USSR Academy of Sciences.

The Presidium of the USSR Academy of Sciences awarded Kotel'nikov with the highest distinctions of the Academy — the M V Lomonosov Large Gold Medal, and the M V Keldysh Gold Medal.

Vladimir Aleksandrovich was a quiet, even-tempered man, who treated everyone, from a factory worker to an academician, a general or a government minister, with equal kind-hearted attention. In his enormous erudition, obligatoriness, and desire to get to the bottom of each issue — whether it was a problem in science, or in the Institute's internal politics, or a matter connected with the Presidium of the Academy of Sciences, or just a complication in the life of a concrete collaborator — Kotel'nikov was invariably attentive to each individual and tried to help in any way open to him. He created in the IRE a rather specific, very friendly atmosphere. We practically never suffered from squabbles among the staff.

We, the people who worked at the IRE RAS, deeply respected and loved Vladimir Aleksandrovich. We consider it our obligation and moral duty to sustain the creative atmosphere that he built up in our Institute and to try and follow his principles in our daily lives.