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Commemoration of the centenary of the birth of Academician V A Kotel'nikov

(Joint scientific session of the Physical Sciences Division of the Russian Academy of Sciences and the Division of Nanotechnologies and Information Technologies of the Russian Academy of Sciences, 17 September 2008)

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The joint scientific session of the Physical Sciences Division of the Russian Academy of Sciences and the Division of Nanotechnologies and Information Technologies of the Russian Academy of Sciences (RAS), devoted to the centenary of the birth* of Academician V A Kotel'nikov, was held on September 17, 2008 in the Rotunda Hall of RAS. The following reports were presented at the session:

(1) **Gulyaev Yu V** (Kotel'nikov Institute of Radioengineering and Electronics, RAS, Moscow) "Creative career of Vladimir Aleksandrovich Kotel'nikov (opening address)";

(2) **Pustovoit V I** (Scientific and Technical Center of Unique Instrument Making, RAS, Moscow) "Acousto-optics: modern status and prospects";

(3) **Zelenyi L M, Armand N A** (Space Research Institute, RAS, Moscow) "Vladimir Aleksandrovich Kotel'nikov and Solar System studies";

(4) **Mikaelyan A L** (Research Institute of Systems Studies, RAS, Moscow) "Research on waveguide techniques for communication systems";

(5) **Kardashev N S** (Astrocosmic Center, P N Lebedev Physical Institute, RAS, Moscow) "V A Kotel'nikov and terrestrial and space radio astronomy";

(6) **Kuznetsov N A, Sinitsyn I N** (Kotel'nikov Institute of Radioengineering and Electronics, RAS, Moscow) "Development of Kotel'nikov's sampling theorem";

(7) **Kaevitser V I, Razmanov V M** (Fryazino Branch of the Kotel'nikov Institute of Radioengineering and Electronics, RAS, Fryazino, Moscow region) "Remote sensing of sea bottom by hydroacoustic systems with complex signals";

(8) **Matyukhin V G** (Information Technologies Federal Agency, Moscow) "Information protection in an electronic State".

* Untill recently, all documents had indicated that V A Kotel'nikov was born on September 6, 1908. According to the archival document "Extract from the registration book of Varvarinskaya church in the city of Kazan' for newborn children in 1908", discovered by N V Kotel'nikova (the daughter of V A Kotel'nikov) in 2008, the day of Kotel'nikov's birth falls on August 28, 1908 (Julian calendar) or on September 10, 1908 (Gregorian calender). (*Editor's note*.)

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Vladimir Aleksandrovich Kotel'nikov
(06.09.1908 – 11.02.2005)

An abridge version of Yu V Gulyaev's opening address and reports 3, 6, and 7 is given below.

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Creative career of Vladimir Aleksandrovich Kotel'nikov (opening address)

Yu V Gulyaev

The Russian scientific community celebrated in autumn 2008 the hundredth anniversary of the birth of Academician

Vladimir Aleksandrovich Kotel'nikov — an outstanding scientist, engineer, teacher, and science administrator, one of the founders of radiophysics, informatics, radio astronomy, and cryptography in this country. His pioneering work was seminal for the burgeoning of new fields in science and technology: informatics and digital methods of signal transmission, statistical radiophysics, planetary radar, cryptography in the USSR, and large-scale studies of space.

As the journal *Uspekhi Fizicheskikh Nauk* (*Physics – Uspekhi*) has quite recently published a number of articles which discussed in detail the life and work of Vladimir Aleksandrovich Kotel'nikov [*UFN* **176** (7) 751 (2006); *Phys. Usp.* **49** 725 (2006)], I will not repeat their contents but will briefly outline the main stages of the creative life of this brilliant scientist; I will pay special attention to his last efforts which were never discussed previously on the pages of *UFN*.

This creative path in the life of Vladimir Aleksandrovich Kotel'nikov covered 78 years.

It began at the age of 19 with the creation of the first device known as 'triple characterograph' in this country. This work was carried out after V A Kotel'nikov graduated from the first year of the Moscow Higher Technical School (MVTU in *Russ. abbr.*) and was spending his summer vacations in the Nizhny Novgorod radio laboratory (1927). The paper "Triple characterograph" was published in 1928.

At the age of 24 V A Kotel'nikov was the first to give a correct mathematical formulation and prove, in the context of communications technologies, what subsequently became the classical sampling theorem (the Kotel'nikov theorem) which formed the basis of information theory, digital systems of message transmission, and the control, encoding, and processing of information [1932, Moscow Power Engineering Institute (MEI in *Russ. abbr.*)].

When he was 27 years of age, the first multichannel letter-printing radio system in the USSR was created under his leadership and with his participation; it had much better parameters than similar Western systems and was later widely used in the USSR [1935, the Research Institute of Communications of the People's Commissariat of Communications (NIIS NKS in *Russ. abbr.*)].

At 28, V A Kotel'nikov wrote two pioneering papers in which he, as one of the first to achieve it, applied probability theory to studying the efficiency of systems of signal diversity reception in a multibeam channel and proposed a general analytical method of studying nonlinear distortion of signals in various devices. Such methods were further improved and extended only at the end of the 1940s in the work of the best Soviet and foreign scientists (1936, NIIS NKS).

At the age of 30 he was awarded the degree of Candidate of Technical Sciences (an equivalent to a PhD), which was conferred on the merits of publications, without submission of a thesis (1938, Leningrad Electrotechnical Institute) and was elected Head of the Chair of Fundamentals of Radio Engineering at the Radio Engineering Department of the MEI.

At 31, V A Kotel'nikov devised unique multichannel telephone – telegraph equipment for radio communications, which for the first time used a single side frequency band; it was installed on the Moscow – Khabarovsk line (1939). At that time, this trunk line was a tremendous achievement of radio engineering in the USSR and in the world (1939, NIIS NKS).

At the age of 32 he formulated and proved the theorem of the 'one-time key' which laid the basis for the progress of cryptography and clearly defined the criteria of a mathematically nondecipherable system (1941, NIIS NKS). In the same period, he worked out a new class of nondecipherable (at the time) Soviet systems for voice encoding for classified radio communications (1941 – 1943, State Union Research Production Institute 56, city of Ufa). This equipment went through 'baptism by fire' in 1942 when wire communication lines to the Transcaucasian front were disrupted during the battle of Stalingrad. It was subsequently used to connect the Stavka Headquarters of Supreme Command to the fronts and still later for diplomatic connection lines from Moscow to Helsinki, Paris, and Vienna to conduct negotiations on signing peace treaties at the end of World War II, and also during the Tehran, Yalta, and Potsdam conferences of three Heads of States (1943 – 1945). Improved systems of this type were subsequently used with great success for governmental communications up to the 1970s.

At 36, V A Kotel'nikov revived and led the Chair of Theoretical Fundamentals of Radio Engineering at the Radio Engineering Department at the MEI, heading it for 36 years (1944 – 1980). In 1944 – 1947 he supervised the creation of telemetering instrumentation for aviation.

At 38, V A Kotel'nikov developed the theory of potential noise immunity (the topic of his DSc thesis) — one of the main branches of information theory, in which he laid the foundation of a new field of science — statistical radiophysics. This work, which was far ahead of its time, subsequently became one of the cornerstones of the modern theory of communications (1946, MEI).

At the age of 39, he became Head of the Sector of Special Tasks for research in the framework of missile and space programs (SpetsSektor in *Russ. abbr.*) (later renamed the Special Design Bureau of the MEI) — one of the leading developers of radioelectronic equipment for the space rockets programs (1947, MEI). Unique radioelectronic systems for jet engines and space vehicles for civilian and military use were developed in this framework. Many of V A Kotel'nikov's ideas are still used in creating new systems of steering and control of space apparatuses. Being the Chief Designer of the SpetsSektor in 1947 – 1953, he sat on the Interdepartmental Council of Chief Designers that was headed by S P Korolev. He was elected Dean of the MEI Radio Engineering Department (1947 – 1953).

At 45, he was elected Full Member of the USSR Academy of Sciences without even requiring the intermediate step of corresponding membership (1953) and became deputy director of the just founded Institute of Radioengineering and Electronics of the USSR Academy of Sciences (IRE RAS).

At 46, he became Director of the IRE RAS while it was being created; in a very short time it joined the group of leading research organizations in radio electronics both in this country and abroad. He headed the Institute for 33 years (1954 – 1987), and then became its Honorary Director; he continued to chair the Learned Council of the Institute for another 18 years until the end of his life. Vladimir Aleksandrovich guided the progress of many new fundamentally important areas of research and was able to complete a number of outstanding scientific and technological projects. His name is inseparable from a new field in space exploration — planetary radar.

At the age of 52, V A Kotel'nikov wrote a new page in radio astronomy: for the first time, under his supervision and with his active participation, unique experiments on the radar of Venus (1961 – 1964), Mercury (1962), Mars (1963), and

Jupiter (1963) were conducted. As a result of this work, the astronomical unit was measured with high accuracy, and a new theory of the motion of the inner planets of the Solar System was developed and confirmed by measurements. The radar survey of Venus, carried out in 1983–1984 by the aboard integrated radar system of automatic interplanetary probes Venus-15 and Venus-16, was an outstanding world-class achievement; it produced an image of 115 mln km^2 of the northern part of the planet with a resolution of 1 km. An analysis of the unique data allowed the creation and subsequently publication of the first *Atlas of the Venusian Surface* in the history of science (Moscow: MIIGAiK, 1989). Its editor-in-chief was Academician V A Kotel'nikov (1961–1989, IRE).

Along with working on scientific problems and teaching, Vladimir Aleksandrovich was doing a great deal of science administration. In 1969–1988, V A Kotel'nikov was acting President, Vice President, then First Vice President of the USSR Academy of Sciences (AS), and headed a number of Learned Councils of the USSR AS and then Russian Academy of Sciences, as well as some interdisciplinary scientific and technical councils and commissions; he combined all this with systematic daily work at the IRE. He was doing a great deal of work on organizing and supervising long-term exploratory and fundamental research projects at the Academy, and coordinated the research of numerous organizations in the country that specialized in various fields of modern radio engineering and electronics. By realizing his enormous scientific potential and accumulated experience, possessing his phenomenal capacity for work, and through his innate responsibility for any assignment he was given, he was able to produce results with maximum efficiency.

In 1987, Vladimir Aleksandrovich resigned from the directorship of the IRE and in 1988 from the vice-presidency of the USSR AS; still heading the learned councils and taking part in the life of the Institute, he returned to theoretical work in radiophysics.

At the age of 88 to 89, he published his last papers, which completed the circle of his work in radiophysics (1996–1997).

As in his younger days, he worked on these papers without assistance and published them almost on the eve of his 90th birthday. The problem he was solving was the inverse of the one he treated in his earlier publications. In those papers he determined the properties that a signal needs to have for it to be transmitted through a given channel; now he reversed it: how to select the properties of a channel in order to best transmit a given signal. As in his youth, he was again far ahead of his time. These days these results have enjoyed great popularity. Radio electronics in the past prohibited the possibility to change the channel, so one had to shape the signal. Nowadays, the channel can be selected in such a manner that it can transmit the signal in an optimal manner, and on top of that, it 'cleans' the signal too, filtering out the noise that would make it impossible to properly decode the signal at the output. These are essentially adaptive channels. These were his last scientific publications. And to top it all, he turned to quantum mechanics.

Vladimir Aleksandrovich became interested in quantum mechanics already in his youth. His creative path began (in 1927) when radio engineering was coming of age, and he just loved it, and quantum mechanics was starting to blossom and provided the major excitement for the scientific intelligentsia; these people hotly discussed the quantum mechanics papers appearing in journals. No wonder that the wave of interest in this 'mysterious' field took hold of the young Vladimir Kotel'nikov.

He started buying books on quantum mechanics that began to appear in the USSR and browsed through them — there was not enough time to do serious reading. Vladimir Aleksandrovich later remembered that each time he was left with a feeling of dissatisfaction as he felt "unable to comprehend this quantum mechanics to the very bottom." He dreamed of "some day figuring it all out."

At last he "got a bit of free time" and tackled the subject. He did not regard himself as a specialist in the field and tended to look at his new project as a "hobby for an old man."

He began by carefully reading the available books on 'classical' quantum mechanics. He decided to shun all 'alternative trends' in order to avoid undesirable influences; he wanted to see what he could produce himself. His 'square one' was the Schrödinger equation. By the end of 2003 he was ready to discuss the obtained results with specialists, but time ran out for him. V A Kotel'nikov died on February 11, 2005. The 97th year of his life ended with a nearly complete but unpublished work *Model Nonrelativistic Quantum Mechanics*; the drafts were published in 2008.

In this manuscript Vladimir Aleksandrovich presented nonrelativistic quantum mechanics (based on the Schrödinger equation) in terms of classical probability and classical concepts of the existence of trajectory of a particle and a field acting on it (see Appendix). The theory that he developed is an example of so-called theories of hidden parameters on which Luis de Broglie, D Bohm, and some others worked in the 20th century. Vladimir Aleksandrovich was unaware of the results published by these authors. He independently reproduced the entire logic of the theory of hidden parameters, introduced his own terminology and notation, and generated all the basic results of nonrelativistic quantum mechanics in his own terms. By this we mean wave packet spreading, analysis of the two-slit experiment and quantum interference, construction of the theory of stationary states, the theories of the hydrogen atom and oscillator, the theory of nonstationary states and quantum transitions, and the explanation of tunneling effect.

We who worked in the Kotel'nikov Institute of Radioengineering and Electronics, RAS loved and respected Vladimir Aleksandrovich. We consider it our unwavering duty to sustain the creative atmosphere that he built in the Institute, and strive to follow his principles in our work.

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Appendix
Model Nonrelativistic Quantum Mechanics. Considerations*

V A Kotel'nikov

INTRODUCTION

Quantum mechanics considers the motion of very small bodies such as elementary particles. Experiments have

* Below, the Introduction and Chapters 1 and 2 are presented. The full text of the work was published in 2008 (Moscow: Fizmatlit, 2008), 72 pages (in Russian).