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Vladimir Aleksandrovich Kotel'nikov (on his ninetieth birthday)

September 6, 1998, marks the 90th birthday of Academician Vladimir Aleksandrovich Kotel'nikov, a distinguished scientist, the dean of Russian communications engineers and one of the prominent captains of science in this country.

The active life of Vladimir Aleksandrovich is inseparable from the advancement of radio engineering and radiophysics around which the communications, radar, radio navigation, radio astronomy, computers, etc. are progressing rapidly The scientific contribution of V A Kotel'nikov and the collectives under his leadership to the majority of these fields is quite considerable. In the first place we ought to recall his fundamental works on the general theory of communication, and certainly his famous paper "On the carrying capacity of 'ether' and wire in electrical communication" published in 1933. It is in this paper that he formulated the theorem of sampling and demonstrated how a sum of discrete samples can represent continuous functions with a limited spectrum. This is one of the basic theorems in the theory of digital systems, and actually has a much more universal application than just communication theory. In mathematics this theorem had been known earlier; one of the first to prove it was Edmund Whittaker; after Kotel'nikov, the same theorem was later proved by Claude Shannon. V A Kotel'nikov, however, was the first to estimate the important technical implications of the theorem of sampling and thus to give it a new scientific dimension. This is the reason why this statement is often aptly referred to by radio engineers as the Kotel'nikov theorem.

An outstanding accomplishment of V A Kotel'nikov is his widely acclaimed "Theory of optimum noise immunity" (1946). Of great importance for many communication, radar, measuring and other systems is the problem of extracting the useful information against a background of noise and interference. Here the principal physical constraints occur, which hold fundamental significance for the separation of signals and identification of their parameters. These issues are addressed in this treatise, which wins V A Kotel'nikov a place among the founders of modern information theory.

The scientific results of V A Kotel'nikov were successfully implemented in a number of engineering projects that were accomplished under his guidance before and during the World War II and which twice made him the laureate of the prestigious State Award. In this connection it should be noted that V A Kotel'nikov has a unique feel for the engineering implications of scientific theories. If he said that a device would be inoperative or would not work properly, there is no sense in disproving. This ability makes him a recognized authority both among scientists and among engineers, and the common belief that "theory is one thing, and practice is something different", does not apply to V A Kotel'nikov.

It is not surprising then that from the early days of rocket design and launching of first satellites, the Kotel'nikov team was

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entrusted with the radio engineering support of the space program. The work of this period includes the development of systems for trajectory measurements, the reception of signals from the first sputnik, and so on. It was quite natural that V A Kotel'nikov stood at the beginning of a new science — planet radar astronomy. The interest here was stimulated mainly by space navigation requirements, since successful flights to other planets require knowledge of the dimensions of the Solar system to a high accuracy. It is customary to express them in astronomical units, equal to the mean distance from Earth to the Sun. Subsequent studies include the measurement of the angular velocity of rotation of Venus, measurement of the electrophysical parameters of the surface layers of planets, investigation of large-scale elements of their relief, and the like. Technically, all these feats are extremely complicated. Planet radar astronomy requires huge antennae several dozen meters across, radar transmitters with continuous power of approximately a hundred of kilowatts, supersensitive receivers with a noise temperature of order ten kelvins or less, reasonably powerful computers, control systems, etc. The complexity of the task can be illustrated by the fact that at the early stages, when the technical facilities were fairly modest, the signal reflected from the surface of Venus was separated from noise through many hours of integration. One has to be someone to be in charge of such a job.

The relative accuracy of planet radar ranging may be as high as 10^{-8}. Such accuracy is high enough to verify the theory of movement of planets, including the effects of general relativity. In this way, the planet radar astronomy is one further tool that can be used for verifying the implications of general relativity.

The natural next step in the planet radar astronomy was the transition from ground-based to space-craft observations. This was accomplished in the course of the *Venera-15* and *Venera-16* space missions. Synthetic aperture radars and altimeters were

used to obtain a radio image of the northern part of the surface of Venus with a spatial resolution of the order of 1 km, and for measuring the elevation profiles. Formally, Vladimir Aleksandrovich was not in charge of this project: it was his successors in the Institute of Radioengineering and Electronics RAS, the Design Bureau of the Moscow Power Engineering Institute, the Lavochkin NPO, and some other organizations. Without his active participation, however, this project would hardly been brought to a close. The success of this mission is a great scientific and technological accomplishment. US scientists were able to continue this research at a higher technical level much later, in the course of the *Magellan* mission. Incidentally, the planning of this mission relied to a considerable extent on the results of *Venera-15* and *Venera-16* space missions, which were made available to the US side as part of our scientific cooperation. This cooperation went on to the joint processing of the results of both space missions.

V A Kotel'nikov's colleagues were contemplating a continuation of these investigations in the course of the *Mars-96* space program which involved subsurface remote sensing of Mars to a depth of several hundred meters. Sadly, the mission was a tragic failure, but there still is hope to repeat this experiment in the future.

The interest of V A Kotel'nikov in space research has never subsided over many decades. He made a major contribution to the furtherance of scientific research as Vice President of the USSR Academy of Sciences, as the long-time chairman of the Scientific Council on radio astronomy, as the chief coordinator of international cooperation within the *Intercosmos* program, and even today as the Vice Chair of the Space Council of the Russian Academy of Sciences.

V A Kotel'nikov much influenced the development of other branches of science as well. This influence took and is currently taking different forms. For example, studies in the submillimeter wave band were started on his initiative at the Institute of Radioengineering and Electronics which at that time he headed. These studies embraced a broad range of problems related to this wave band: troposphere propagation, element base and receiving equipment, gas spectroscopy, etc. On other occasions, like in the case of parametric amplifiers and fiber optics, at the initial stage he assumed command so as to give sufficient momentum to the project. One could name many research areas in which the development took a particular course just because V A Kotel'nikov is what he is.

We ought to remember the uncommonly benevolent attitude of V A Kotel'nikov to any discussion, be it scientific, managerial, or otherwise. It often seems quite natural to ask him for advice in a difficult situation. The encyclopaedic knowledge and wise understanding of V A Kotel'nikov invariably lead to a decision that resolves the complications. It would be risky, however, to approach V A Kotel'nikov with immature suggestions. With his systematic reasoning, he will quickly expose all inconsistencies.

For his fruitful scientific, pedagogical, organizational achievements, V A Kotel'nikov has twice been awarded an order 'Hero of Socialist Labor', he is a recipient of Lenin and State Prizes, his many awards include the Lomonosov, Popov, and Keldysh gold medals of the Academy of Sciences. He has been elected to numerous international scientific societies and associations.

Asteroid No. 2726 has been named for V A Kotel'nikov.

On the eve of his 90th birthday, V A Kotel'nikov has been awarded an order 'For Service to Fatherland' of the Second degree for his great services to the country, for his outstanding personal contribution to the development of science, and for his pedagogical activities.

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