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QUANTUM GENERATOR IN SPACE

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SUMMARY

The utilization of quantum generators in space is examined. Particular emphasis is given the utilization of molecular generators in the airborne apparatus of the Earth's artificial satellites. The experiment on AES Kosmos-97 is described. This experiment was with quantum generator using ammonia and to conduct it one the variants of the "KOSMOS" series was applied, i. e. that with solar cells.

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In order to generate and amplify the high-frequency electromagnetic oscillations Soviet scientists and academicians, N. G. Basov and A. M. Prokhorov proposed to utilize the induced emission of "active" molecules. In the same year 1954, when the proposal was made, they also gave the basis of the theory of the device, subsequently called "molecular generator", and created the first quantum coherent emission generator with 1.25 cm wavelength on the beam of ammonia molecules(**). An identical generator was concomitantly and independently created by American researchers, Gordon, Tsayger and Tauns(***). With the creation of the molecular generator, the occasion was marked as the birth of a new science — the quantum radiophysics. New astonishing possibilities have emerged for numerous contiguous regions. A new independent direction was born — the quantum electronics, encompassing the physical foundations and the application of quantum generators and amplifiers.

Quantum electronics has reliably entered the fields of science and practice. It is made evident by the fact that numerous quantum devices were adopted by industry in a comparatively short time, and are the object of mass production. Owing to the high stability of quantum generators on a beam of ammonia molecules, they could be used as time and frequency standards. At the present time the precision of time measurement with the aid of frequency standard with a beam of cesium molecules is so high that the possibility opens up to renounce the utilization of the motion of celestial bodies as a time standard.

(*) KVANTOVYI' GENERATOR V KOSMOSE. (**) The coherence is a coordinated course in time of a few random processes, in particular the constant in time correlation between phases of radiowaves. (***) in transliteration.

Following the quantum generators of centimeter electromagnetic waves molecular amplifiers of centimeter and decimeter radiowaves on solid operation substance were proposed. These amplifiers, with low level of proper noises, exceed by one to two orders the threshold response of the apparatus. Such devices made possible the location of Venus, Mars, Mercury and Jupiter, and also observations of weak radiosignals arriving from the depth of the Universe.

The next stage in the development of quantum electronics was the transfer of its methods toward shorter waves, through optical waves. A large number of various types of optical quantum generators— the lasers, were created. They found their application in chemistry, medicine, industry. The utilization of powerful lasers in research has led to the emergence of new area of science — nonlinear optics.

And finally, about one year ago a quantum device was placed in space by means of an Earth's artificial satellite. The significance of this event is difficult to overestimate. The subsequent development of space investigations, particularly with the aid of long range probes, requires the creation of radio-systems capable of assuring reliable communication at any distances from the Earth, to be placed on board interplanetary probes. This problem may be solved by two methods. Either by the creation of powerful antenna systems at points on the ground, or by substantial increase of frequency stability, and consequently also by narrowing the emission band of electromagnetic oscillation-creating generators.

The quartz generators applied to date have a comparatively low frequency stability. Besides, they are subject to aging, inducing drift and a significant frequency shift.

By comparison with them the molecular generators do not differ by a greater power, but their stability exceeds by very much that of the best quartz generators, owing to which the sensitivity of the receiving apparatus is also increased many times.

The utilization of molecular generators in the airborne apparatus of the Earth's artificial satellites allows not only to materialize their guidance and the long-range telemetry, but also to considerably increase the operational precision of the time-program devices and system of satellite trajectory determination.

The ammonia quantum generator is the most convenient for its utilization as a highly stable airborne frequency generator. It is endowed with such indispensable properties in the conditions of operation on board AES as the simplicity of constructions, steadiness to vibrations, compacity and length of operation. Precisely such a generator, operating on two counter molecule beams was installed aboard "KOSMOS-97". The satellite moved along the orbit with parameters: 2160 km in apogee and 221 km in perigee; the inclination of the orbit to the equatorial plane was $48^{\circ}48'$.

To conduct the experiment one of the variants of "KOSMOS" series was utilized — with solar cells.

The frame of the satellite is a cylinder, of which the spherical half-shells serve as bilges. Inside, the frame is divided in three compartments: one for the scientific apparatus; one for the disposition of the service apparatus and another one for the block of buffer batteries.

The molecular generator is installed on the external surface of the satellite and enclosed in a casing with double walls having apertures, of which the area assures the required ammonia drift in space. The disposition of the apertures is arranged so as to prevent the molecular generator being directly hit by solar radiation and cosmic particles. The casing serves at the same time as the base for placement of the receiving and transmitting antennas.

The electrical connection between the molecular generator and the feeding sources serving the apparatus and the scientific devices placed inside the frame is realized by hermetic plug-type connectors installed on special flanges.

The pressure of the inert gas inside the frame is sustained near the atmospheric. To assure a specific and sufficiently stable temperature regime of apparatus' operation on the satellite, a special thermoregulating system has been installed. Included in its composition is a radiator with shutters. The frame's lower half-shell serves as the radiator, on whose external surface a ceramic coating has been placed with increased radiating capability. The shutters, consisting of movable screens, corresponding in shape and size to the painted areas, freely shifting above the surface of the radiator, allow the regulation of its radiating capability and to correspondingly sustain the equilibrium between the absorbed and emitted radiations.

The control of the state and the operation of the molecular generator, of the scientific, as well as the servicing apparatus, was achieved by a radiotelemetric system, into which the airborne apparatus are switched alongside with ground stations.

A special apparatus for orbit radiocontrol was installed on the satellite at different moments of time for the measurement of the characteristics of satellite motion (coordinates and velocity vector components). On the basis of data obtained from it orbit determination and forecast of the motion required for the delivery of target designations to ground observational points could be made.

When processing the data of scientific measurements there might appear the necessity of accounting for the errors stemming from satellite spinning. To that effect there was installed a system of indication including the combination of sensitive pickups, according to whose indications the angular position of the satellite was determined at each moment of time, and by the same token its rotation velocity.

The operation control of the molecular generator was realized by command transmitted on board the object by special radioline command from ground points and autonomously with the aid of the program-temporal device.

The experiment on "KOSMOS-97" required first of all the possibility of measuring the nominal value and the frequency stability during space flight. To that effect it was necessary to resort to its comparison with ground frequency standard.

Three identical and independently operating molecular generators were used for the ground standard (gauge), having the same construction and operational regime as the airborne generator. The variation of the frequency of any of the ground generators could be accurately determined relative to the other two.

When transmitting the frequency of the airborne generator to the ground station, it will be significantly shifted on account of the Doppler effect. To eliminate the latter a method was worked out under the guidance of academ. N. G. Basov and Prof. M. I. Borisenko of Doppler effect's automatic compensation during the two-way radiocommunication between the ground station and the satellite.

Altogether 13 radiocommunication sessions were conducted with the view of measuring the frequency of the airborne molecular generator.

Thus, as a result of the flight, tests were conducted of the molecular generator under conditions of natural vacuum; at the same time verification was made of the influence of weightlessness and other factors of space flight on its operation.

The generator operated normally and with high stability at various altitudes above ground, inside and beyond the radiation belt, under conditions of its illumination by the Sun and in the shadow of the Earth.

The possibility of frequency synchronization of the airborne and ground generators was verified experimentally during flight and with the aid of the two-way radiocommunication.

The data obtained allowed us to derive the conclusions necessary for further constructive processing of the onboard quantum frequency standards with the aim of creating industrial samples of broad application.

**** T H E E N D ****

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