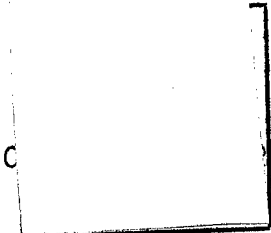


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NOTE ON THE ACCELERATION OF RELATIVISTIC ELECTRONS
IN THE IONOSPHERE AND THE EFFECT OF THE EARTH'S
MAGNETIC FIELD ON THEIR TRAJECTORIES

- USSR -

By A. A. Vorob'yev

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NOTE ON THE ACCELERATION OF RELATIVISTIC ELECTRONS
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[This is a translation of an article written by A. A. Vorob'yev in Izvestiya Vysshikh Uchebnykh Zavedeniy, Fizika (News of the Higher Institutions of Learning, Physics), No. 2, 1959, pages 171-172.]

Great attention is being paid to the construction of accelerators for charged particles. Wilson, the designer on the 1.2 Bev synchrotron, expressed the opinion that different epochs of human society are characterized by different large buildings. The ancients built pyramids, those living in the Middle Ages, cathedrals, and in our days accelerators are built. The greatest proton synchrotron, in Dubna, produces protons of energy 10^{10} ev. There are grounds for assuming that in cosmic rays there are particles with energies 10^{16} ev.

The development of methods of obtaining high energy particles remains an urgent scientific problem. We have proposed a scheme for a cyclic accelerator with a closed waveguide, in which the particles are accelerated by means of the electric vector of a traveling wave. In this connection, a theory concerning the motion of radio waves in enclosed waveguides is now being developed at the Tomsk Polytechnic Institute.

The phase velocity in the waveguide depends on the frequency. For wavelengths less than critical, the phase velocity is equal to the velocity of light. As a result of the limited transverse cross section of the waveguide, there exists a critical wavelength for the waveguide, and also dispersion.

In the ionosphere, the velocity of radio waves also depends on the frequency. One can create conditions for guided propagation of radio waves in the ionosphere at a velocity less than that of light. Dispersion arises in the ionosphere because the radio waves propagating in the ionosphere

cause electrons to oscillate. The amplitude of these oscillations increases with decreasing frequency of propagation of the wavelength. The electron current, directed opposite to the displacement current, causes a reduction in the equivalent dielectric constant and an increase in the phase velocity. Since the value of the current is inversely proportional to the square of the frequency, the phase velocity of electromagnetic waves of different frequencies will depend in the ionosphere on their wavelengths.

The results of observations of the propagation of radio waves in a closed path around the earth's sphere are in agreement with the theory of traveling waves in a closed waveguide. At an altitude of 100 kilometers, the concentration of neutral particles amounts to 2.6×10^{15} , and at an altitude of 200 kilometers it ranges from 5 to 10×10^{10} , i.e., 10^9 times less than on the surface of the earth. Such a rarefaction is sufficient to accelerate the electrons.

The concentration of the electrons at an altitude of 100 -- 600 kilometers fluctuates between 10^5 and 1.6×10^6 electrons/cc. It depends on the time of the day, on the geographic latitude, on the time of the year, and on the solar activity.

It is known that radio waves bend around the earth and return to the transmitting station. This phenomena is known as around-the-world echo and is continuously observed. Sometimes a double or triple around-the-world echo is observed.

The constancy of the delay time of the around-the-world echo is proof that the ionosphere as a whole, considered as a shell surrounding the entire earth's surface, is quite stable in its properties and structure. It has been known in general that the around-the-world echopropagates best of all along the arc of a great circle passing close to the line of the twilight zone.

It is proposed that the around-the-world echo propagates as a gliding wave along the lower boundary of the F-layer at an altitude of 204 kilometers within a time of 0.135 seconds, at a velocity of 299,776 km/sec, or along a zigzag trajectory at an altitude of 200 or 300 kilometers.

The number of electrons in a tube of radius 6,400 + 200 kilometers with a cross section area of one square centimeter amounts to 4×10^{15} .

In modern accelerators, it is proposed to capture and accelerate on an orbit of a charge only up to 10^{11} electrons. During the time of one revolution around the earth, equal to 0.1373 seconds, the current density in such an accelerator amounts to 460 ampere/cm². Based on these figures, this accelerating scheme is quite satisfactory.

The intensity of the electric field of a radio wave in the ionosphere depends on the strength of the source and changes in a complicated manner as the distance from it increases, being affected by many factors. It is therefore difficult to calculate the increase in the energy of an electron accelerated by the electric vector of a radio in the ionosphere after one revolution around the earth.

The use of the proposed scheme of acceleration of electrons, in view of its complexity, can be justified only for the purpose of obtaining electrons of energy 10^{12} eV and more. In such a case, with a small number of revolutions around the earth, a wave having a field intensity of 20 v/cm should be able to accelerate approximately 10 electrons.

The maintenance of so high a field intensity over the entire path along a great circle is a problem requiring a special solution.

The theory of inductive acceleration of electrons on a cosmic scale has been developed by Ya. P. Terletskiy. The hypothesis of waveguide acceleration of electrons with the aid of the electric vector of a traveling electromagnetic wave in cosmic space has also been verified. Even at a small electric field intensity, relativistic electrons moving with a velocity close to that of light will acquire a high energy after covering large distances in cosmic space.

It can be recalled that it has been proposed to construct a cyclic accelerator of electrons using a chamber located around the earth's sphere and using the earth's magnetic field for control of the trajectory. In this proposal, provision is also made to accelerate the electrons with an accelerator on the same cosmic scale, but the construction of a chamber is eliminated and a specific idea concerning the system used to accelerate the electrons is proposed.

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