Artificial injection of very low frequency (VLF) waves into the ionosphere and the magnetosphere of the earth

V. M. Chmyrev, V. K. Roldugin, I. A. Zhulin, M. M. Mogilevskiĭ, V. I. Di, V. K. Koshelevskiĭ, V. A. Bushmarin, and O. M. Raspopov

Institute of Terrestrial Magnetism, Ionosphere, and Radio Wave Propagation, USSR Academy of Sciences
(Submitted February 9, 1976; resubmitted March 18, 1976)
Pis'ma Zh. Eksp. Teor. Fiz. **23**, No. 8, 452–455 (20 April 1976)

We observed variations of the fluxes of electrons spilled out of the magnetosphere and short-period oscillations of the earth's magnetic field, stimulated by pulsed signals from a land- based VLF transmitter.

PACS numbers: 91.87.Ks, 91.85.Ef, 91.35.Az

In February 1975, our Institute jointly with a number of other organizations has carried out a preliminary active wave experiment (the "Juliana" program) aimed at investigating the possibility of controlled action on the fluxes of the electrons trapped in or spilled out of the earth's magnetosphere, by using signals from a high-power land-based VLF transmitter. We also undertook to observe artificially stimulated perturbations of the earth's magnetic field, conducted with injection of VLF waves into the ionosphere.

We used a high-power transmitter located at a geometric latitude $\Phi \approx 60°$. The transmitter emitted radio pulses at 12.5 kHz frequency of duration 0.5 and 15 sec, with a repetition period 3 and 30 sec, respectively. The optical and magnetic observations were carried out at a point located at a distance ~200 km from the transmitter. To observe the effects of stimulated spilling (or trapping) of electrons by means of the variations of the luminosity of the night sky, we used a photometer based on a FÉU-19 photomultiplier, sensitive to optical radiation in the 3800—6000 Å band. We recorded the alternating component of the luminosity. The sensitivity of the instrument was several Rayleigh units and the accuracy of reconciliation with the transmitter signal was 0.2 sec.

The geomagnetic micropulsations were recorded with a magnetovariational installation developed at the Department of Earth Physics of Leningrad University.[1] We recorded the variations of the modulus of the total field vector. The recording sensitivity was 0.01 γ/mm. We present in this communication the result of measurements performed on 20 February 1975 at 4:20—5:02 local time. The variation of the sky luminosity with the VLF repetition period was observed in the interval 04:20—04:41, when the transmitter radiated short pulses of duration 0.5 sec with a repetition period 3 sec. Since the observations were made under conditions of a rather high level of optical interference, we used the epoch-superposition method to separate the useful signal. We chose two recording intervals of 28 and 56 sec duration and digitalized them in steps of 0.2 sec. The readings were referred to the leading fronts of the pulses; there were nine transmission pulses in the first section and 18 in the second.

Figs. 1a and 1b show the values, averaged over the aggregate of the lumino-

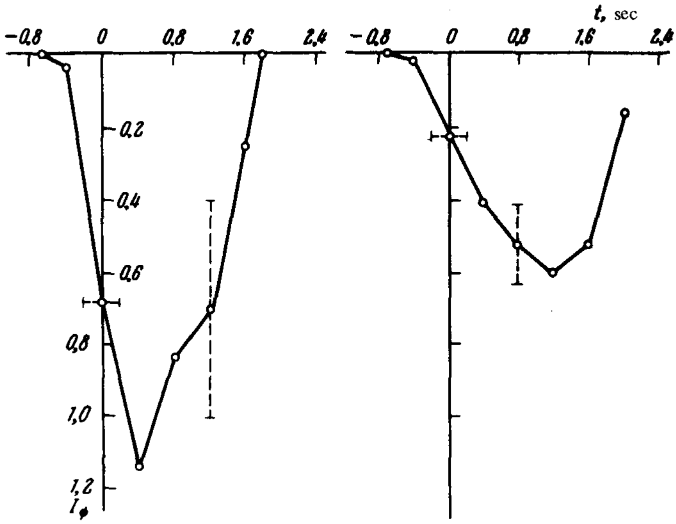

FIG. 1

ty and relative units, for the first section (Fig. 1) and for the second section 'ig. 1b) at instants of time from − 0.8 sec (prior to the start of the pulse) to 0 sec after the leading front of the transmitter pulse, in steps of 0.4 sec. he rms deviations are shown by vertical dashed lines, and the error in the me reconciliation is shown by horizontal dashed lines. We see that there is a onrandom variation of the luminosity, exceeding the rms error. This variation onstitutes a pulse of negative polarity, beginning near the start of the trans- itter pulse and lasting about 1.6 sec. Thus, the figures indicate a periodic ecrease of the luminosity of the atmosphere under the influence of the trans- itter pulses. The experiment took place in the sub-auroral zone, where an ppreciable contribution to the glow of the sky is produced by background elec- 'ons spilled out of the magnetosphere. The effect of heating the ionosphere hould have led to an increase of the glow intensity. We can therefore assume iat the observed variation of the luminosity is connected with a light-radiation omponent due to the background of spilled-out particles. If this is the case, ien the periodic decreases of the sky luminosity, which correlate with the op- ration of the VLF transmitter, are probably due to the blocking of the flux of ie electrons that spill out in the magnetospheric trap as a result of their re- istribution over the pitch angles, either directly in the field of the intense 'ave from the transmitter, or else as a result of scattering by electrostatic scillations that are effectively excited in the magnetosphere during the course f the decay or induced scattering of the strong VLF waves. [2]

The geomagnetic pulsations correlated with the VLF action were registered 1 the time interval 04 : 41—05 : 02 with the transmitter operating in the regime f long transmissions (duration 15 sec, repetition period 30 sec). In the indi- ated interval, we performed three runs lasting seven minutes. In each run, uring the first three minutes, the transmitter emitted pulses in the indicated egime, and then was silent for four minutes. To observe the sought signal in he magnetic field, we also used the method of epoch superposition to reduce he data. The recorded plot was broken up into sections of duration 30 sec (the rigin being taken to be the leading front of each pulse of the transmitter) and

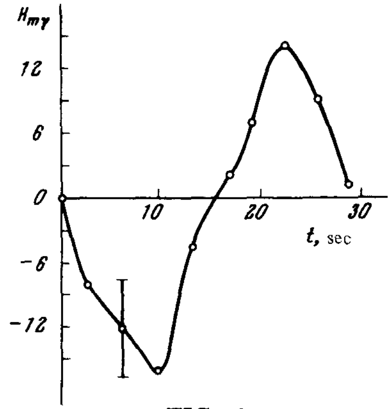

FIG. 2

digitalized with integrals of 3.3 sec. Thus, during three three-minute interva of transmitter operation we had 18 such sections. The field variations averag over these sections are shown in Fig. 2 with an integral of 3.3 sec. The rms deviation, which is approximately the same for each point, is shown in the figure by the vertical line. It is seen from the figure that we registered a non-random signal that exceeds the rms deviation, with a period of 30 sec and an approximate amplitude 16 mγ. During the silence of the transmitter, there wa no signal with 30-sec period (we observed random uncorrelated field pulsations). Thus, our result offers evidence that it is possible in principle to excite terrestrial magnetic-field oscillations having the repetition period of puls from a VLF transmitter. The effect of the transmitter on the regime of generation of geomagnetic pulsations was demonstrated experimentally in[3], whe an increase of the activity of pulsations of type Pc-1 during the periods of tran mitter operation was noted. The physical mechanisms that lead to the excitation of the artificial pulsations of the geomagnetic field can be attributed eithe to stimulated oscillations of the fluxes of the spilling particles, or to heating of the lower ionosphere in the field of the high-power wave from the transmitter. Both processes should lead to variations of the conductivity of the ionosphere, and consequently to pulsations of the earth's magnetic field.

A specially planned experiment will make it easy to separate the different effects that lead to generation of the pulsations.

The authors thank Yu. M. Markeeva and E. F. Kozlov for the work, and also I. N. Kapustin for useful discussions of the results.

[1]Yu. A. Kopytenko and V. A. Bushmarin, Ekonomichnyĭ magnitometr s fotoelektricheskim preobrazovaniem signala, in: (Economical Magnetometer with Photoelectric Signal Conversion) in: Geomagnitnye issledovaniya (Geomagnetic Investigations) No. 20, Nauka, 1976 (in print).
[2]D. A. Kotik and V. Yu. Trakhtengerts, X Vsesoyuznaya konferentsiya po rasprostpaneniyu radiovoln, tezisy dokladov (10th All-Union Conference on Radio Wave Propagation, Abstracts of Papers), Sec. III, 164, Nauka, 1972.
[3]A. C. Fraser-Smith and C. A. Cole, Geophys. Res. Lett. 2, 146 (1975).