aggregate of processes in the interior of the sun and on its surface.

The paper was based on results published in the following papers:

G. E. Kocharov, Izv. Akad. Nauk SSSR, Ser. Fiz. **37**, 1228 (1973), **39**, 244 (1975); in: Trudy mezhdunarodnogo seminara "Solnechnye kosmicheskie luchi i ikh proniknovenie v magnitosfery zemli" (Proceedings on International Seminar on "Solar Cosmic Rays and Their Penetration into the Earth's Magnetosphere"), Izd. LIYaF Akad. Nauk SSSR, Leningrad, 1973, p. 7; USSR Academy of Sciences Physico-technical Institute Preprint No. 457, Leningrad, 1973; in: Proc. of 13th Intern. Conference on Cosmic Rays, Denver, USA, 1973, p. 1602.

G. E. Kocharov and Yu. N. Starbunov, ZhETF Pis. Red. **11**, 132 (1970) [JETP Lett. **11**, 81 (1970); in: Proc. of 12th Intern. Conference on Cosmic Rays, Vol. 7, Australia, 1971.

I. A. Ibragimov and G. E. Kocharov, USSR Academy of Sciences Physico-technical Institute Preprint No. 456, Leningrad, 1974; Izv. Akad. Nauk SSSR, Ser. Fiz. **39**, 287 (1975).

R. Ramaty and R. Lingenfelter, in: Trudy mezhdunarodnogo seminara "Uskorenie chastits i yadernye reaktsii v kosmose (Proceedings of International Seminar on "Particle Acceleration and Nuclear Reactions in Space"), USSR Academy of Sciences Physico-technical Institute Preprint, Leningrad 1974, p. 25.

R. Ramaty and W. Kozlowski, ibid., p. 58.

L. F. Vereshchagin, E. N. Yakovlev, and Yu. A. Timofeev. The Possibility of the Transition of Hydrogen to a Conductive State. The development of a process for the synthesis of polycrystalline diamonds of the carbonado type by the USSR Academy of Sciences Institute of High Pressure Physics opened new possibilities for the attainment of high pressures.

It was shown in earlier studies (made jointly with G. N. Stepanov, B. V. Vinogradov, K. Kh. Bibaev and T. I. Alaeva) that carbonado diamonds are capable of withstanding contact pressures up to 3 Mbar. These pressures are several times those presently attainable with the aid of hard alloys (0.5 Mbar).

Carbonado diamonds have been used to build miniature chambers for the study of dielectric-metal transitions. The high-pressure chamber consists of two anvils (one flat and one tapered with a blunted point), between which a layer of the dielectric is placed.

If the substance to be studied is a gas, the anvils are cooled to the appropriate temperature and the test substance is condensed on the anvil surfaces. To investigate hydrogen, the anvils were cooled to 4.2°K.

Among the solid dielectrics, the author investigated (jointly with V. P. Sakun) transitions in diamond, silica, corundum, and various other substances.

The appearance of a conductive phase is determined from the resistivity jump.

Resistivity jumps due to electric breakdown, to tunneling of carriers through the dielectric layer, or simply to contact were distinguished from jumps due to phase transitions by applying a special test. The latter is based on the effect of metastability that always accompanies first-order phase transitions in solids under pressure.

The metastable states are manifested in the form of a hysteresis that decreases as the temperature rises. The test developed consists in the fact that the substance heats up at forces near the direct and reverse transitions.

If heating in the dielectric state results in a stepwise decrease in resistivity (usually by a factor of 10^6—10^8) and heating in the conductive state brings about an increase (by a factor of 10^6—10^8), this corresponds to "unfreezing" of the metastable dielectric and conductive states. We take observation of the "unfreezing" effect as proof of the phase transition.

In addition to the test described above, there are various other criteria that can be used to confirm the phase transition. An example is the observation of two resistivity jumps in a mixture of powders of two dielectrics.

It was observed in a study of the resistivity of hydrogen that it decreases under pressure by a factor of at least 10^6. Heating of the hypothetical metastable conductive phase resulted in an increase of the resistivity to the original value (by a factor of 10^6).

This set of phenomena, which is analogous to that observed earlier in other dielectrics, served as a basis for the conclusion that a transition of hydrogen to a conductive phase is possible. These experiments yielded only an order-of-magnitude estimate of the transition pressure: $P \sim 1$ Mbar.

A. V. Gurevich. The Artificial Ionospheric Mirror. Considerable attention is being given to study of the phenomena that arise on artificial modification of the upper ionosphere under the action of powerful radio waves[1,2]. Large-scale layering of the disturbed region of the ionosphere [3], oscillations of a powerful pulsed signal reflected from the ionosphere [4], and intensive excitation of plasma and ion-acoustic oscillations [5] are among recent observations.

An interesting new phenomenon was recently discovered at Boulder, Colorado: the formation of an artificial ionospheric mirror that reflects radio waves in a broad frequency range, up to and beyond 100 MHz [6]. The reflections are caused by small-scale layering of the ionosphere. It was found that inhomogeneities with plasma-density fluctuations $\delta v = \delta N/N \sim 10^{-2}$ and strong elongation along the earth's magnetic field **H** appear under the action of the powerful wave. They are approximately 1 meter across and approximately 1 km long or longer. The inhomogeneities are formed on disturbance of the ionosphere by the ordinary wave, in the region of its reflection. The effective dimensions of the strongly disturbed zone are height 10—20 km, width 100—150 km. The extraordinary wave apparently does not cause such disturbances.

Radio waves of various frequencies can be scattered on these inhomogeneities. The scattering is sharply anisotropic because the inhomogeneities are strongly elongated along **H**. The scattering maximum lies on a cone whose axis is directed along **H**, while its generatrix form the same angle as the incident ray with the normal to **H**. It is as though the waves were reflected from slender specular rods oriented along **H**.

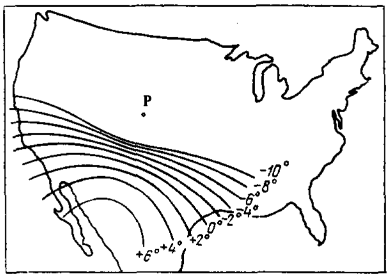

FIG. 1. Structure of reflections from artificial mirror located at Platteville (P) (40.18°N, 104.73°W).

Figure 1 shows the curves formed by the intersection of the scattering cone with the earth. It is assumed that the scattering volume is situated over P (Platteville) at a height of 230 km. The 0° curve is formed by the intersection of the plane normal to **H** with the earth. Rays originating from the ±K° curves form angles ±K° with the normal. If, therefore, the transmitter is on the "+K°" curve, for example, its rays will strike the "−K°" curve after reflection from the "mirror" P and vice versa. We see that the region covered by this artificial reflector spans 2000–4000 km. Barry's experiments[6] indicated the possibility of establishing reliable radio and teletype communications by use of reflections from the artificial mirror. We note that the same reflector can also be used to excite ionospheric wave ducts[7], a point of importance for ultralong-range radio propagation.

The scattering cross section σ is largest in the evening hours, provided that the disturbing wave is reflected somewhat below the maximum of the ionospheric F layer. During the daytime hours, σ is much smaller (by a factor of 10 to 100). It is seen from Fig. 2a that the cross section is nearly constant up to frequencies of the order of 80 MHz; under optimum conditions it is exceptionally large, at $\sim 10^8$ m^2. Figure 2b shows that the cross section decreases rather slowly with decreasing power of the disturbing station.

Strong reflection begins one or two minutes after the transmitting station is switched on, and the effect is fully developed after 8–10 minutes. It is interesting that under the conditions of the already steady process, the scattering cross section varies much more rapidly with varying power: in 1–5 sec. Thus, we have a certain "priming" of the ionosphere out of its original undisturbed state (Fialer[6]). We note also that when the disturbing-station frequency is near the critical frequency of the F layer, the scattering region gradually assumes the shape of a ring: the plasma density decreases at the center under the action of the field of the powerful wave, and, without reflection, it produces the "hole" that was observed to form (see[1]).

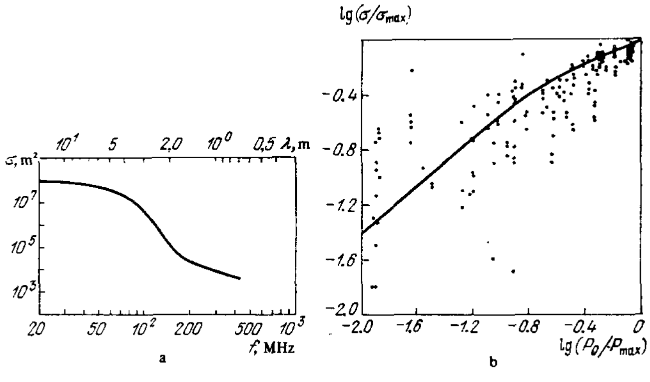

FIG. 2. Scattering cross section of ionospheric mirror vs. frequency f of wave (a) and power P_0 of disturbing transmitter (b). The maximum power of the Boulder transmitter was $P_{max} = 1.9$ MW at an antenna directivity of ~50 [2]. The solid curve in Fig. (b) represents the calculation using formula (4).

Investigation of the frequency spectrum of the signal reflected from the inhomogeneities showed that the signal frequency has a shift on the order of 10–30 Hz, and that the line broadening is of the order of 1–5 Hz. Evidently, both the shift and the broadening are due to drift of the inhomogeneities in the ionosphere. In addition to the principal line, two satellite lines, shifted by the frequency of the disturbing station away from the main line, are also observed[6]. The frequency shift and broadening of the satellite lines are of the same order as those of the main line. The relative intensity I_s of the satellite lines appears to be very low at low frequencies, f $\lesssim$ 100 MHz (they could not be observed). As the signal frequency f is raised, I_s increases sharply: thus, at f = 155 MHz, the ratio $I_s/I_0 \sim 0.1$, and at f = 435 MHz it is as large as 10 (I_0 is the intensity of the main line). Scattering in the satellite lines does not exhibit conspicuous anisotropy like the scattering on the main line.

What is the nature of this phenomenon? The formation of inhomogeneities that are strongly elongated along the earth's magnetic field is evidently caused by ejection of locally heated plasma.

In[8] we considered the following mechanism of this effect: In the reflection region, the ordinary wave is dissipated on the inhomogeneities extending along the magnetic field. The dissipation is associated with linear transformation of the ordinary wave into plasma waves. Figure 3 shows the structure of the reflection region. The extraordinary wave is reflected at the level $v = 1 - u^{1/2}$, below the existence region of plasma waves, so that for all practical purposes it does not excite the latter. The ordinary wave is reflected at the level v = 1. In the presence of an inhomogeneity, it excites plasma waves in the region $1 - u \leq u \leq 1$, and most efficiently near the upper hybrid resonance $v = 1 - u$. The plasma waves are damped as a result of collisions or absorption at resonance ($v = v_r$). The total power dissipated in the inhomogeneity is

$$P = C\,(\lambda\mu)^{-1}\,(\delta v)^2\,SP_0, \tag{1}$$

where $\mu = N^{-1}|dN|dz|$ is the electron-density gradient in the layer, λ is the length and P_0 the power of the incident wave, $\delta v = \delta N/N$ is the concentration disturbance in the inhomogeneity, S is the cross section of the inhomogeneity, and C is a numerical factor ~10.

As a result of absorption of energy, the electrons are heated up, and this ejects plasma, i.e., it intensifies inhomogeneities with $\delta N < 0$. In turn, this increases the dissipation, and this again causes growth of the inhomogeneities, and so forth. The instability that arises in this way ("resonant instability" in[8]) should cause a

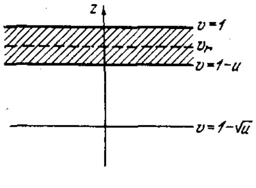

FIG. 3. Structure of reflecting region at normal incidence of radio waves on the layer of inhomogeneous plasma. The electron density N increases in the direction z of wave propagation. The existence region of plasma waves is shaded. $v = 4\pi e^2N/m\omega^2$, $u = \omega_H^2/\omega^2 = e^2H^2/m^2c^2\omega^2$.

sharp strengthening of the inhomogeneous structure of the plasma and disintegration of the smooth plasma layer in the reflection region of the orindary wave. The instability develops if the initial concentration disturbance in the inhomogeneity is negative, $\delta v_0 < 0$, and exceeds δv_p in absolute magnitude, where

$$\delta v_{p}=\left|\frac{\delta N_{\text{п}}}{N}\right|=C_1\frac{\nu_e}{\omega}\mu L\left(\frac{E_p}{E_0}\right)^2; \tag{2}$$

here ν_e is the electron collision frequency, L is a characteristic length determined by heat conduction and diffusion[9], E_0 is the amplitude of the disturbing-wave field, E_p is the characteristic plasma field[1,9], and C_1 is a numerical factor ~1. In the ionosphere at $(E_0/E_p)^2 \sim 1$, we have $\delta v_p \sim 10^{-4}$–10^{-5}.

Resonant instability results in sharp strengthening of the inhomogeneities extending along the magnetic field. But the absorption of incident-wave energy also increases. The total absorbed power is

$$P=P_0\left[1-\exp\left(-\frac{\overline{\delta v^2}}{\delta v_k^2}\right)\right],\quad \delta v_k^2=C_2\mu\lambda,\quad C_2\sim 0.1. \tag{3}$$

Hence we see that when $\overline{\delta v^2}$ is comparable with δv_k^2, the absorbed power P approaches P_0. At this point the inhomogeneities cease to grow and the instability stabilizes. Under ionospheric conditions $\delta v_k \sim 10^{-2}$. Such plasma-density disturbances account for the observed scattering; they should also result in effective absorption both of the waves that caused the disturbance and of other ordinary waves reflected in the disturbed zone. Under certain hypotheses, Eq. (3) yields simple relationships for the coefficient of reflection R of the waves from the ionosphere and for the total scattering cross section σ for high-frequency radio waves as functions of the power P_0 of the disturbing wave:

$$\frac{R}{R_0}=(1+\alpha P_0)^{-2},\quad \frac{\sigma}{\sigma_0}=\ln(1+\alpha P_0). \tag{4}$$

These relations are both consistent with the observational results (see Fig. 2b and the paper by Getmantsev et al.[10]). We note that at $\delta v \lesssim \delta v_p$ in the initial stage of inhomogeneity development, other instabilities—dissipative parametric instability[11] and drift instability—may also prove to be significant.

The artificial ionospheric mirror may find application in practical radio communication. It is also possible to create an artificial ionosphere in specific regions. In fact, one mirror, as we see from Fig. 1, covers an area of 3–5 million km^2. A system of 10–20 mirrors could form an artificial ionosphere that would support radio and possibly even television communications for an area the size of Europe. As Fig. 2b shows, a total power of about 10 MW would be necessary to create such a system. Reflection from the mirrors should then guarantee reception of 1–10-kW transmitters over the entire area in a broad frequency range extending up to 10 MHz. In addition, the same reflectors could be used to generate ultralong-range and round-the-world short radio waves in the ionospheric wave ducts.

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