[1] In the investigation of the inertia of the nonlinearity mechanisms that cause the frequency mixing, the frequency f ranged from 3 GHz to 150 MHz.

[2] $\Delta R_2(P_{f_2}, I)$ was measured only at 75 GHz $\leq f_2 \leq$ 300 GHz, whereas $\Delta R_1(P_{f_2}, I)$ was measured in the entire range of f_1.

[3] If the resistance is determined only by the absorbed power, then k is the absorption coefficient of the high-frequency power.

[4] There was practically no heating of the semiconductor lattice. This is evidenced by the similarity of the plots of R(I) and $P_{f_2-f_1}(I)$ at $\Delta R_1 \ll \Delta R_0$ in the continuous regime and in the regime when microsecond pulses were applied with a large off-duty cycle.

[5] To estimate P_{f_2} for the purpose of determining η, we used the dependence of R on I (Fig. 1) and assumed that the sample resistance is mainly a function of the absorbed power.

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SOME RESULTS OF INVESTIGATIONS OF NONLINEAR PHENOMENA IN THE F-LAYER OF THE IONOSPHERE

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Results of experiments on the nonlinear action of powerful radio waves on the F-layer of the ionosphere are reported and discussed.

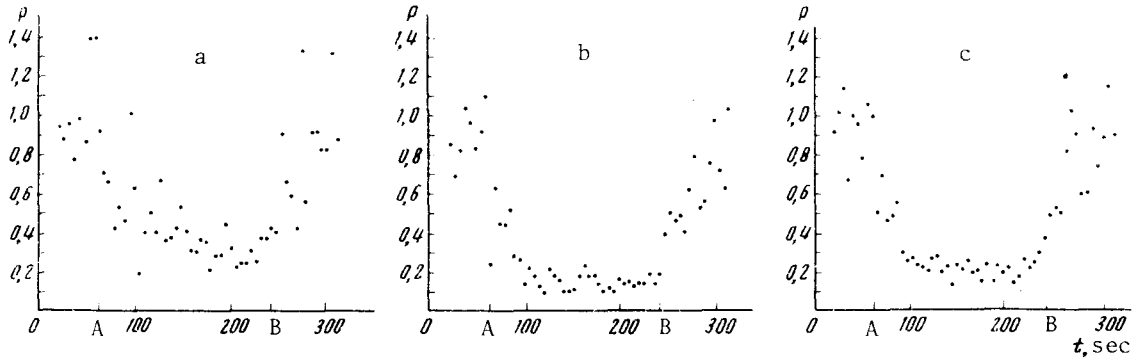
Ginzburg and Gurevich back in 1959 [1], and later Farley [2], pointed out that a strongly-ionized plasma, particularly the F-layer of the ionosphere, can be the site of nonlinear effects connected with heating the plasma with sufficiently powerful electromagnetic radiation. Experiments on the nonlinear action of powerful short-wave radiation on the F-layer were performed in Boulder and in Arecibo (Puerto Rico) in 1970 [3 - 5].

We present here some experimental data on nonlinear effects in the F-layer, obtained in the city of Gor'kii in 1973.

A circularly polarized pump wave was radiated vertically upward at 5.75 MHz by an antenna with gain G ≃ 150. The transmitter had an average power P ≃ 60 kW and could operate in either a cw or a pulsed mode with $P_p \simeq 300$ kW, pulse duration $\tau \simeq 8$ msec, and repetition frequency 25 Hz.

An auxiliary ionospheric station, located at the same site, was used for the diagnostics of the F-layer state.

The experiments were performed in March - June 1973, in morning and evening hours, when the critical frequency of the F layer was close to 5.75 MHz, and the radio-wave absorption in the D region of the ionosphere was low. When the pump wave was turned on, an appreciable decrease (by a factor 3 — 10) was observed in the intensities of thepump wave as well as of the sounding waves in the 5.5 — 5.9 MHz band, and with an approximate characteristic signal-intensity fall-off time 40 sec. When the pump wave was turned off, the intensities of the sounding waves reflected from the ionosphere returned to their initial values after approximately the same characteristic time (see the figure). This phenomenon is apparently analogous to the effect observed in Boulder [3 - 5]. When the sounding-wave frequency was set 0.2 MHz lower than f = 5.75 MHz, the anomalous attenuation of the sounding wave was noticeably reduced (figure). The decrease in the pump-wave and sounding-wave intensities was observed only evenings, only with



Variation of the intensity P(t) (in relative units) of the sounding waves reflected from the ionosphere) in response to a powerful radio wave incident on the ionosphere: a) sounding wave frequency f = 5500 kHz, b) f = 5745 kHz, c) f = 5760 kHz. A and B are the instants when the high-power transmitter is turned on and off, respectively. Each point is a result of averaging of the sounding wave over 12 successive operating cycles of the high-power transmitter (3 minutes on, 2 minutes off), from 6 to 7 PM, 5 April 1973.

waves of "ordinary" polarization, and only in those cases when the F-layer critical frequency exceeded 5.75 MHz.

In addition to the already mentioned anomalous attenuation of the radio waves reflected from the ionosphere, we observed in our experiment also other effects. In the presence of the pump wave, the frequency of the fadings due to the ionospheric inhomogeneities of the electron density increased (on the average by 30%). In addition, immediately after turning on the pump wave we observed a brief (1 — 3 sec) decrease (and sometimes increase of the sounding-wave intensity, by 5 — 10%, if the frequency of the latter deviated not more than 20 kHz from 5.75 MHz.

When the transmitter power was increased slowly (over 10 minutes) from 0 to 60 kW, the anomalous attenuation of the sounding-wave intensity increased, and when the power was subsequently decreased smoothly, the increase of the sounding-wave intensity was much less pronounced. When the transmitter operated in the pulsed mode, the observed effects were similar to those with cw operation. Unfortunately, the data presented on the change in the statistical properties of the signals reflected from the ionosphere and the dependence of the nonlinear effects on the pump-wave power are only qualitative, and to obtain quantitative results it is necessary to perform more prolonged measurements.

The foregoing experimental data are difficult to explain within the framework of classical concepts based on ohmic heating of a plasma in the field of a high-power wave [6]. In particular, the heating of a plasma in which electron-ion collisions predominate should lead to a decrease in the number of collisions, and hence to an increase in the intensity of the sounding waves. Yet the change of the electron density resulting from the heating, and the associated self-focusing effects, should be small under the conditions of our experiment [6].

The decisive factor is here apparently parametric instability, which leads to a strong increase of the intensity of the plasma waves near the point of reflection of the powerful wave with "ordinary" polarization. This conclusion is favored by direct experiments on the diagnostics of plasma waves, performed at Arecibo, and by the theoretical arguments developed in [7 - 9]. However, the theory of parametric instability in an isothermal plasma, where excitation of low-frequency turbulence is forbidden, cannot explain the principal effect, namely the decrease of the intensity of the waves reflected from the ionosphere in a wide frequency band (exceeding 0.2 MHz), with a characteristic time $\sim$ 40 sec. This effect may be due to the decay of the transverse wave into plasma and low-frequency ion-cyclotron oscillations, which can exist also in a weakly-nonisothermal plasma ($T_e \gtrsim T_i$). The increments of such decays are much lower than the maximal increments of the parametric instability, and under the conditions of the ionospheric experiment the characteristic times can amount to dozens of seconds. Owing to accumulation effects, the intensity of the low-frequency turbulence can turn out to be sufficient to cause a strong anomalous attenuation of the transverse-wave energy.

Thus, the results described above and of similar experiments are, in our opinion, crucial for the development of a theory of nonlinear interaction between powerful electromagnetic radiation and a plasma.

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NONSTATIONARY PARAMETRIC TURBULENCE OF A PLASMA

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We have investigated the evolution of plasma turbulence initiated by parametric instability (by the decay of the pump wave into two plasmons) and saturated by induced scattering of the plasmons from the ions. We show that parametric turbulence develops in a dense plasma during a nanosecond pulse from a powerful neodymium laser, and is essentially nonstationary as a result of the oscillations of the noise about the turbulence level.

A vital problem in the theory of parametric instability of plasma is the determination of the temporal evolution of the plasma turbulence (parametric turbulence), which is the physical basis for the mechanisms of absorption and scattering of powerful radiation, and of the heating and acceleration of the plasma particles (see, e.g., the review [1]). We report here the results of a theory of nonstationary parametric turbulence excited in a uniform plasma through decay of a pump wave (with frequency ω_0 and wave vector $\vec{k}_0$) into two plasmons [2, 3] and stabilized by induced scattering by ions[1]. Near the instability threshold, the spectral energy density of the plasma noise is given by

$$W(k, \theta, t) = \sqrt{2}(2\pi/k)^2 s_0 n_e \kappa T_e y(x, \tau)\, \delta(k - k_m),$$

where the angular distribution y(x, t) satisfies the equation

$$\frac{\partial y(x,\tau)}{\partial \tau} - \frac{1}{y(x,\tau)} = y(x,\tau)\left[a^2 - x^2 - \alpha \int_{x_1}^{x_2} dx'\, q(x' - x)\, y(x', \tau)\right]. \qquad (1)$$

Here $k_m = r_{De}^{-1}\sqrt{\omega_0 - 2\omega_{Le}}/\sqrt{3\omega_{Le}}$ is the wave number with extremal value for instability development, ω_{Le} and r_{De} are the Langmuir frequency and Debye radius of electrons with density n_e and temperature T_e (κ is Boltzmann's constant), and θ is the angle between the wave vectors $\vec{k}$ and $\vec{k}_0$. This angle is connected by the relations $x = \theta - \pi/4$ $(0 < \theta < \pi/2)$ and $x = \theta - 3\pi/4$ $(\pi/2 < \theta < \pi)$ with the variable x that determines the deviation of the propagation of the short-wave plasmons $(k \gg k_0)$ from the optimal pump directions $\theta = \pi/4$ and $\theta = 3\pi/4$; $\tau = 4\tilde{\gamma}t$, where $\tilde{\gamma}$ is the plasma-wave damping decrement and takes into account the Coulomb electron-ion collisions and the Landau damping by the electrons. The quantity $a^2 = (1/2)(L - E_{min}/E_0)$ characterizes the excess over threshold, i.e., the excess of the pumping-field intensity E_0 over the minimum E_{min} necessary for instability development. The parameters α and s_0 give the relative weights of the respective contributions of the nonlinear interaction of the turbulent noise and the spontaneous noise described by the second terms in the left-hand side of Eq. (1) (c is the speed of sound, v_{Ti} and