Self-modulation of a powerful electromagnetic pulse reflected from the upper layers of the ionosphere

I. S. Shlyuger

Radio Research Institute

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Anomalous absorption and deep amplitude modulation of a radio pulse reflected from the F layer of the ionosphere have been observed.

The study of the action of radio waves on the upper layers of the ionosphere is of considerable interest. [1] Thus, a number of nonlinear phenomena have been observed[2–4] to occur when strong radiowaves, of frequency close to the critical frequency of the F layer, interact with the ionosphere. Unlike the experiments described in [2–4], we report here the results of vertical sounding of the upper layers of the ionosphere in 1967–1968, carried out at lower frequencies.

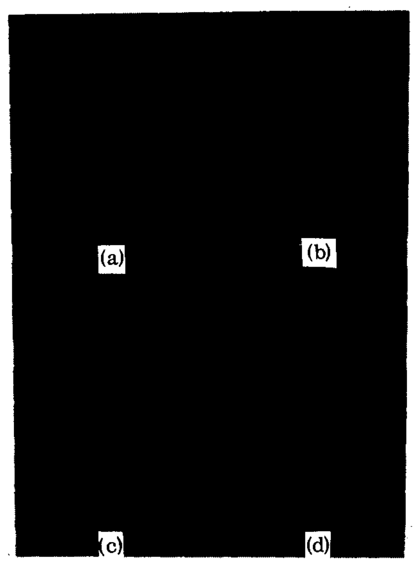
It is shown that the interaction of a short radio pulse of high intensity with the ionosphere plasma has an essentially nonstationary character.

We used for the sounding exciting pulses of almost rectangular waveform, of duration $\Delta t = 5\times10^{-4}$ sec and repetition frequency 25 Hz. The pulse carrier frequency $\omega = 8.48\times10^{6}$ sec^{-1} was chosen to be close to the cyclotron frequency of electrons in the earth's magnetic field. The polarization of the radio signal was rigidly fixed (either ordinary or extraordinary wave).

During the course of the experiments we photographed the sweeps of radio pulses reflected from the ionosphere at various values of the radiated power. The registration rate was 10 frames per second. The obtained pulse power increased linearly within 15 sec from 15 dB to a maximum value 0 dB. The amplitude of the reflected pulses first increased monotonically in this case, but at a rate slower than linear. This, as shown by a detailed comparison with the theory, [1] is well accounted for by the increased frequency of the collisions between the electrons and the neutral particles in the lower layers of the ionosphere, owing to the heating. In nighttime, this nonlinear absorption is small and does not exceed 4–5 dB.

This picture remains only up to some critical value of the power, which is reached approximately at the 10th to 12th second. When this value is exceeded, the amplitude of the reflected signal no longer increases, but decreases with increasing radiation power, i. e., an anomalous absorption of the radio wave appears. Simultaneously, strong distortions of the waveform of the pulse envelope develop at a fast rate, i. e., deep amplitude modulation of the reflected radio signal is observed. These pulse-waveform distortions are irregular in character and pulsate rapidly in time.

The described picture is illustrated in Figs. a–d. The vertical bands in the figure are time markers spaced 10^{-4} sec apart (from left to right). Figures a and b show the reflected pulses at relatively low radiation power (1–3 sec and 7–10 sec, respectively). It is seen that the intensity of the reflected pulse increases with increasing power. Figure c corresponds to a small excess over the critical power (13th second), and Fig. d corresponds to the maximum radiated power (15th sec-



od). We can see that the average power of the reflected signal decreases and that the signal is deeply modulated at a frequency $f = (3-5)\times 10^3$ Hz.

It must be emphasized that the anomalous absorption and modulation of the reflected pulse is observed only during the dark part of the day for an ordinary perturbing wave. Measurement of the pulse delay time shows that in this case the pulse is reflected from the F layer of the ionosphere at heights $h = 200-250$ km. The electron collision frequency at such altitudes is low, so that the characteristic heating time of the electrons is longer by 4–5 orders of magnitude than the duration of the pulse. Special additional measurements carried out at a fixed transmitter power have shown that the average amplitude and frequency of the modulation of the reflected signal remain practically unchanged for a long time, on the order of 10 minutes and more. All this gives grounds for assuming that the observed new phenomena are not due to electron heating.

On the other hand, in the region of reflection of the ordinary wave in the ionosphere, when the threshold E_{thr} of the parametric instability is exceeded, effective excitation of Langmuir oscillations is possible.[5] In our case, the wave field in the region of reflection from the F layer exceeds by more than one order of magnitude the threshold field E_{thr} indicated, e.g., in [6]. The interaction of the incident wave with the excited Langmuir noise can lead to its anomalous absorption and to modulation of the reflected radio pulse. According to [7, 8], the characteristic period of this modulation is $T \sim (1-10)/\gamma$, where γ is the maximum instability increment; under our conditions, $\gamma \sim 10^{-4}$ sec^{-1}.

From the point of view of this interpretation, the observed effects are the results a direct manifestation of self-action of radio waves in the ionosphere, due to excitation of parametric instability. It is therefore undoubtedly of interest to carry out further research, and particularly to measure the phase modulation of the reflected pulse.

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