

Observation of pulsating luminescence of the lower ionosphere, synchronous with pulsed action of a powerful radio wave

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A procedure for observing pulsed luminescence of the lower ionosphere induced by radiation from a powerful pulsed transmitter and the first results of such observations are presented. Emission, synchronous with the pulses of the transmitter, is detected in the short-lived emission of sodium.

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Pulsed injection of radio waves in experiments on perturbing the ionosphere permits greatly increasing the amplitude of the disturbances due to the higher power radiated in the pulse as compared with stationary injection. In the diagnostics of the perturbations, there arises the problem of detecting the emission of the ionosphere, which corresponds to a separate pulse from the transmitter. These measurements can give information on the processes involved in the development and relaxation of disturbances arising during the short pulse of a transmitter. The emission of atomic oxygen from long-lived levels was investigated in a previous work.¹ This technique did not permit observing the temporal variation of the luminescence corresponding to separate pulses from the transmitter. Because of the strong deactivation of excited levels of atomic oxygen, the appearance of the emission of the ionosphere at altitudes of 80–120 km, where heating of the electrons under the action of radiation from the transmitter is maximum,² was also not observed.

Below we present the technique and the first results of observations of pulsating emission of the lower ionosphere induced by the action of radiation from a powerful pulsed transmitter.³ The transmitter emits a “zero”-mode radio wave at a frequency of 1.35 MHz vertically upwards. The pulse duration of the radiation is about 0.5 ms with a repetition frequency of 50 Hz. The ratio E_0/E_p at altitudes of ~ 80 –100 km was ~ 4 –6.

Estimates show that it is impossible to record and, especially, to measure the temporal characteristics of the emission corresponding to a separate pulse from the transmitter due to its low intensity and the considerable level of the background emission of the atmosphere.

To observe the pulsating emission, we use the method of recording and storing separate quanta synchronously with the transmitter pulses, subtracting out at the same time the background emission during the pauses. Figure 1 shows the temporal sequence of pulses from the transmitter, and the periods of summation and subtraction of separate quanta. The technique is based on the reasonable assumption that the intensity of the short-lived emission in the lower ionosphere must relax to the background level within the time between two pulses from the transmitter.

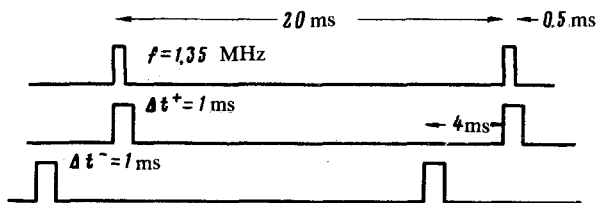


FIG. 1

The use of the proposed technique allowed us to observe the weak pulsating emission to eliminate the dependence of measurements on variations of the background emission intensity with a time scale exceeding 20 ms and to determine the temporal dependence of the emission intensity relative to the transmitter pulse by displacing the periods Δt^+ relative to the pulses from the transmitter.

Figure 2 shows a block diagram of the setup that implements the technique described here. After passing through the amplifier-shaper 1, the pulses from the photomultiplier (PM) corresponding to separate quanta of the emission (the PM operated in the single-electron mode) entered two switches consisting of three-pole I-Ne (&) circuits. The periods with which the switches were opened Δt^+ and Δt^- were controlled by generators of paired 2 and single 3 pulses. Sequential triggering of the single-pulse generator by the paired pulses was necessary in order to eliminate the effect of nonuniform variation in the duration of pulses in a pair on the measurements. The reverse counter 5 accumulated the differences in the count of the light quanta in the periods Δt^+ and Δt^- . The magnitude of the background emission intensity was recorded by the frequency meter 4. The periods Δt^+ were synchronized with the pulses from the transmitter, which were recorded by the receiver 6, according to the alternating-current power grid with 50-Hz frequency and was monitored on the oscilloscope screen 7.

We chose the sodium emission ($\lambda = 5890$ and 5896 \AA) for the measurements. It is well known that Na occurs in the atmosphere in the form of a thin layer at an altitude of 80–100 km, i.e., precisely at the location where changes in the electron temperature produced by the transmitter are large. The low excitation potential (2.09 eV) of this allowed emission with a short de-excitation time $\sim 10^{-8} \text{ s}$ permitted counting on its excitation during the operation of the transmitter.

The photometer, placed 90 km from the transmitter, was oriented toward a region of the ionosphere above the transmitter at altitudes 80–100 km. An interference light filter ($\Delta\lambda_{1/2} = 60 \text{ \AA}$) was used to separate the yellow doublet of sodium. In

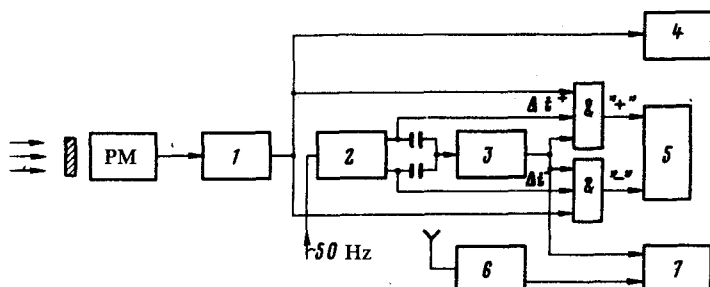


FIG. 2.

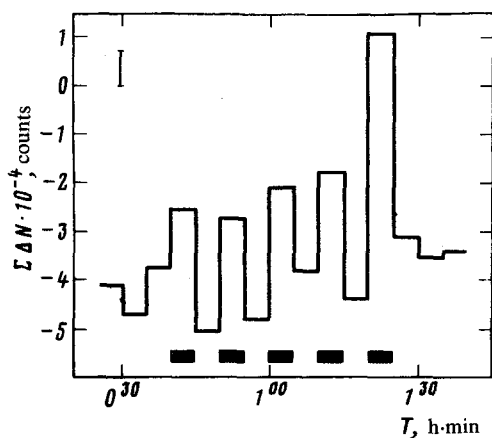


FIG. 3.

checking out the setup, special attention was devoted to ensuring its stable operation and identifying the possible parasitic effects of 50-Hz modulation of the counting rate. Calibration from the constant light source established that the instrumental modulation was $\sim 0.5\%$.

Background observations revealed modulation of the glow of the night sky at a 50-Hz frequency with a depth of not less than 2%. The trivial explanation of this effect is that nighttime illumination of populated areas, whose modulation at a 50-Hz frequency with the common phase of the power grid is entirely realistic, scattered in the atmosphere was recorded. A more interesting possibility is the possibility of pulsations of emission at the level of the ionosphere under direct or indirect action of the radiation from the power grids. In the latter case, the effect deserves detailed investigation, which we propose to conduct in the future.

Figure 3 shows the results of one of the experiments performed on April 11, 1983. The five-minute periods of operation of the transmitter with an equal pause are indicated at the bottom; the random error in the measurements is shown in the upper left corner. The periods of accumulation of the difference in the counts which also amount to 5 min were matched with the operation of the transmitter. We clearly see an increase of the difference in the counts correlated with the operation of the transmitter. This increase, which was observed during each of the five periods of operation of the transmitter, greatly exceeded the error in the measurements. Assuming that during the period Δt^- only background emission was recorded, it may be concluded that the effect of the additional emission within the period Δt^+ corresponds on the average to detection of 1.5 quanta with a detection of 120 quanta from the background emission. Taking into account the geometry of the experiment, and the characteristics of the photometer and the input filter, we estimate that the magnitude of the additional light effect over the period $\Delta t^+ = 1$ ms attains 100 Rayleighs, which corresponds to a surface brightness of the order of 10^7 quanta/cm²·sr·s.

Thus, in our experiments on the action of the radiation from a powerful pulsed transmitter on the ionosphere, we observed the emission of the lower ionosphere, which was detected in the short-lived emission of sodium. The pulses from this emis-

sion were synchronized with the pulses of the transmitter. The data obtained indicate considerable heating of particles in the lower ionosphere over the time of the short pulses from the transmitter.

Further experiments will be directed primarily toward studying the temporal dependence of the emission pulsations: the rise time and the decay time of the emission intensity relative to the pulses from the transmitter.

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