RADIOWAVE SCATTERING IN INHOMOGENEOUS PLASMA IN EXPERIMENTS WITH ELECTRON PULSES IN THE IONOSPHERE

N.S.Erokhin [1], N.I. Izhovkina [2], L.A.Mikhaylovskaya [1]

[1] *Space Research Institute, Russian Academy of Science*
[2] *Pushkov Institute of Terrestrial Magnetism, Ionosphere, and Radio-wave Propagation, Russian Academy of Sciences*

Abstract. The damping and absorption of telemetry radio signals at frequencies of 250 and 75 MHz, transmitted from rockets, was observed in the ARAKS and Zarnitsa 2 rocket experiments, respectively, with electron pulses injected in ionosphere. The signals were registered with ground based receivers. Only four cases of complete signal absorption on the propagation path were observed in the ARAKS experiment. In other periods of electron gun operation scattered telemetry signals were valid to use in analysis of data. These signals were not suppressed by scattering in inhomogeneous plasma. The radio damping and absorption at frequencies substantially higher than the plasma and upper hybrid frequencies can be related to wave scattering by plasma inhomogeneities. It is shown that plasma inhomogeneities were generated when electrostatic oscillations damped in the regions with decreased plasma density at a decrease in the natural oscillations phase volume in the frequency – wave vector space with decreasing plasma density. The observed phenomena of radio waves propagation through unstable and inhomogeneous plasma perturbed by injection of electron pulses could be related to reflectionless wave scattering in an inhomogeneous plasma structure.

Introduction

Telemetry radio wave onboard transmitters are used to supply data from spacecraft equipment. Signal power of such standard communication systems is usually substantially lower than the threshold levels of the wave parametric processes in ionospheric plasma. In active experiments plasma physics studies are performed under specified initial conditions [1]. In ARAKS experiment two rockets with electron guns were launched to generate artificial auroras in geomagnetic conjugate ionosphere and study plasma processes. The onboard equipment included RPA analyzers of electron fluxes with a retarding potential to determine rocket electric potential during injection of electron pulses [2]. The telemetry equipment operated at a frequency of 250 MHz and a wave length of ~ 1 m [3]. A decrease (absorption) in the power level of the telemetry signal, caused by signal scattering by plasma inhomogeneities, was observed during injection of electron pulses from the rocket into ionosphere and between pulses. The wave frequency was substantially (by more than an order of magnitude) higher than the plasma and upper hybrid frequencies of undisturbed ionosphere and several times as high as the indicated frequencies when electron pulses were injected. Radio signal absorption was also observed in the Zarnitsa 2 experiment. In this case, the onboard telemetry operated at a frequency of 75 MHz and a wave length of ~ 4 m [3].Only four cases of complete signal absorption on the propagation path were observed in the ARAKS experiment. In other periods of electron gun operation scattered telemetry signals were valid to use in analysis of data. These signals were not suppressed by scattering in inhomogeneous plasma. The radio damping and absorption at frequencies substantially higher than the plasma and upper hybrid frequencies can be related to wave scattering by plasma inhomogeneities. It is shown that plasma inhomogeneities were generated when electrostatic oscillations damped in the regions with decreased plasma density at a decrease in the natural oscillations phase volume in the frequency – wave vector space with decreasing plasma density [4]. The time of plasma run away from the regions with decreased plasma density heated by damping of electrostatic oscillations can be estimated as $\tau \sim 10^{-2} - 10^{-1}$s for 1 - to 10 m scales of such regions [4]. The observed phenomena of radio waves propagation through unstable and inhomogeneous plasma perturbed by injection of electron pulses could be related to reflectionless wave scattering in an inhomogeneous plasma structure.

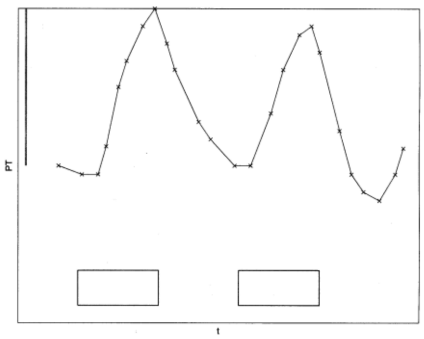

Fig.1 PT absorption curve of a telemetry signal in the ARAKS experiment for two successive electron pulses lasting 20 ms and the pause between these pulses 20 ms. The pulses are shown with rectangles. The vertical straight line segment in the left hand part of the figure corresponds to the absorption variation PT ~ 10 dB which corresponds to a decrease in the received telemetry signal power by ten times relative to the normal level.

Plasma inhomogeneities the characteristic dimensions of which are comparable with the telemetry transmitter wave length, could be generated in the disturbed ionospheric region on the radio beam propagation path, when electron pulses were injected from the rocket into ionosphere. The inhomogeneous plasma density modulation could be substantial when electrostatic oscillations damped in the regions with decreased plasma density. The electron fluxes observed with the RPA devices at the electron distribution high energy tails could be stimulated by electrostatic oscillations damping and a charged particles polarization drift [4]. Inhomogeneous plasma structures near the rocket could be initiated at an electrostatic instability of hot, low temperature for the ionosphere, magnetized plasma. This could result from non monotonic dependence of the electrostatic oscillation permeability on the spatial coordinates at a monotonic initial dependence of the plasma density on coordinates [5]. The observed telemetry signal absorption could be related to reflectionless radiowave scattering in an inhomogeneous plasma structure. The telemetry signals were strongly damped but were proper to use in the analysis of data of the onboard equipment. And these radio signals crossed the plasma cloud near the rocket strongly perturbed by electrostatic oscillations and inhomogeneities.

Conclusion

The radiosignal absorption growth time in telemetry operation in ARAKS and Zarnitsa 2 experiments relative to electron pulse injection onset is comparable with the time during which the regions with a decreased plasma density were heated by the electron component electrostatic oscillations damping. The plasma density spatial modulation is intensified as the broad band spectrum of free electrostatic oscillations is transformed and the oscillations which fall in the range of the forced disturbances when propagate in an inhomogeneous plasma, damp. The telemetry signals were strongly damped but were valid to use in the analysis of data of the onboard equipment. So the nonreflection wave scattering is proper to explain the conservation of the telemetry signals in the cross through the clouds of unstable and inhomogeneous plasma.

References

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