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Parametric frequency transformation in time-varying magnetoplasma and the formation of the discrete spectra of radio emissions in space and laboratory plasmas

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Abstract

We consider an effect of the amplitude and frequency modulation of the waves in time-varying magnetoplasma. Model laboratory experiments are performed on large KROT device, in which we study the propagation of electromagnetic waves in plasmas with intense low-frequency magnetic disturbances. Based on the results obtained we propose the model for the formation of the discrete structure of the radio emissions in planetary magnetospheres, including Earth and Jupiter.

Introduction

Adiabatic (or non-resonant) frequency transformation occurs when the electromagnetic wave propagates in a medium with time-varying refractive index. Generally, the frequency modulation can be described by the frequency transfer equation as follows:

$$\frac{\partial f}{\partial t} + (\mathbf{v_g}\nabla) f = -f\left(\frac{\partial(nf)}{\partial f}\right)^{-1}\frac{\partial n}{\partial t},$$

where f is a radiation frequency, $\mathbf{v_g}$ is a group velocity vector, n is a refractive index of the medium. In magnetoplasma, time variations of the parameters like density or ambient magnetic field lead to frequency modulation. Primarily we consider the magnetic perturbations, since the magnetic field is less “sluggish” than the plasma density, and even strong variations of the magnetic field in Earth magnetosphere are not always accompanied by the density disturbances. Indeed, some types of structured – or discrete – radio emissions in planetary magnetospheres are accompanied by intense magnetic disturbances of the corresponding period, like modulated whistler-band emissions or structured Pc1 pulsations in Earth magnetosphere. Moreover, when frequency modulation occurs, amplitude modulation appears due to group velocity dispersion and corresponding compression effects, especially around the cyclotron resonance frequencies, either electron or ion.

Experimental results and discussion

KROT plasma device is designed for the model studies of space plasma physics phenomena. It represents a stainless steel vacuum chamber with the volume 180 m^3, which is evacuated down to the base air pressure $p = 3 \times 10^{-6}$ torr. Working gas (Ar) pressure is $p = 5 \times 10^{-5} \ldots\ 5 \times 10^{-3}$ torr. Plasma is produced via pulsed inductive RF discharge in ambient magnetic field of up to $B_0 \sim 100$ G. Electromagnetic waves with frequencies 50 – 200 MHz were injected into plasma by antennas, and low frequency magnetic disturbances (0,1 – 5 MHz) of intensity up to $\Delta B/B_0 \sim 5\%$ were generated via additional coils with ac current. The electromagnetic waves were exited mainly in a whistler mode, i.e. below the electron gyrofrequency.

Experiment (Fig. 1) shows that during its propagation the wave, which is initially monochromatic, undergoes the modulation of the amplitude and the frequency with the period of the magnetic field variations. Relative frequency shift is as large as relative magnetic disturbance, $\Delta f/f_0 \sim \Delta B/B_0$. Deep amplitude modulation due to group velocity dispersion is observed; the signal which is initially continuous transforms into the sequence of wave bursts with carrier frequency drift.

Based on our results we propose the mechanism for the formation of structured natural emission spectra due to intense MHD disturbances in planetary magnetospheres. In Earth magnetosphere, this mechanism can lead to structured Pc1 (or “pearls”) formation due to modulation of continuous ion-cyclotron waves by intense long-period Pc4-5 pulsations. The correlation between pearls occurrence and Pc3-5 pulsations was considered in a number of papers [1]. Moreover, for Pc1 some dimensionless parameters like the relative magnetic disturbance level, number of the wavelengths along the propagation path, high frequency / low frequency ratio and so on are quite similar in KROT experiment for whistler waves and in Earth magnetosphere for Pc1 waves.

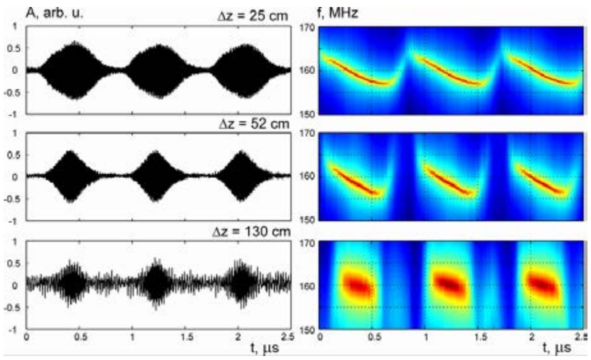

Figure 1. The waveforms (left) and dynamic spectra (right) of the test whistler wave along the propagation path in plasma region with periodic magnetic field disturbance.

The similar parametric effect can explain the formation process of S-bursts in decametric Jovian radio emission. In this case, the wave bursts with the pronounced carrier frequency drift can be generated from the continuous waves exited around the electron gyrofrequency during their propagation in ionospheric regions with intense MHD disturbances, particularly in Io flux tube. The analysis of this situation can also be performed based on laboratory experimental results and calculations [2].

Conclusions

Laboratory experiment shows the importance of the adiabatic frequency transformation effect in a time-varying magnetoplasma. The mechanism is demonstrated for the structuring of continuous radiation by the magnetic disturbances. Based on the amplitude-frequency transformation effect in a time-varying magnetoplasma, the new models for the modulation of natural emissions by low-frequency MHD disturbances in planetary magnetospheres are proposed.

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References

[1] Plyasova-Bakounina, T.A., J. Kangas, K. Mursula et al, Pc1-2 and Pc3-4 pulsations observed at a network of high-latitude stations. J. Geophys. Res., V.A101, pp.10965-10975 (1996)

[2] Shaposhnikov V.E., S.V. Korobkov, H.O. Rucker et al, Parametric mechanism for the formation of Jovian millisecond radio bursts. J. Geophys. Res., V.A116, pp. A0325 (1-10) (2011)