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Parametric generation of low frequency waves by electrons accelerated in ECR regime

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Abstract

Resonant plasma heating in the vicinity of powerful satellite-borne transmitters is observed if the operating frequencies approach the main (plasma and cyclotron) resonances and their harmonics [3], [4], [5]. In this paper we propose to use the flows of accelerated particles arising from electron cyclotron resonance (ECR) plasma heating for the parametric generation of low frequency waves in Earth ionosphere. The model laboratory experiments are performed on KROT device, in which the proposed generation scheme is verified.

1. Introduction

The idea of low frequency waves' generation can be described as follows. ECR acceleration of electrons is the vicinity of antenna is accompanied by an increase of their average magnetic moment. As a result the diamagnetic effect is observed in the flux tube filled with accelerated particles. If the HF signal applied to antenna is modulated periodically, than the diamagnetic effect is also modulated with corresponding period, and the radiation of the waves at the modulation frequency to the surrounding plasma is possible. Since the "bodiless" antenna is of the magnetic type, the favorable conditions for the electromagnetic waves' excitation are realized, such as whistler and Alfven modes.

2. Experimental arrangement and results

Laboratory model experiments were performed on large KROT device [2] in an afterglow, Maxwellian, cold, and weakly magnetized plasma. Experimental parameters were chosen according to "similarity transformations" with scaling factor $\gamma \sim 100$ [1], and corresponded to physical conditions in topside ionosphere. Magnetic loops as well as electric dipole antennas were used to accelerate the electrons with the maximum HF power input of about 300 W at frequency $f \sim 70$ MHz. Resonant diamagnetic effect caused by ECR acceleration of electrons at first and second gyroharmonics was clearly detected at the level of up to $|\Delta B|/B \sim 10^{-3}$ (see Fig. 1).

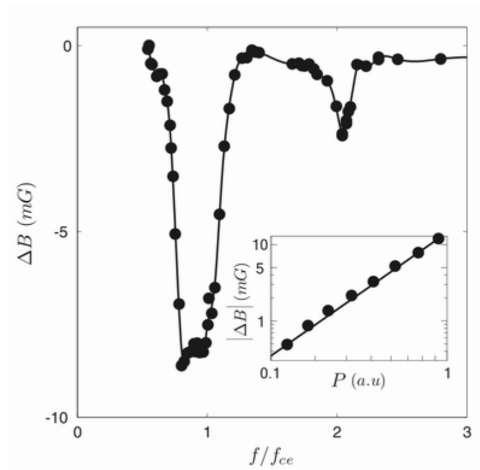

Figure 1: Diamagnetic effect in antenna vicinity as a function of transmitter frequency f versus electron gyrofrequency f_{ce}. Inset shows the diamagnetic effect versus HF power. Plasma density $n_e \sim 10^{10}$ cm^{-3}, electron temperature $T_e \sim 1$ eV.

As the HF power feed to antenna was modulated periodically, excitation of the waves at the modulation frequency was observed. The modulation frequency f_m was chosen considerably higher than the ion gyrofrequency, $f_{ci} << f_m << f_{ce}$, and the excitation of whistler mode waves took place. Detailed analysis identified these waves as Gendrin modes having a perpendicular wave number far exceeding the parallel one. Excitation of these waves is explained by the geometry of the "bodiless" antenna, which is narrow (the diameter of the flux tube filled with accelerated electrons is determined by the antenna aperture), but stretched along the ambient magnetic field direction.

The waves exited were detected over the huge plasma area: although the perturbed plasma area (“antenna”) diameter was smaller than 10 cm, low frequency radiation occupied the entire plasma column having a diameter of 150 cm. The amplitude of the magnetic component in low frequency waves was two orders smaller than in initial (source) diamagnetic disturbance, and was about $|\Delta B|/B \sim 10^{-5}$. The maximum intensity of the waves was observed as the transmitter frequency approaches the main gyroresonance, $f \sim f_{ce}$ (Fig. 2).

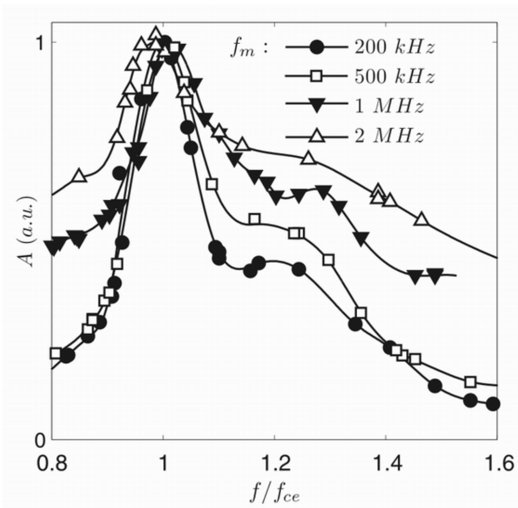

Figure 2: The normalized amplitude of low frequency whistler waves excited at a modulation frequency f_m as a function of the transmitter frequency f versus electron gyrofrequency f_{ce}. Experimental parameters are the same as for Fig.1.

3. Summary and Conclusions

The model laboratory experiments show that the ECR acceleration of electrons by the amplitude-modulated HF signal in a vicinity of the satellite borne transmitter in Earth ionosphere can be used for the excitation of low-frequency waves, particularly of the whistler mode waves. Based on the laboratory results, and using the similarity transformations [1], the diamagnetic disturbances induced in ionosphere in 10-100 m antenna vicinity are estimated as $|\Delta B| \sim 10–100$ nT for the transmitter power of 100–1000 W. Correspondingly, the amplitude of the magnetic component in VLF whistler mode waves with frequencies 1–10 kHz can reach the level of about $|\Delta B| \sim 0.1–1$ nT.

We propose to use the proposed method of VLF waves’ excitation in future active ionospheric experiments with powerful topside sounders.

Acknowledgements

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