The analysis of double-peaked spectrum in the enhanced plasma lines

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Abstract

The polar winter ionospheric heating experiments with the heating frequency linearly varied are carried out on November 23, 2011 at Tromsø, Norway. The heating waves were O-mode polarization. A double-peaked spectrum is present in the enhanced plasma lines which observed with UHF incoherent radar, and the two peaks are at different frequencies. The enhanced structure is present throughout all the heating time, and the enhancement could reach several tens of thousands times larger than that of background. By the analysis of UHF radar data and the theory which could affect the plasma lines structure, the enhanced plasma spectrum in this paper may be caused by suprathermal electrons. With the incidence of powerful HF waves on ionosphere, the ambient electrons around reflection height are accelerated, and some of them become suprathermal electrons. Then the electron speed distribution function is changed, hence the double-peaked spectrum is formed.

Keywords: ionospheric heating; plasma lines; linearly varied heating frequency; suprathermal electrons

1. Introduction

Ionosphere is an important region of the earth's atmosphere, which can impact on the electronic wave. Along with the progress of science and technology, people can study ionosphere with artificial measure and ionospheric heating is one important method. Many phenomena can be observed from the ionospheric heating experiments, such as temperature enhancement[1], electron density depletion[2], abnormal absorption of radio wave[3], Langmuir turbulence excitation [4][5], simulated emission [6][7], VLF, ELF and ULF waves excitation [8][9], airglow[10], filed aligned irregularities[11][12].As the basis of ionospheric heating effect, the disturbance of plasma line has been widespread studied[13][14]. The enhanced ion-line and plasma-line during ionospheric heating are introduced in detail by Rietveld and Kohl, in the matching height of parametric instability, cascades can be observed in the plasma line spectra[15][16]. Some initial enhanced plasma lines observed by EISCAT are described in Hagfors's review[17]. However, most of the ion and plasma lines introduced above usually observed in a constant heating frequency experiments.

The polar winter ionospheric heating experiments with the heating frequency linearly varied are carried out on November 23, 2011 at Tromsø, Norway. Based on the analysis of the experiments data, a double-peaked plasma lines is present and the possible mechanism is also introduced in this paper.

2. Description of the experiment

The polar winter ionospheric heating experiments are carried out on November 23, 2011. The high power heating facilities and the diagnose facilities used in the experiments are located in Tromsø, Norway(69.59N, 19.23E). EISACT heating facilities have three antenna arrays[16]. In order to obtain a good result, we use the arrays 1 in this experiment according to the ionosphere condition. The heating waves used are O-mode polarisation, and heating beams point to the direction of geomagnetic field. The whole experiment consisted of 4 consecutive cycles, and each cycles contains an 18 min HF-on period and 12 min HF-off period, as is shown in Table1. The first cycle of this heating experiment is mainly studied in this paper. The start time is 12:00, the end time is 12:18, and heating frequency is varied with time from 7 MHz to 6.7MHz. The frequencies are being steeped every 10s. The diagnose facilities are UHF incoherent radar. The UHF radar works in beata mode: time resolution of 5s, spatial resolution of 3km, and detection range of 76~670km. The UHF radar scanning mode is CP1, and the detection direction is parallel to the direction of the magnetic field.

Table1. Heating schedule on 23th November 2011.

	Case1	Case2	Case3	Case4
HF-on	12:00-12:18	12:30-12:48	13:00-13:18	13:30-13:48
HF-off	12:18-12:330	12:48-13:00	13:18-13:30	13:48-12:00
f/MHz	6.99722~6.70278	6.70278~6.99722	6.99722~6.70278	6.70278~6.99722

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3. The Analysis of UHF Radar Data

By the analysis of the experiments data, the plasma lines observed with UHF radar is shown in Fig.1. The x-axis represents Doppler frequency, and the y-axis represents the amplitude of echo power. The up panel of Fig.1 is plasma lines with heater-off, and the maximum value of plasma line in the natural state is below 0.02K/kHz. The down panel is plasma lines with heater-on, the amplitude of plasma lines is enhanced immediately when the heater is on, and a double-peaked structure is present in the plasma spectra. The two peaks are at different frequencies. In Fig.1, the first peak is at ~7MHz which is closed to the heating frequency, and the second peak is at ~9.5MHz.

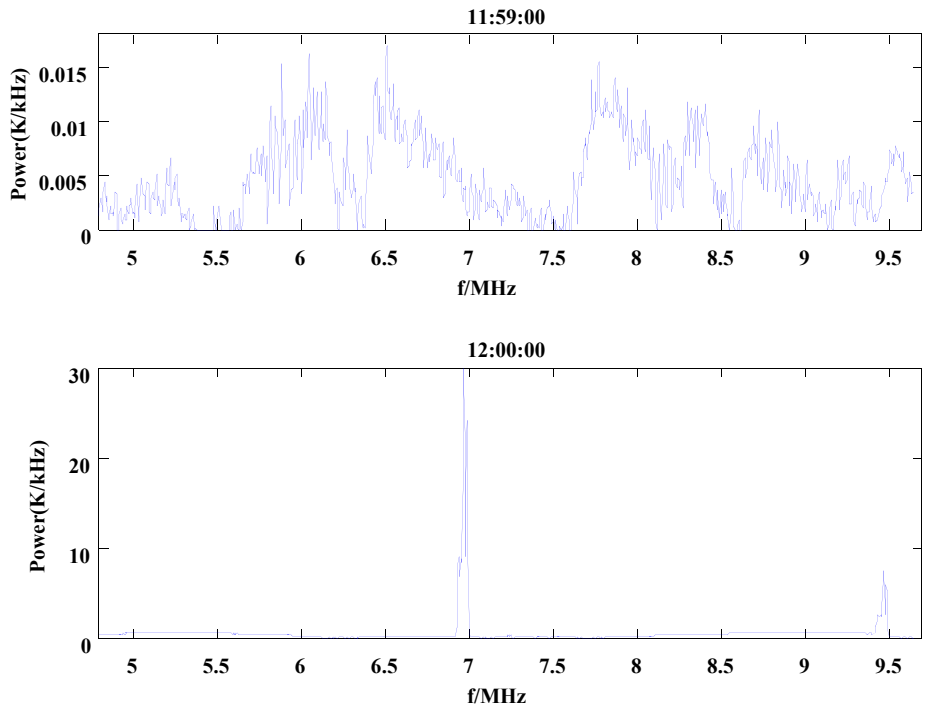

Fig.1. Plasma lines with heater off or on

Then the mechanism for the double-peaked plasma lines is discussed below. In general, the structure of plasma line is determined by the electron velocity distribution function. According to hydrodynamics, the plasma line is simulated, and the Fig.2 and Fig.3 are the diagrammatic sketches of the simulation result. In the nature station, the electrons in the ionosphere are normal distributed, and the corresponding plasma line is shown in Fig.2. The plasma line is one-peaked lines in the nature station. When the heater is on, the powerful HF wave is incident on ionosphere, the ambient electrons around reflection height are accelerated. As the mass of electron is extreme little, the velocity of electrons can be easily enhanced, and some of them become suprathermal electrons. Then the electron speed distribution function is changed, hence the double-peaked spectrum is formed. As is shown in Fig.3, the double-peaked structure is formed in the plasma line, hence the double-peaked plasma lines in this experiment may be caused by suprathermal electrons.

4. Conclusions

The polar winter ionospheric heating experiments are carried out on November 23, 2011 at Tromsø, Norway. A double-peaked spectrum is present in the enhanced plasma lines which observed with UHF incoherent radar, and the two peaks are at different frequencies. The enhanced structure is present throughout all the heating time. In general, the structure of plasma line is determined by the electron velocity distribution function. In the nature state, the plasma line is one-peaked. When the heater is on, the powerful HF wave is incident on ionosphere, the ambient electrons around reflection height are accelerated. As the mass of electron is extreme little, the velocity of electrons can be easily enhanced, and some of them become suprathermal electrons. Then the electron speed distribution function is changed, and the double-peaked spectrum is formed. So the double-peaked plasma lines in this experiment may be caused by suprathermal electrons.

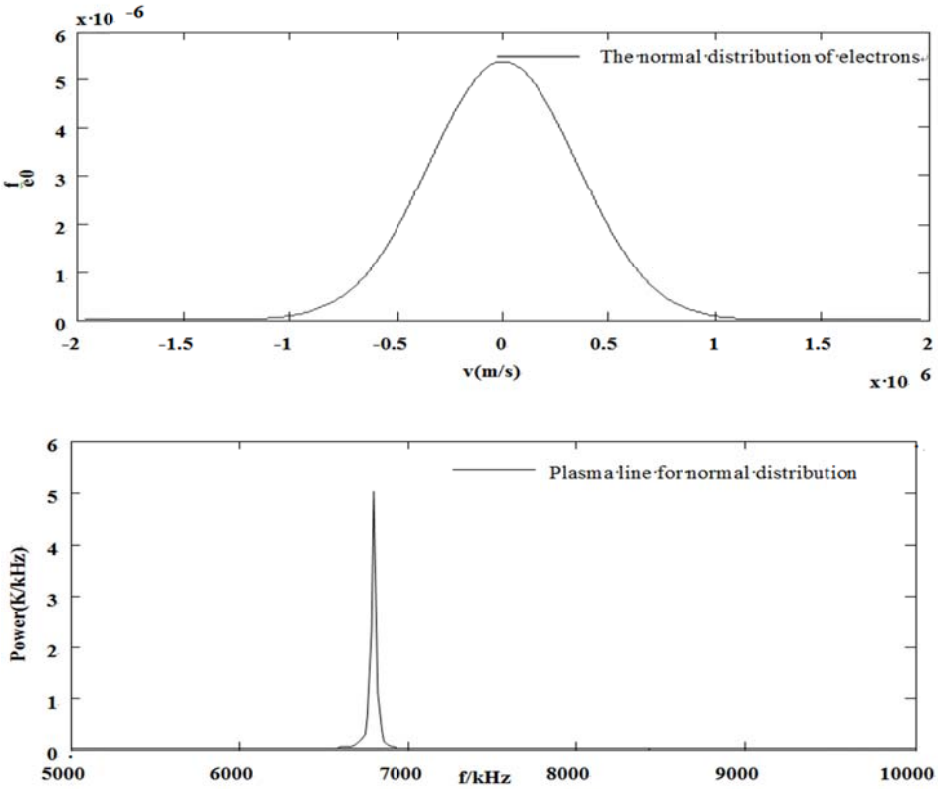

Fig.2. The normal distribution of electrons and the corresponding plasma line

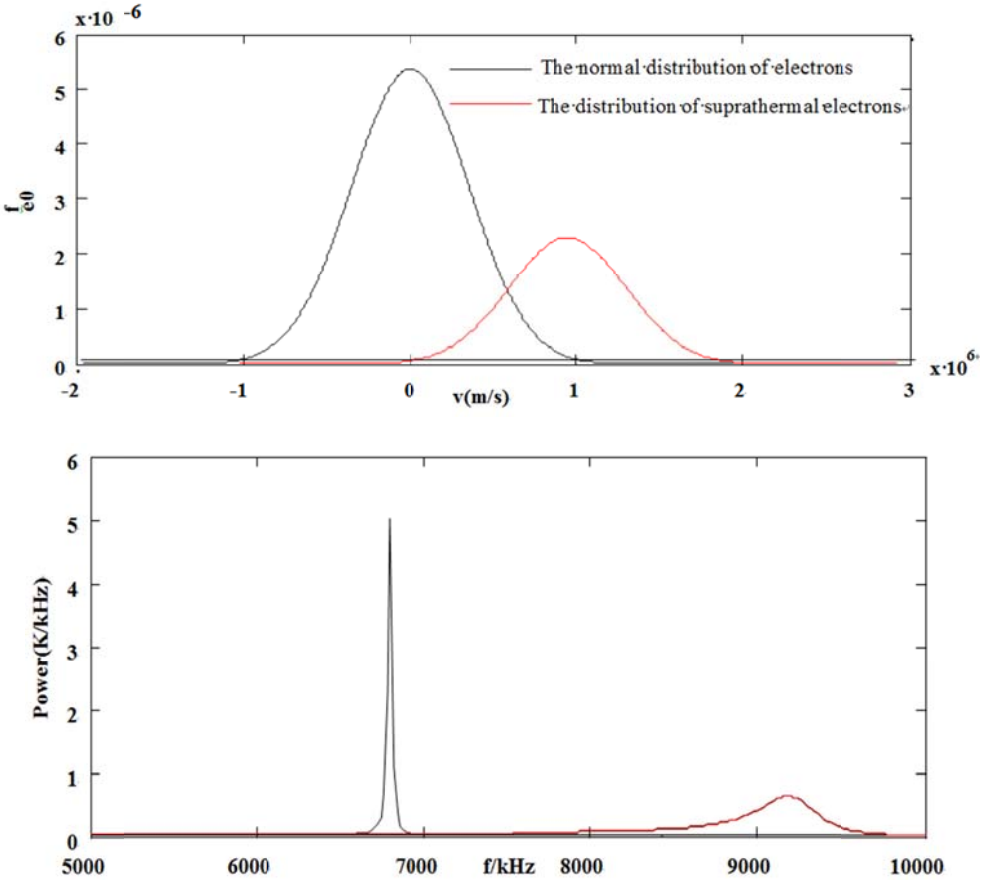

Fig.3. The normal distribution of electrons and the corresponding plasma line

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