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Observation of VHF incoherent scatter spectra disturbed by HF heating

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ABSTRACT

We report on EISCAT ionospheric heating experiments carried out on 13 September 2010 at Tromsø, Norway. This paper focuses on the long-lasting enhanced ion- and plasma-lines observed by the VHF incoherent scatter radar. In previous experiments, the enhanced ion-lines observed by VHF radar lasted ~200 ms. Observations of long-lasting enhanced ion- and plasma-lines in the VHF radar have not been reported before. The enhanced lines may be caused by Parametric Decay Instability (PDI). In addition, the VHF data show that the enhanced ion-lines are descending in altitude with time during the heater-on period. Likewise, the temporal and spatial evolution of the enhanced plasma-lines also show a similar morphology and generally occur at the same height. At last a possible mechanism for the altitude evolution is given in this paper.

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1. Introduction

It is well known that powerful HF radio waves transmitted from high-power ground-based heating facilities can strongly modify the ionosphere plasma. Rietveld et al. (1993) and Kohl et al. (1993) discuss the enhanced ion-line and plasma-line during ionospheric heating in their reviews. The excitation of artificial small-scale field-aligned irregularities (or so called striations) (Blagoveshchenskaya et al., 2007; Blagoveshchenskaya, et al., 2011; Gurevich et al., 1998), temperature enhancement and density depletion (Robinson et al., 1996; Saito et al., 2001; Bin et al., 2010), VLF, ELF and ULF excitation (Rietveld et al.,1984; Rietveld et al.,1987), airglow (Bernhardt, et al., 1989; Mishin et al., 2000; Mishin et al., 2003), PMSE overshoot (Havnes et al., 2003; Isham et al., 1990), and stimulated electromagnetic emission (Nordling et al., 1988; Tereshchenko et al., 2006) are associated with HF heating experiments. Among these phenomena discovered from ionospheric modification experiments, one of the most outstanding is the enhancement of incoherent scatter radar (ISR) ion- and plasma-line backscatter (Borisov and Hagfors, 2001; Rietveld et al., 2000).

Hagfors et al. (1983) presented some initial observations of heater-induced plasma-line enhancements observed by the EISCAT UHF radar, and the overshoot and the higher-order spectral features were described in detail. Djuth et al. (1986) investigated the temporal evolution of the HF-enhanced plasma-line in the F region at Arecibo with several different HF pulse lengths and HF transmitter duty cycles. Djuth et al. (1987) showed that the temporal development of the HF-enhanced ion waves exhibit an "overshoot" behaviour similar to that of the HF-induced Langmuir waves in their experiments. Fejer et al. (1989) investigated the different growth times of the thermal and ponderomotive type parametric instabilities with simultaneous observations of the enhanced plasma-line and the reflected HF wave. Noble and Djuth (1990) measured HF-enhanced plasma-lines and artificial geomagnetic field-aligned irregularities with two radar systems simultaneously.

Pump-induced ion-line (and plasma-line) enhancements in incoherent scatter radar data are commonly observed, both in UHF and VHF, and are usually short-lived. Long-lived enhancements have been reported in the EISCAT UHF radar (Ashrafi et al., 2007; Djuth et al., 1994). These are generally thought to occur when HF pumping near gyro-harmonic frequencies, which suppresses the growth of field-aligned plasma irregularities (Kosch et al., 2002). These so-called striations cause anomalous absorption of the HF pump wave by scattering. To the authors' knowledge, long-lived VHF enhancements at EISCAT, observed in the experiment described below, have not been reported before. In this paper, long-lasting enhanced ion- and plasma-lines observed by the VHF ISR are studied, some typical characteristics are analysed, and finally the major conclusions are given.

2. Description of the experiment

The experiment was carried out with the EISCAT high power ionospheric heating facility (Rietveld et al., 1993) and radar

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Table 1
Heating schedule on 13th September 2010.

	Case1	Case 2	Case 3	Case 4	Case 5	Case 6
HF-on	10:00–10:08	10:12–10:20	10:24–10:32	10::36–10:44	10:48–10:56	11:00–11:08
HF-off	10:08:10:12	10:20–10:24	10:32–10:36	10:44–10:48	10:56–11:00	11:08–11:12
	Case 7	Case 8	Case 9	Case 10	Case 11	Case 12
HF-on	11:12–11:20	11:24–11:32	11:36–11:44	11:48–11:56	12:00–12:08	12:12–12:20
HF-off	11:20–11:24	11:32–11:36	11:44–11:48	11:56–12:00	12:08–12:12	12:20–

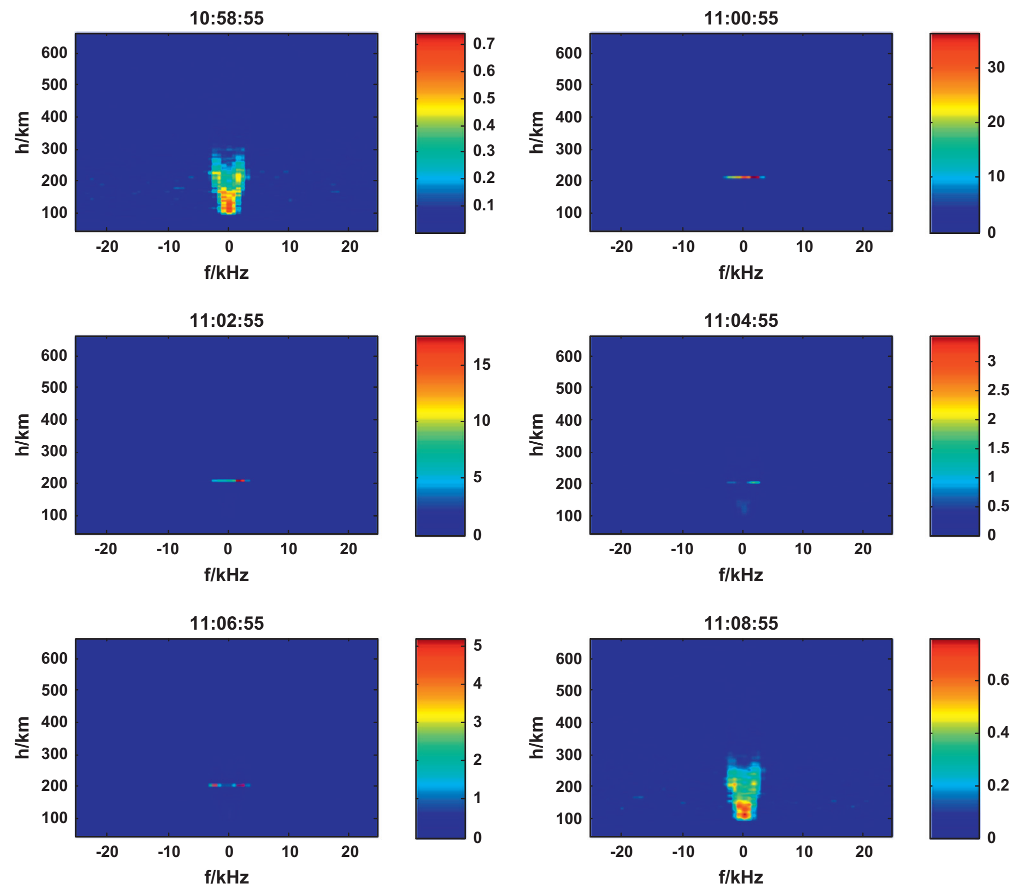

Fig. 1. Ion line spectra with the HF-pump off or on. The *x*-axis represents Doppler frequency, the *y*-axis represents height, and pseudo-colour corresponds to the amplitude of echo power. The first and last panels are the spectra with HF off.

diagnostic facilities on 13th September 2010 at Tromsø, Norway. The EISCAT heater is composed of three antenna arrays designed to cover the frequency range from 4 to 8 MHz. According to the ionospheric condition we chose array 1 for this experiment. The heater transmitted at a frequency of 5.423 MHz, which is close to the fourth electron gyro-harmonic frequency in the F-layer above EISCAT. The heater used O-mode polarisation, with an effective radiated power (ERP) of 286 MW, and its pointing direction was parallel to geomagnetic field. The VHF radar was pointed vertically to measure the backscatter, electron temperature and electron density. Since the heater was pointing 12°S, the ERP in the vertical direction was 3.3 MW. The whole experiment consisted of 12 consecutive cycles, with each of the heating cycles containing an 8 min HF-on period and 4 min HF-off period. As is shown in Table 1, the experiment started at 10:00 UT with the transmitter on and ends at 12:20 UT. The VHF radar used the beata code in this experiment, giving a spatial resolution of 3 km with a detection range of 77–674 km, and time resolution of 5 s.The integration time used in this paper is also 5 s.

3. The characteristics of enhanced ion and plasma lines

The enhanced ion-lines observed with VHF radar for pump cycle 6 (11:00–11:08 UT) with a time resolution of 5 s are shown in Fig. 1. The *x*-axis represents Doppler frequency, the *y*-axis represents height, and pseudo-colour corresponds to the amplitude of echo power. There is a typical smooth double-humped spectrum above 150 km before the HF transmitter is switched on (see first and last panel), which is due to the normal ion Landau damping. The spectral shape is directly related to the ionospheric parameters, i.e. the area of ion-line spectra is proportional to the electron density and the peak to valley ratio is proportional to the ratio of electron to ion temperature (Evans, 1969). At lower altitudes, the double-humped spectra gradually degrade to a single peak because of the decrease of the ratio of electron to ion temperature and the increase of the collision frequency.

At heater on, the structure of the typical incoherent scatter spectra disappears around the reflection height (∼210 km) immediately. At other heights the normal incoherent scatter spectra are still present,

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