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EXCITATION OF IONOSPHERIC ALFVEN RESONATOR BY ARTIFICIAL MAGNETIC PULSATIONS

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Abstract. On November 19, 1998, time interval 15.30-17.30 UT, an experiment on generation of artificial magnetic pulsations in Pc1 frequency range was carried out. The pump wave was modulated with three frequencies of 1, 2 and 3 Hz; each modulation frequency being used for 5 minutes. The heating wave frequency was 5.423 MHz; for three modulation cycles the pump wave polarisation was Ordinary (o-mode) and then for one cycle it was changed to eXtraordinary (x-mode). Clear ionospheric response is detected during the first hour of the heating at 180-km distance by induction magnetometer. A very interesting feature of the ULF emissions at 1 Hz is seen in the time interval 16.20-16.25 UT: pulsation amplitude is significantly increased, especially in D-component. EISCAT radar electron density and electric field measurements do not exhibit any changes in the ionosphere for this interval. However, natural pulsations of decreasing frequency indicate the resonance frequency of the Ionospheric Alfven Resonator (IAR) before this modulation cycle. It seems to be around 1 Hz and the growth of artificial pulsation intensity observed on the ground may be interpreted in terms of IAR eigenmode excitation.

1. Experiment setup

The EISCAT heating facility in Tromsø was used for generation of artificial electromagnetic emission. A two-hour heating run on November 19, 1998 was aimed at effective generation of artificial magnetic pulsations in the Pc1 frequency range. Three modulation frequencies of 1, 2 and 3 Hz were used. The HF transmitter power with an Effective Radiated Power of 280 MW was modulated as a sine-wave and the frequency of the HF-pump wave was chosen to be 5.423 MHz. Heating with a fixed modulation frequency lasted for five minutes. Duration of an experiment sequence is equal to 15 minutes, and at any fourth and eighth sequence commencement polarization of the pump wave was turned from o-mode to x-mode and visa-verse.

A modification of the electron temperature takes place in accord with the pump wave power (Rietveld et al., 1986). Changes in the temperature of the electrons via the electron-neutral collision frequency modify the ionospheric conductivity. Variation of the conductivity in the heated volume produces disturbances in the ambient currents in the ionosphere, the magnetic effects of these can be observed on the ground as low frequency electromagnetic pulsations (Rietveld et al., 1986; Maul et al., 1990).

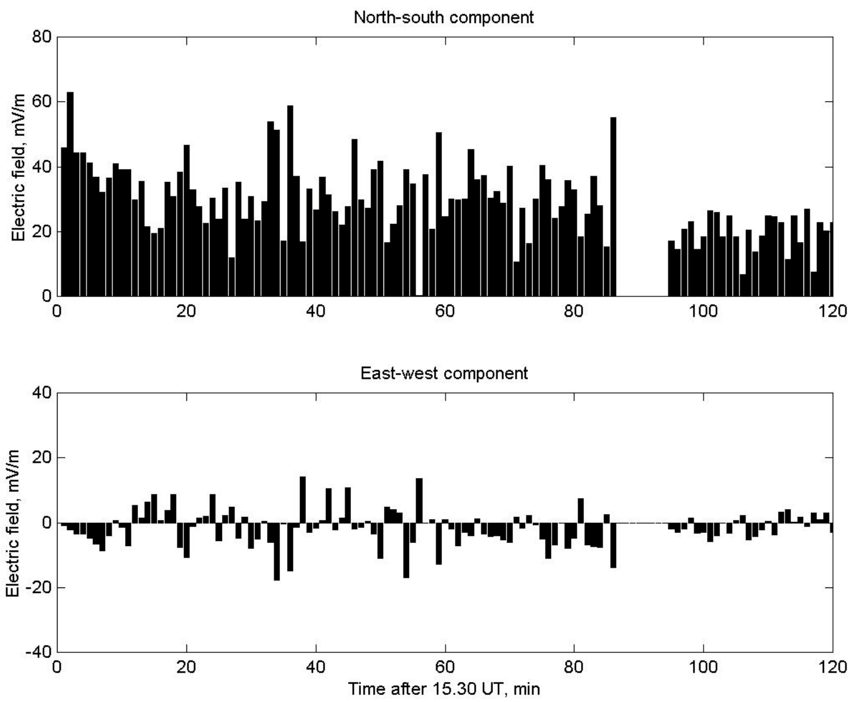

Figure 1. Ionospheric electric field components measured by EISCAT

Numerical modelling shows a strong dependence of the artificial emission amplitude on the electron density profile (Pashin et al., 1995). Main ionospheric parameters controlling the emission generation were measured by the EISCAT radar.

Analysis of time depended profiles of the electron density shows that during this experiment the ionosphere was rather stable. At least for the first 90 minutes there were no significant changes in the electron density.

The dependence of the artificial emissions intensity on the electric field is more straight forward. One can use an approximate expression derived by Lyatsky and Maltsev (1983). EISCAT radar measurements of the electric field are presented in Fig.1.

The top diagram shows the north-south component, positive direction being towards the north; the east-west component is presented at the bottom panel, positive direction being to the east. One can see that the time interval 15.30-17.30 UT is characterized by strong electric field, the mean value of the north-south component is equal to ~30 mV/m. The presence of strong electric field is necessary for the artificial pulsation excitation. The east-west component displays small variations around zero values. For the electric field as well as for the electron density we can see again very stable conditions on time scales of our experiment.

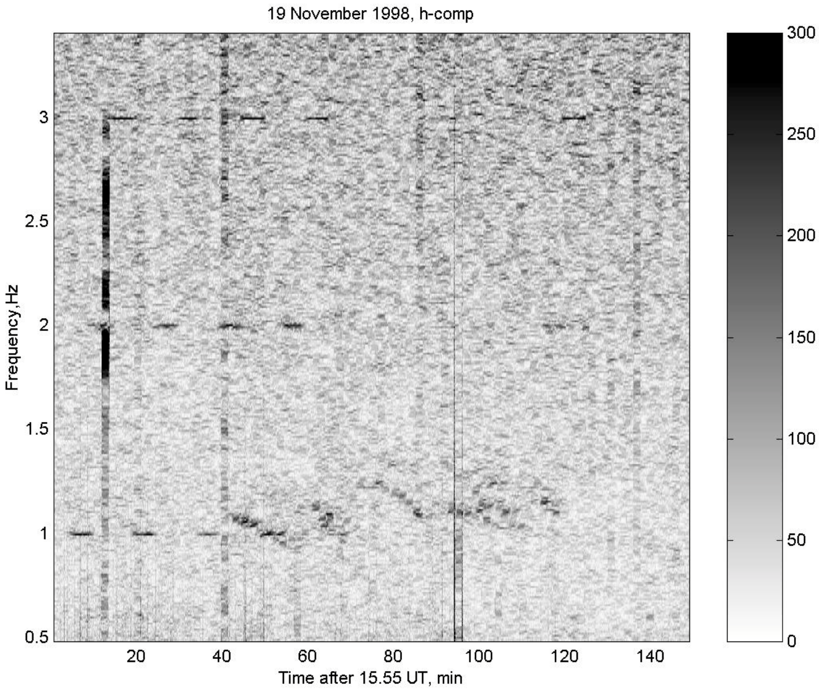

Figure 2. Shading-coded spectrogram of the H-component disturbances**.**

2. Magnetic pulsation data analysis

Magnetic pulsations were recorded by an induction magnetometer in Kilpisjarvi, 150 km far from the heating site. The sampling interval of the data is 0.1 sec, so we are able to get spectrograms of the disturbances up to 3 Hz. The data analysis is based on numerical spectral methods such as FFT. Spectrograms for the whole interval of the heating are presented in Figs. 2 and 3.

The power spectral density is shown as function of frequency and time by a shading-code, the map of shading is shown at the right side of the diagrams. The spectrogram of H-component indicates a clear ionospheric response at the modulation frequencies for the first hour of the experiment. As we concluded from EISCAT data the ionospheric conditions did not change significantly for, at least, 90 minutes after the heating started. The north-south orientation of the ionospheric electric field can explain, in general, the more intense amplitude of the disturbance in the H-component (if one takes into account the ratio Hall to Pedersen conductivity).

According to the theory, there should not be a frequency dependence of the artificial emissions intensity. The difference in the intensity of the artificial emission at different frequencies is related to the non-flat frequency response of the induction magnetometer. The spectrograms also show the appearance of natural Pc1 pulsations with strong amplitude modulation of one-minute period (pearls). The frequency of the Pc1 pulsations decreasing during a few modulation sequences is slightly higher than 1 Hz.

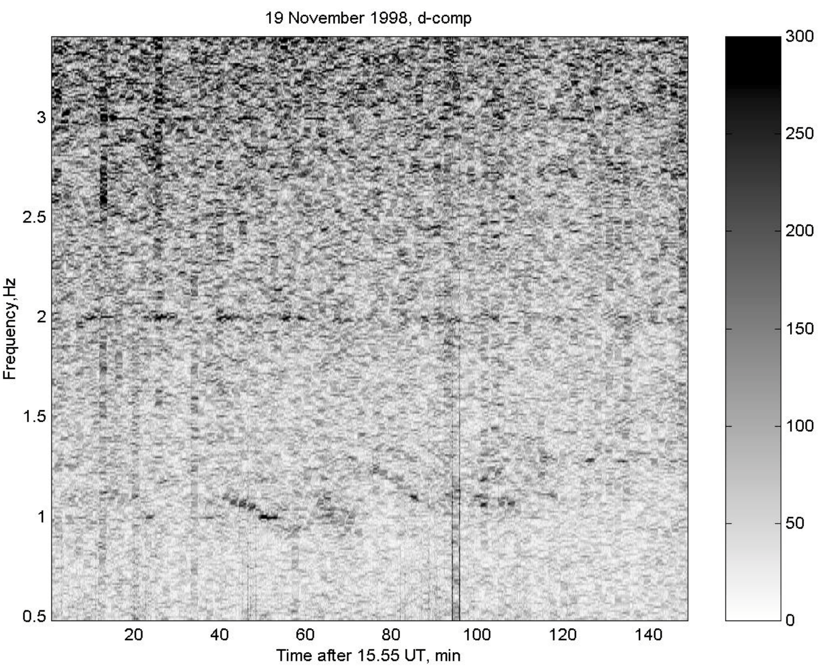

Figure 3. The same as fig.2, but for D-component.

3. Interval of the IAR excitation

A more detail inspection of the spectrograms shows that during the fourth modulation cycle an anomalous behaviour of the artificial pulsation intensity at 1 Hz occurs. A possible influence of the Ionospheric Alfvén Resonator (IAR) to magnetic pulsation amplitude is discussed in (Belyaev et al., 1990). The amplitude of the emission in the D-component significantly increased, but the H-component does not exhibit the same tendency. Just before the interval of intensity enhancement the Pc1 pulsations are observed. Fig. 4 presents the same spectrograms as Figs. 2 and 3 but with better time and frequency resolution.

Intensive patches of spectral power density are “in phase”, also their frequencies are practically the same in both components. The values of the amplitudes don’t differ either. The question arises, whether it is not just a superposition of the natural pulsations and artificial emissions that leads to the spectral density increase. The previously observed significant differences of the emission intensity at 1 Hz from that for the natural pulsations don’t support this suggestion.

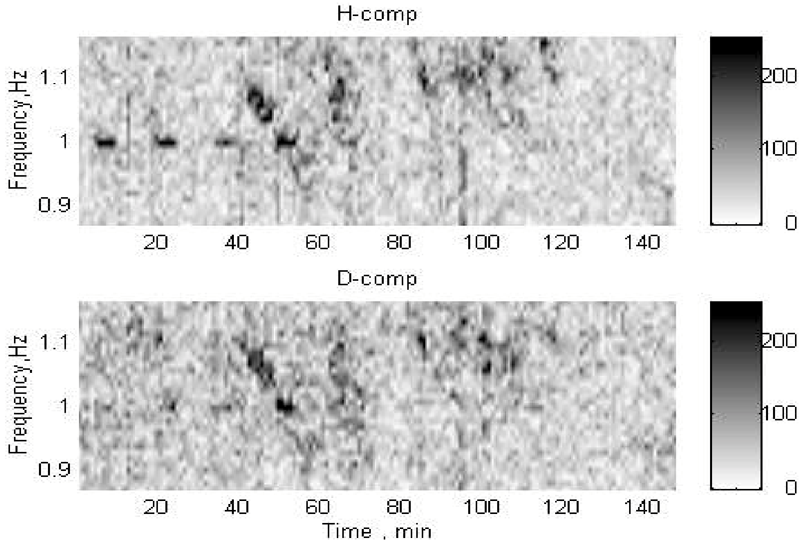

Figure 4. The same as figs. 2, 3, with better resolution.

Let us list the features of the 1 Hz emission: the amplitude in the D-component is larger; its value being greater than that of the natural pulsations, their maxima and minima in the H- and D-components are out of phase. Very strong enhancement of D-component intensity occurs only during one five-minute interval against one-hour interval of the artificial emissions. The anomalous behaviour manifests only at 1 Hz. Resonance-like increase in the artificial pulsations has been reported earlier by Belyaev et al. (1987) and Bösinger et al. (2000).

4. Arguments in favour of IAR interpretation

- No emission increase in the absence of Pc1 pulsations
- Emission enhancement takes place at the frequency close to the frequency of the pulsations
- Patches of Pc1 pearl pulsations in the H- and D-components are in phase
- Pc1 H- and D-components of equal intensity are observed
- The enhancement occurs mainly in the emission D-component
- Amplitude of the D-component of the emission is larger than that of Pc1
- Anticorrelation of intensity of the emission components is seen
- Emissions at 2 and 3 Hz do not exhibit similar behaviour

5. Results

A heating experiment on November 19, 1988 demonstrates higher efficiency of the artificial magnetic pulsation generation in the frequency range of 1 Hz. Sporadic nature of the pulsations and their disappearance without noticeable changes in the ionosphere may be related to the D-region physics.

We consider that an anomalous increase of the artificial emission intensity at 1 Hz is accounted for by influence of the IAR on the pulsation amplitude. The generation of the artificial pulsations provides a tool for experimental study of the ionospheric resonance.

Recommendations for further examination:

- to examine Pc1 pulsations at other magnetometer stations
- to estimate L-value of a source region of the Pc1 pearl pulsations from their modulation period (bounce period in the magnetosphere)
- to verify parameters of Spectral Resonance Structure (SRS) at Kilpisjarvi, such as period and Q-value

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