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GENERATION OF ARTIFICIAL MAGNETIC PULSATION BY SPEAR HEATING FACILITY AT SVALBARD

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Abstract. A series of heating experiments have been carried out in 2006 at the SPEAR heating facility on Svalbard. The experiments on modulated ionosphere heating were mainly aimed on injection of artificial MHD waves into the upper ionosphere. Ground based observations of the artificial magnetic pulsations near the heating site provided by the Polar Geophysical Institute at Barentsburg show some interesting features. Probability of their excitation is rather small (~10%) and independent of the K-index of magnetic activity. The density of background ionospheric currents estimated from magnetic disturbances during the intervals of artificial emission generation is in the range 100 – 200 mA/m, corresponding to moderately disturbed conditions. The pulsation intensity does not vary significantly, with the exception of one case where the amplitude is greater than for others by an order of magnitude. Numerical modeling of the ground based artificial emissions could solve the problem of their effective generation.

Introduction

Different aspects of ionospheric modification by HF waves have been described in a review paper by Reitveld et al. (1993). Generation of low frequency emissions occurs in the modification experiments due to low frequency modulation of the pump wave and its non-linear interaction with ionospheric electrons (Belyaev et al., 1978). This interaction leads to absorption of the HF wave energy by the electrons resulting in variations of electron temperature in accord with the pump wave power. 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 (Maul et al., 1990).

In agreement with Ohm's law, the magnitude of the disturbed ionospheric currents is determined by the product of the disturbed values of the electric field and the conductivity. These ionospheric currents are observed on the ground as the magnetic disturbances. One may expect a growth of the artificial emission intensity with increasing background electric field (Lyatsky and. Maltsev, 1983). The value of the electric field and intensity of magnetospheric convection will grow during the course of increasing magnetic activity. Such a clear pattern however is broken due to background magnetic variations increasing with as magnetic activity grows. The background variations mask the artificial emissions complicating the problem of the artificial pulsation analysis.

The dependence of the disturbed ionospheric currents on the electron density profiles is more complicated. A local conductivity is defined by a charge density, particle gyro-frequencies and collision frequencies. The electron-neutral collision frequency, the HF wave absorption, and the electron temperature disturbances constitute a circle of inter-dependent parameters. Positive feedback for the radiowave absorption is possible when the wave power density is large enough. The value of the disturbances also depends on the lower ionospheric layers absorbing some part of the HF power. Naturally such parameters of the wave as the frequency and polarisation affect the energy absorption. Calculations of such disturbances need to be produced for a wide range of the parameters. A systematic study by Pashin et al. (1995) based on numerical modelling showed that the effective excitation of artificial emissions in the Pc1 magnetic pulsations frequency range is expected under conditions of a well-developed D-region ionosphere. Estimation of the emission amplitude on the ground near the modified region gives values of a few pico-Tesla.

Bosinger et al. (2000) has reported on results of experiments on the generation of artificial pulsations (also named as Ultra Low Frequency – ULF emissions). The Heating facility near Tromso used modulations in the Pc1 frequency range from 1 to 3 Hz during 30 hours of experiments under different local time and ionospheric conditions. One may conclude that efficiency of the pulsation excitation is rather low, only 10 % of experimental runs have been successful in the observing emissions. A comparison of the emission parameters with those obtained from models shows that calculations give a true order of the artificial pulsation amplitude. However, the model is not able to explain the sporadic nature of the low-frequency emissions, i.e. why the artificial pulsations under the same conditions are sometimes observed but sometimes not. It is possible that this may be explained by limitations in the modelling (Bosinger et al., 2000).

The SPEAR Heating facility (Robinson et al. (2006) is located at Svalbard at polar cup latitudes. The transmitter system provides HF radiowave with an Effective Radiated Power (ERP) of up to 30 MW with a frequency in the range 4 to 6 MHz, polarised in X- are O-mode. During 2006 a series of experiments aimed at injecting ULF emissions into the magnetosphere were conducted with the SPEAR heating facility. Such wave injections have been shown to be successful at modulation frequencies of Hz (Scoffield et al., 2006) and mHz (Clausen et al., 2008). Like the experiments described above in the auroral zone, the heating at the SPEAR facility was carried out under a variety of ionospheric conditions. Ground based observations of the magnetic pulsations at the Barentsburg observatory of the Polar Geophysical Institute by a three component magnetometer with a 40 seconds sampling rate gives an opportunity to complete the study by Bosinger et al. (2000).

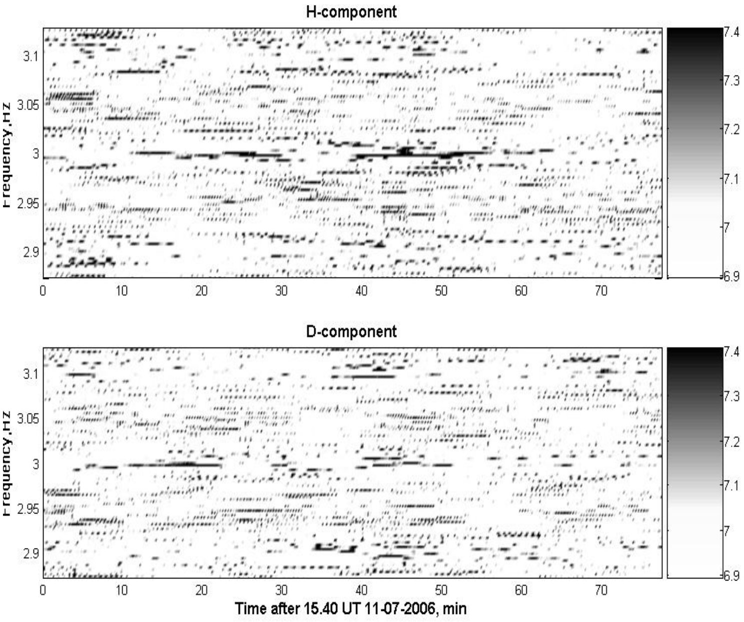

Fig. 1. Spectrograms of the artificial magnetic pulsations recorded at Barentsburg on July 11, 2006.

Observations

Only the two horizontal components of magnetic variations are analysed in this study. The frequency response of the magnetometer system is constant in the range 0.2 to 20 Hz. Data analysis is based on standard Fast Fourier Transform (FFT) for 4000 data samples. Dynamic spectra of the components are used for distinguishing the artificial signal from the background variations. Here we discuss in detail results of three experimental runs on July 11, July 12 and July 15 2006. Spectrograms are plotted versus two axes; the X-axis corresponds to the time, the Y-axis to the frequency, and power spectral density is colour-coded. For all these experiments the pump wave frequency of 4.45 MHz and sine-wave modulation with 3 Hz were used.

Spectrograms for the July 11, 2006 event are presented in Figure 1. This experiment gives a clear response of the ionosphere to the heating but a non-stationary artificial signal is observed. A one hour heating run took place from 15:50:50 to 16:50:32 UT. The artificial magnetic pulsations are observed for this experiment with ten minute gap in the ULF emission generation from 16.10 to 16.20 UT in the H-component power density. Natural disturbances at frequencies neighbouring the modulation frequency are also clearly seen. More intensive background variations at frequencies close to 3 Hz mask the artificial signal in the D-component. Figure 2 shows the spectral density of the magnetic field variations for July 12, 2006 event. For this event the clear artificial emission at the spectrogram of the H-component marks whole one hour interval of the heating from 05:29:59 to 06:30:03 UT. In the D-component an interference of the background emissions and flickering signal at the modulation frequency can be recognised. On July 15, 2006 the ionosphere heating occurred from 05:31:52 to 06:30:02 UT. Geophysical conditions for this event are very similar to those of July 12, 2006 event, the K-index for both events being 4. The ionospheric modification took place on neighbouring days at the same local time. However differences in the ionospheric response are evident. Power spectra for July 15, 2006 are presented in figure 3. Although we consider this run as unsuccessful one, a weak narrow banded signal at 3 Hz is seen in the H-component for 10 minutes during the experimental time interval. Nothing is observed in the D-component.

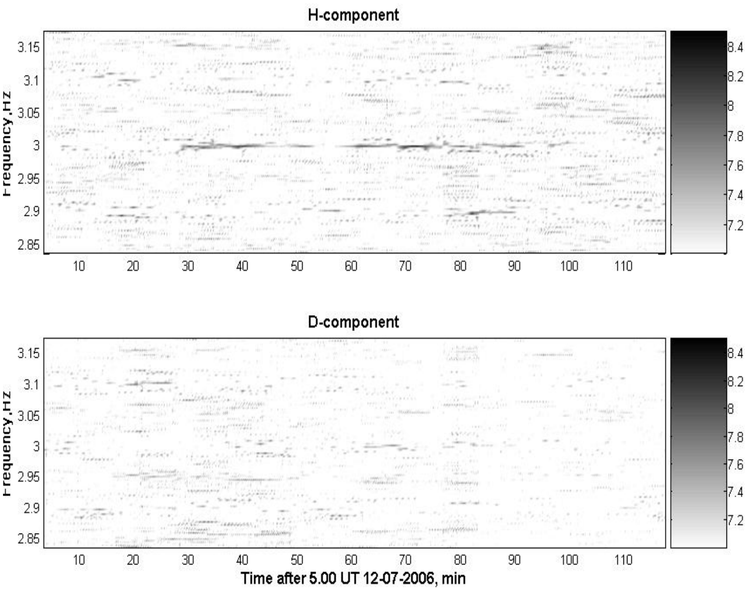

Fig. 2. Spectrograms of the artificial magnetic pulsations recorded at Barentsburg on July 12, 2006.

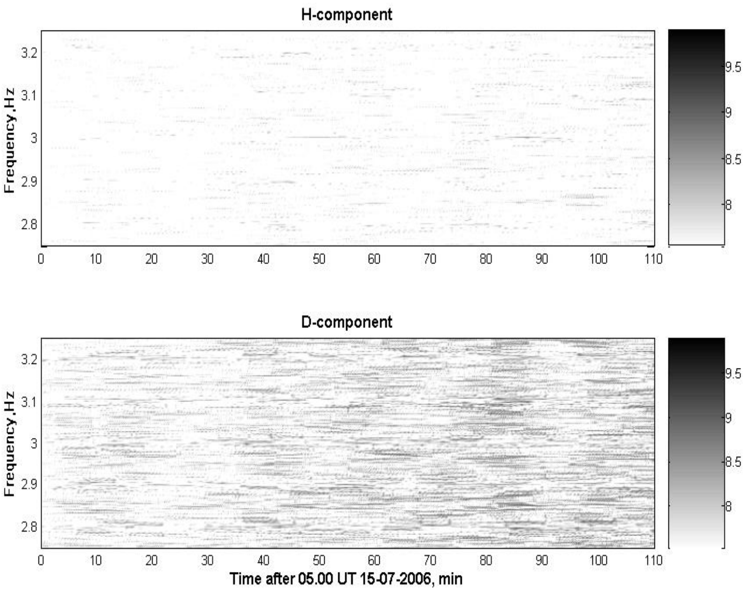

Fig. 3. The spectral density of the magnetic field variations for July 15, 2006 event.

An interesting peculiarity of the artificial magnetic pulsations in the auroral zone is their sporadic nature (Bosinger et al., 2000). We believe that two heating experiments considered here: the successful run on July 12 and the unsuccessful run on July 15 also clearly display this property but in this case for polar cap conditions. The generation of ULF emissions due to ionospheric heating in the auroral zone take place occasionally, with a probability of pulsation excitation of around 10 %. The number of heating experiments at the SPEAR facility which succeeded in the emission excitation in 2006 also comes to around 10 %. The question arises how to increase the efficiency of the ionospheric heating, in other words what are conditions more preferable for the emission production?

The statistical relationship between magnetic activity indexes and the ionospheric electric field is well-known. An attempt to check the magnetic activity influence on the ULF generation is summarized in figure 4. For each experiment the K-index from Longyearbyen data was defined and the histogram presents the distribution of the number of heating runs over the activity index. The total number of the experiments is shown in light gray, dark bars correspond to the cases where emission generation was successful. The maximum of the number of successful runs occurs for K=2, the overall distribution also has a maximum for K=2. However it is clear that the probability of the artificial pulsation generation is essentially independent of the magnetic activity.

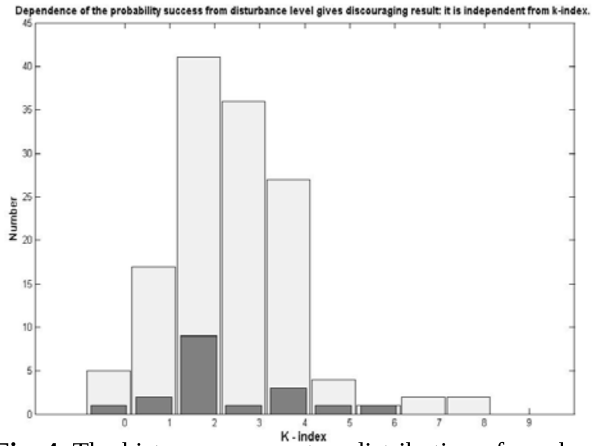

Fig. 4. The histogram presents a distribution of number of the heating runs over the activity index. Total number of the experiments is shown in light gray, dark bars correspond to the cases of the emission generation.

Observations of ionospheric convection through HF radar systems such as SuperDARN (Greenwald et al., 1995; Chisham et al., 2007) gives another chance to examine relationship of the ULF generation and the ionospheric electric field.. Consideration of the drift velocity is made for the two events of emission excitation on July 11 and July 12. For the event of July 11, 2006 Figure 5 shows the convection pattern near Svalbard for 6 sequential radar observations. In figure 5 line of sight velocities from the SuperDARN radar at Pykkvibaer, Iceland are presented, in addition to equipotential contours derived from all SuperDARN radars via the map potential technique (Ruohoniemi, and Baker, 1998). The convection is rather stable, with the direction of the drift predominantly westward at a velocity of around 500 m/s. At the same time the artificial magnetic pulsations as seen from Figure 1 demonstrate an unsteady generation regime.

Inspection of Figure 2 shows a continuous record of the emission at the modulation frequency for the July 12 event. The convection for the time interval of this experimental run, presented in Figure 6, in the same format as Figure 5, demonstrates rather more variability in the direction and magnitude of the flows. These peculiarities confirm the conclusions on the sporadic nature of the artificial ULF emissions obtained previously from the auroral zone experiments.

Conclusions

In brief, our results may be summarised as follows:

- The effectiveness of the excitation of artificial emission in the Pc 1 range by SPEAR is rather low at Svalbard latitudes as has been reported earlier for the auroral zone. The probability of a successful experiment is around 10 percent in both cases. It should be noted that the ERP of the heater at Tromso is greater than that of SPEAR by factor at least 10.

- A dependence of the generation probability on the local magnetic activity is not clearly seen. This is an unexpected result and should be more accurately tested with a larger set of experiments.
- Much more surprising is non-correlated behaviour of the artificial magnetic pulsation excitation and convection. A more detailed study of the July 11 and July 12 events is needed, including additional data on the ionospheric content and modelling of the artificial pulsations.

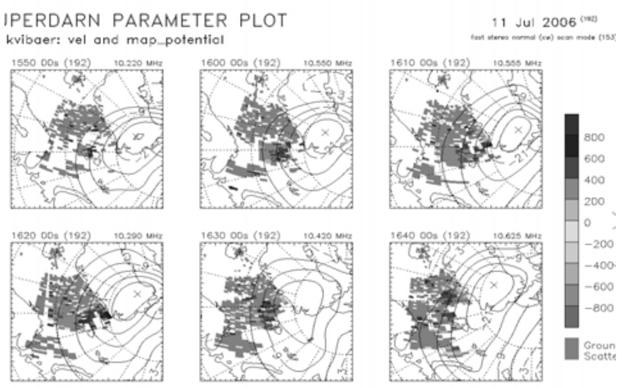

Fig. 5. The convection pattern near Svalbard for 6 sequential radar observations on July 11, 2006. 15.50-16.50 UT**.**

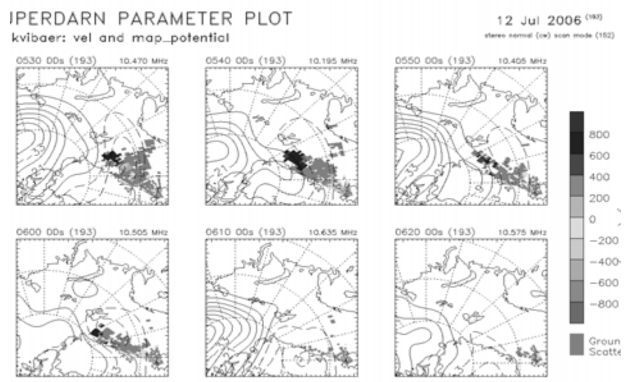

Fig. 6. The convection pattern near Svalbard for 6 sequential radar observations on July 12, 2006. 5.30-6.30 UT.

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