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INFLUENCE OF NEUTRAL SPICES ON THE ARTIFICIAL MAGNETIC PULSATIONS EXCITATION

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Abstract. During last decade series with the EISCAT Heating Facility were carried out with the purpose of producing artificial magnetic pulsations in the 0.1 – 3 Hz frequency range. For several experiments the EISCAT radar provided measurement of ionospheric electric field and electron density. Numerical model of artificial pulsation excitation has been verified. The predicted amplitude of the pulsation is in accordance with the measured values, however model could not explained sporadic nature of the artificial signals. Variations of neutral spice densities are a possible way to explain this feature. Numerical modelling shows strong dependence of the conductivity modification on neutral density. Experiment on generation of artificial magnetic pulsations in Pc1 frequency range on November 19, 1998 is discussed in the framework of numerical simulation. Clear ionospheric response is observed during the first hour of the heating at 120-km distance by induction magnetometer but the artificial signal at the modulation frequencies disappeared for the next hour of the heating. The main ionosphere parameters do not show significant variations during this experimental run. Disappearance of artificial pulsations may be related with density variations of the neutral components of ionosphere.

1. Experimental results and objectives

The excitation of artificial emissions has a long-lasting history (Belyaev et al., 1978; Rietveld et al.,1986). The generation of artificial magnetic pulsations in Pc1 frequency range was a significant part of numerous Heating Campaigns organized and funded by the EISCAT community. Most interesting results of these studies seem to be heating induced excitation of Ionospheric Alfven Resonator (IAR) reported by Bösinger et al. (2000) and observations of the artificial pulsations onboard FAST satellite by Robinson et al. (2000) and their investigations by Kolesnikova et al. (2002) and Wright et al. (2003). Ground-based observations of the artificial pulsations show that ionospheric response to the HF heating take place rather rare. Only 10 percents of experimental runs were succeeded by the artificial pulsation excitation (Bösinger et al., 2000). Numerical modeling involved into the study of artificial emission generation predicts true amplitude of the pulsations (Maul et al., 1990; Pashin et al., 1995) for the intervals of their observation. However Bösinger et al. (2000) reported that during intervals when the excitation is expected magnetic records do not show any variations at the modulation frequency. Sporadic nature of the artificial emissions in frequency range of Pc1 magnetic pulsations is unresolved question. One may disapprove with this point of view paying attention to factors varying from experiment to experiment but have not included into numerical modeling. As an example note impedance of Earth surface and its influence on heater beam width.

Strong additional argument for sporadic regime of the generation has been presented by Pashin et al. (2003). A two hours heating run on November 19, 1998 was aimed at the 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 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. The main ionospheric parameters controlling the emission generation were measured by the EISCAT radar. EISCAT measurements show that neither electron density nor ionospheric electric field do not change during the first 90 minutes of experimental run. After that a minor increase of the electron density is accompanied by some decay of the electric field (Pashin et al., 2003).

Magnetic pulsations were recorded by an induction magnetometer in Kilpisjarvi, 120 km far from the heating site. During the first 60 minutes of the experiment ionospheric response is observed at all three modulation frequencies 1, 2 and 3 Hz. Amplitude of artificial emission is quite stable during the interval of their observations, both mode of the pump wave produce pulsations of the same intensity. Without noticeable changes in the parameters of ionosphere the artificial pulsations disappear after fourth modulation cycle (Pashin et al., 2003). More realistic modelling is needed for explanation of the sporadic nature of artificial pulsation generation. It should be mentioned that low electron density in D-region of the ionosphere is not a favourable condition for generation of the emissions via ionosphere heating (Pashin et al., 1995). Evidently, the pulsation intensity for winter conditions is comparable with the background noise one and small variations in the amplitude of the emissions may lead to their observation or to their masking. It is very significant either to analyse the background noise level and its variations during experiments.

We believe that neutral atmosphere is a parameter, which affected the propagation of the pump wave, modification of electron temperature and ionospheric conductivity, value of disturbed ionospheric current and pulsation amplitude. In such non-linear system the estimation of the disturbance value is impossible and numerical modelling is needed. A numerical model of artificial pulsation excitation presented by Pashin et al. (1995) used for

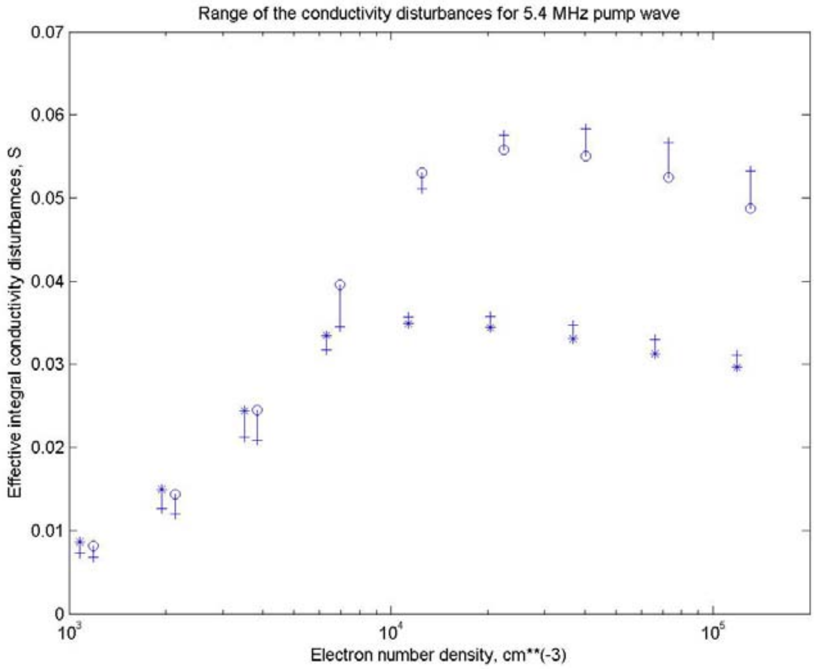

Figure 1. Disturbances of the effective conductivity with the pump wave of 5.4 MHz. o-mode denotes by circles, x-mode – by asterisks. Vertical lines up to crosses show range of conductivity disturbances corresponding to the neutral density decreasing.

interpretation of the heating experiments. In the modelling profile of the neutral component densities were set constant, but in reality their strong variations take place. Especially in the high latitude atmosphere significant non-regular disturbances occur prolonged both in altitude and in horizontal dimension. Let us consider the possible influence of neutral spices variations on the conductivity disturbances induced by the ionosphere heating.

2. Modeling

One can find the description of the numerical model in (Belova et al., 1995; and Pashin et al., 1995). You do not have to pay much attention to the nature of the disturbances of the neutral density, just calculate the values of the ionospheric conductivity disturbances produced by the powerful HF transmitter for two profiles of the neutral atmosphere. One of them corresponds to the MSISE model for the conditions of the experiment on November 19 and the other one with the component density decreased by 20 percent. For modeling we use the pump wave with Ordinary and eXtraordinary polarization and two heating wave frequency 5.4 MHz and 8 MHz. We assume the Effective Radiated Power of the heater equal 300 MW and calculate values of the effective high-integrated conductivity disturbances. The effective conductivity is defined as square root from the sum of the second degree of Hall and Pedersen conductivities. Its value is defined the magnetic disturbances under the circle of disturbed conductivity (Lyatsky and Maltsev, 1983). Under the same background conditions and geometry of the heated area this value can be used as a measure of the artificial emission intensity.

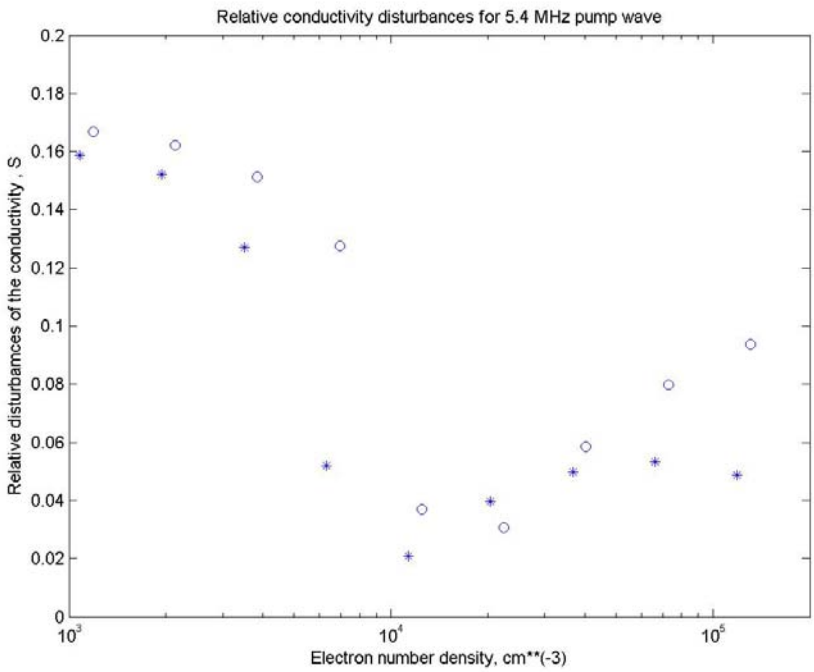

Figure 2. Relative disturbances of the effective conductivity for pump wave of 5.4 MHz. o-mode denotes by circles, x- -mode – by asterisks.

The results of the conductivity disturbance calculations versus electron number density are presented in figure 1 for 5.4 MHz heating wave. The electron density profile is defined as in (Pashin et al., 1995). The concentration being constant in the altitude range higher 90 km is exponentially decreased below this altitude, the decreasing factor is equal to 3. The calculation has been made for slightly different electron densities for o- (circles) and x-mode (asterisks) because of insignificant differences in values of the conductivity disturbances for the both modes. The calculations corresponding to the 20% depletion of the neutrals are

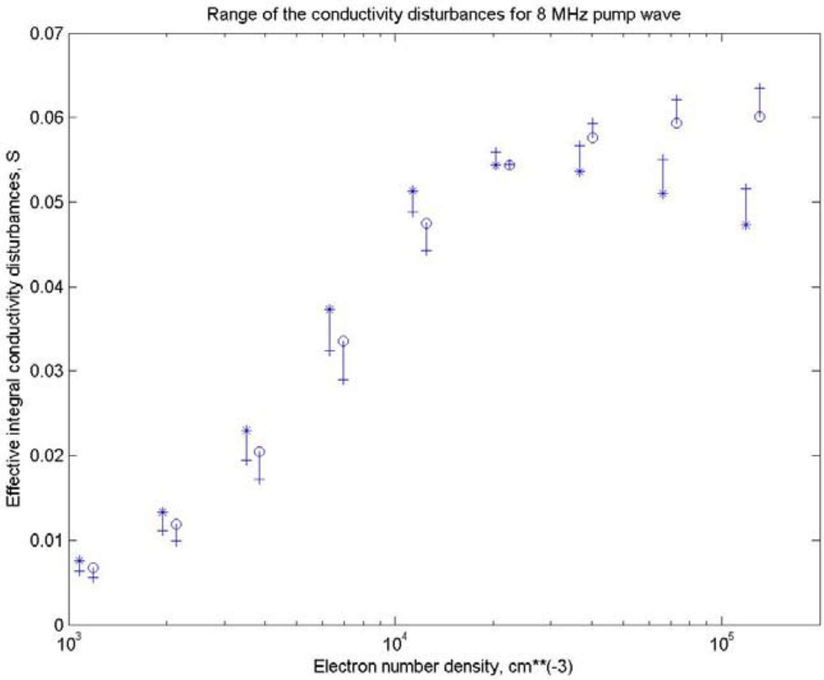

Figure 3. The same as figure 1, but for the pump wave of 8 MHz.

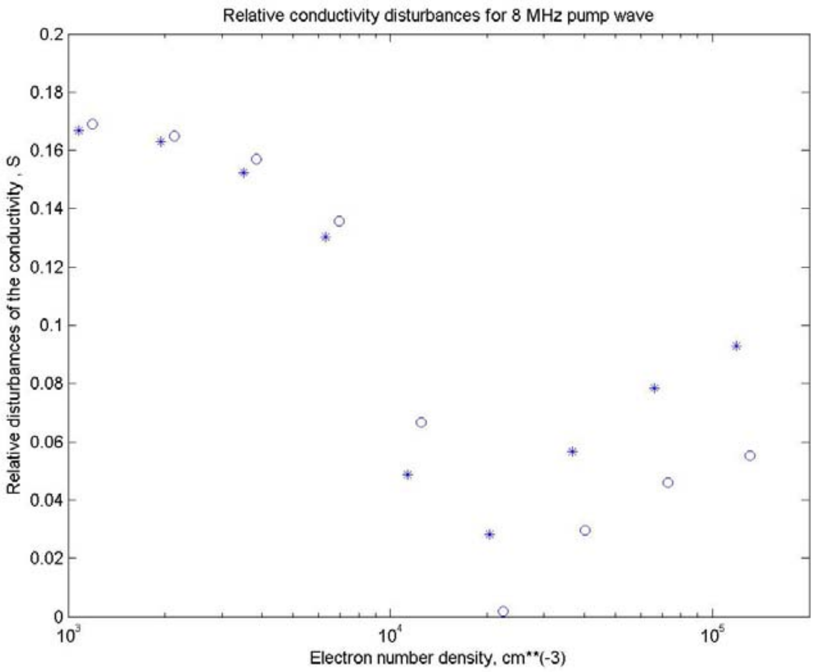

Figure 4. The same as figure 2, but for the pump wave of 8 MHz.

shown by crosses so vertical lines represent a range of the conductivity disturbances variations. One can see that for low electron density both modes show a decrease of the disturbance values with neutral depletion. On the contrary, the decrease of neutral spices for profiles with significant value of electron density increase the disturbance of the conductivity.

The value of the additional disturbance related with the neutral component depletion evidently has a minimum for the mean electron density profile where its sign is changed. The magnitude of the additional disturbances is directly related with the changes of the emission amplitude variations relative. For o-mode of the heating wave the clear maximum of the additional disturbances of the effective conductivity is seen for rather developed ionosphere. On the contrary x-mode demonstrate the maximum of the additional disturbances for profiles with low electron density. Actually we are interested not in absolute values of the additional disturbances of the conductivity. Th variability of the phenomena is defined by relative disturbances. The calculated relative conductivity disturbances are presented in figure 2. The relative disturbances show two maxima for the low and high values of electron concentration. The variability for the low electron density is more significant, relative conductivity disturbances reach the value around 20%. The second maximum is more pronounced for electron density dependence for the waves of opposite polarization are very similar. Curve for o-mode repeats the behavior of the disturbances produced by x-mode with some delay. Relative disturbances reach up to 10 % for o-mode and 6%. We also mention that for conditions of the experimental run on November 19, 1998 numerical modeling demonstrates equal efficiency for the pump wave of different polarization.

As an interesting feature of fig.1 we emphasize the growth, saturation and decreasing of the conductivity disturbances in the course of the electron density increasing. The use of the heating wave with higher frequency should move away to more significant values of the electron density maximum of the disturbances and improve efficiency of the heating. To check this assumption and to get information on the variability of artificial pulsations for the higher pump wave frequency the calculations have also been made for wave of 8 MHz. Significant growth of the disturbances for x-mode and less pronounced for o-mode for large value of the electron density. As for the pump wave of 5.4 MHz additional conductivity disturbances are negative for low concentration and change sign with its growth.

Relative disturbances of conductivity are shown in figure 4 and repeat the behavior of the disturbances for the pump wave of 5.4 MHz with some delay. Variability of the conductivity has the same value for low electron density, but for high electron concentration x-mode produced relative disturbances outdoing the ones related with o-mode heating.

3. Conclusions

Numerical modeling shows the influence of the neutral component density on the value of effective conductivity disturbances. Variations of the upper atmosphere particles are the possible reason of the intensity variability of the artificial pulsations without any changes in the electron density profile or ionospheric electric field disturbances. The relative conductivity disturbances are very significant for rather a low and extremely high electron density. For the experiments on artificial pulsation excitation the variability of their amplitude is most important under the conditions of low electron density. In this case the heater produces emissions of small amplitude being comparable with the background noise intensity. Sporadic nature of the artificial magnetic pulsation generated via the modulated ionosphere heating may be explained on the way of influence of the neutral component concentration on the amplitude of artificial emissions in the frequency range of Pc1 magnetic pulsations.

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