

# SATELLITE OBSERVATIONS OF PLASMA-WAVE DISTURBANCES INDUCED BY HIGH-POWER RADIO EMISSION FROM THE NWC TRANSMITTER

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In this work, we present the results of in-situ measurements of the characteristics of electromagnetic and plasma disturbances in the ionospheric region modified by high-power emission from the NWC transmitter, which were obtained using the onboard equipment of the French microsatellite DEMETER. It is shown that under the influence of VLF emissions from the ground-based transmitters, artificial plasma-wave channels with typical transverse scales of about 1000 km can be formed in the ionospheric plasma.

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## INTRODUCTION

It is known that radio emissions of operating VLF transmitters can turbulize the illuminated region of the ionosphere [1, 2].

Plasma-wave structures generated in the ionosphere by VLF emissions from ground-based transmitters make it possible to change the local ionosphere-magnetosphere coupling and determine the radio communication characteristics in this frequency range.

To study the characteristics of such induced plasma-wave structures, the results of measurements of plasma and electromagnetic-field parameters, which were obtained using the onboard equipment of the DEMETER satellite during its passage above a 1-MW VLF transmitter NWC in 2004...2010, are analyzed in this paper.

## OBSERVATIONS

The NWC transmitter located at Northwest Cape, Australia (21°49' S, 114°10' E) is one of the most powerful communication transmitters in the world that are currently in operation. The radiated power of this transmitter is 1 MW and the operating frequency  $f_{tr} = 19,8$  kHz.

Fig. 1 shows the representative DEMETER observations of the parameters of electromagnetic and plasma disturbances during the satellite passage over the NWC transmitter from 14:43:00 to 15:17:30 UT on September 22, 2006.

Fig. 1,a shows a 17-to-20 kHz spectrogram of the electric-field component of VLF turbulence above NWC, which was obtained by an ICE instrument of the satellite. The NWC signal at 19,8 kHz is present at the very top of the spectrogram. In addition, a band of plasma waves can be seen. Fig. 1,b shows a spectrogram of the magnetic-field component of VLF turbulence observed by an IMSC instrument of DEMETER.

Figs. 1,c and 1,d show the local electron temperature ( $T_e$ ) and density ( $N_e$ ), respectively, which were measured by the Langmuir probe instrument (ISL).

Fig. 1,e shows the number densities of primary ion species observed by the IAP instrument.

The modified region is marked by the solid lines in Fig. 1.

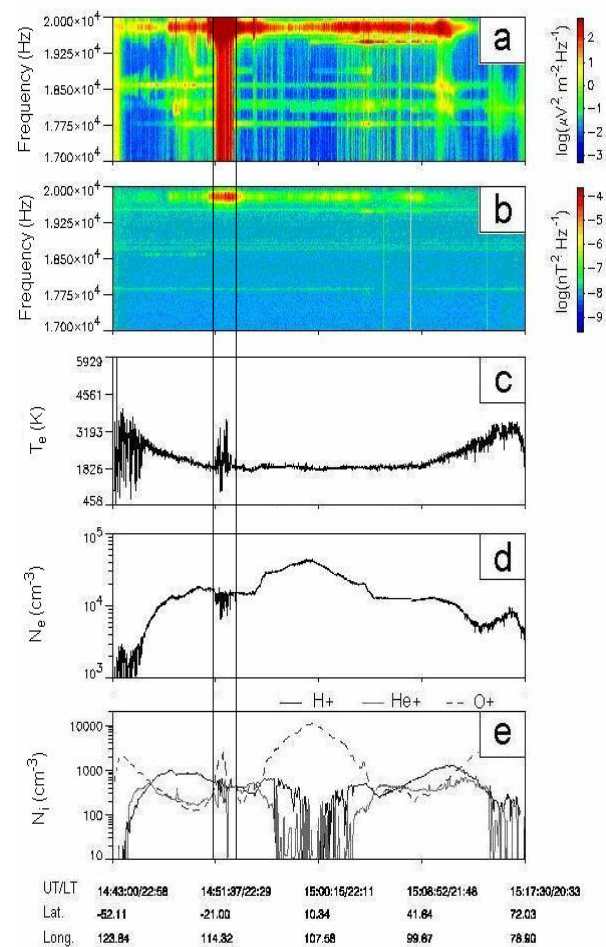


Fig. 1. Electromagnetic and plasma disturbances in the ionospheric region modified by VLF emission from the NWC transmitter

Significant changes in the electron density and temperature ( $N_e$  decreases by  $\sim 50\%$  and  $T_e$  increases

by ~ 50 %), coincident with the localization zone in which the intensity of the NWC signal was high, were observed at the altitudes of the Earth's outer ionosphere, in the region of a disturbed magnetic flux tube. The induced density disturbances were aligned with the geomagnetic field, which allowed one to identify them as artificial plasma-wave channels (density ducts) with nonuniform (stratified) distribution of plasma density.

A typical transverse scale of the density duct along the satellite trajectory is about 1000 km. In such an artificial density duct, guided propagation of whistler-mode waves at the NWC-signal frequency and stimulated intense quasi-electrostatic (QE) waves are observed.

Changes in the ion composition (enhanced density of O<sup>+</sup> species) were also observed in the ionospheric region modified by VLF emission from the NWC transmitter.

Fig. 2 shows the velocity of the ion flow during the passage of the satellite on September 22, 2006.

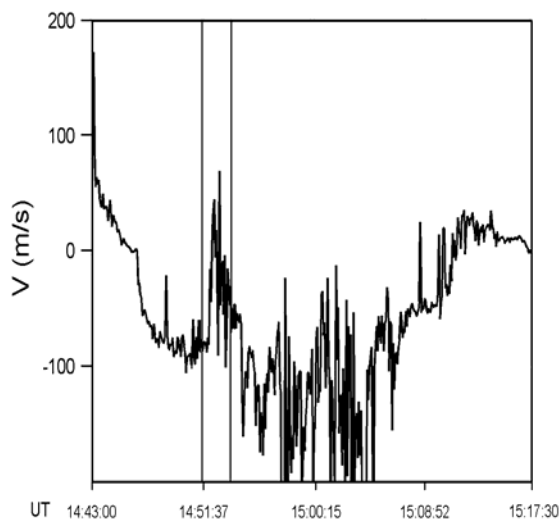


Fig. 2. Velocity of the ion flow in the direction of the geomagnetic field  $B_0$

In the modified region, the direction of the ion-flow velocity reverses its sign, and the upward flows are observed. The stimulated changes in the ion flows contribute to redistribution of the ion composition.

Disturbances induced by VLF high-power radio emission extend along  $B_0$  into the region magnetically conjugate with respect to the NWC transmitter [3]. Fig. 3 shows the DEMETER observations of the parameters of electromagnetic and plasma disturbances during the satellite passage over the NWC conjugate region from 12:51:30 to 13:26:56 UT on February 3, 2009. The format of the figure is the same as in Fig. 1.

Fig. 3,a shows a spectrogram of a component of the observed electric field. The spectra include the NWC signal and intense QE waves (Fig. 3,b shows no discernible magnetic field for these waves).

Figs. 3,c,d show that there are no large disturbances in  $T_e$  and  $N_e$  over the region magnetically conjugate to the NWC VLF transmitter.

This form of turbulence has been associated with small-scale plasma density irregularities [4].

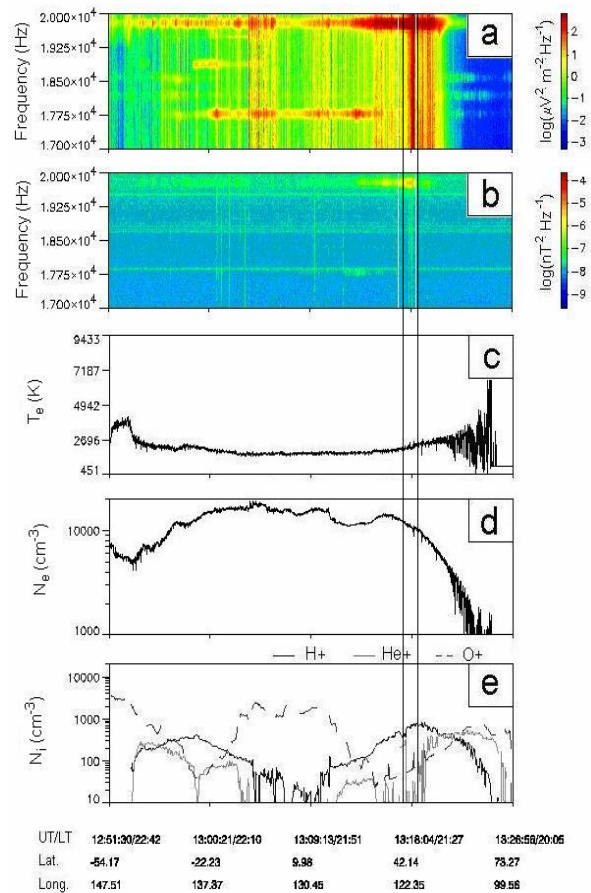


Fig. 3. Electromagnetic and plasma disturbances in the NWC conjugate region

The satellite passages were selected from those which were in the near vicinity of the modified (see Fig. 1) or magnetically conjugate (see Fig. 3) region. The trajectories of the DEMETER satellite are shown in Fig. 4.

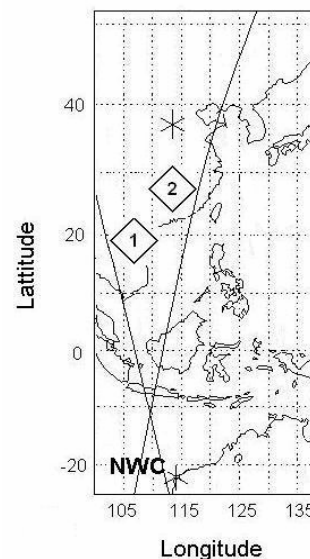


Fig. 4. Trajectories of the satellite on (1) September 22, 2006 and (2) February 3, 2009. The locations of the NWC transmitter and the magnetically conjugate point are indicated by the asterisks

## CONCLUSIONS

The presented results of in-situ measurements allow us to conclude that ionospheric heating by powerful VLF transmitters can lead to the formation of electron and ion density disturbances that are aligned with the geomagnetic field. Such density irregularities can serve as ducts for low-frequency waves.

Since the plasma density distribution in the duct is nonuniform and rapidly varying, the spectrum width of quasi-electrostatic emissions excited via conversion of whistler waves on these irregularities is noticeably wider than the spectrum of the VLF transmitter signal.

In the modified region, the direction of the ion-flow velocity reverses its sign, and the upward flows are observed. As a result, the ion composition is redistributed.

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## СПУТНИКОВЫЕ НАБЛЮДЕНИЯ ПЛАЗМЕННО-ВОЛНОВЫХ ВОЗМУЩЕНИЙ, ИНДУЦИРОВАННЫХ МОЩНЫМ РАДИОИЗЛУЧЕНИЕМ ПЕРЕДАТЧИКА NWC

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Представлены результаты непосредственных (in-situ) измерений бортовой аппаратурой французского микроспутника DEMETER характеристик электромагнитных и плазменных возмущений в модифицированной мощным излучением передатчика NWC области ионосферы. Отмечено, что при воздействии ОНЧ-излучения наземных передатчиков в ионосферной плазме формируются искусственные плазменно-волновые каналы с характерным поперечным масштабом ~ 1000 км.

## СУПУТНИКОВІ СПОСТЕРЕЖЕННЯ ПЛАЗМОВО-ХВИЛЬОВИХ ЗБУРЕНЬ, ІНДУКОВАНИХ ПОТУЖНИМ РАДІОВИПРОМІНЮВАННЯМ ПЕРЕДАВАЧА NWC

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Представлені результати безпосередніх (in-situ) вимірювань бортовою апаратурою французького мікросупутника DEMETER характеристик електромагнітних і плазмових збурень у модифікованій потужним випромінюванням передавача NWC області іоносфери. Відзначено, що при впливі ОНЧ-випромінювання наземних передавачів в іоносферній плазмі формуються штучні плазмово-хвильові канали з характерним поперечним масштабом ~ 1000 км.