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Some Results on the Ionosphere Investigations at Radiophysical Research Institute by Ionosondes of Vertical and Oblique Sounding

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Abstract

Ionosphere investigations carrying out at Radiophysical Research Institute of Nizhny Novgorod State University by ionosondes of vertical and oblique sounding are briefly presented. Some results concerning chirp oblique sounding are overviewed including observable frequency range on subauroral traces determination and travelling ionospheric disturbances diagnostics on closely spaced ionosondes.

1 Introduction

The Radiophysical Research Institute uses in the investigations of the ionosphere two kinds of ionosondes: a Canadian advanced digital ionosonde (CADI) for vertical and a chirp ionosonde manufactured by "SITCOM" LLC [2] for oblique sounding. CADI and transmitting part of the chirp ionosonde are situated at Vasilsursk (56.1ºN, 46.1ºE) co-locating with the SURA heating facility. Receiving parts of the chirp ionosonde are located at Vasilsursk and Nizhny Novgorod.

CADI has been working for regular monitoring of the ionosphere in 15-minutes mode continuously since 2013. During the operation of the SURA heating facility CADI is used for diagnostic purposes in specific modes depending on the kind of experiments carrying out. For instance the study of ionospheric disturbances caused by powerful HF radiation confidently showed an existence of artificial F-spread both at night and daytime when the ionosphere was heated by O-polarized HF radio waves for 5–10 minutes with an effective power of about 80 MW or above.

Chirp ionosonde receivers are used to study both the regular and inhomogeneous structure of the ionosphere. They have been operating in 15-minutes mode continuously since 2017 on the network of transmitters located in the Eurasian region of Russia and at Cyprus. Chirp ionosonde transmitter at Vasilsursk is used occasionally for specific experiments.

Here we present some results of chirp ionosonde studies.

2 Oblique sounding on a subauroral trace

Chirp sounding with linear frequency modulation on a variety of mid-latitude and subauroral trases provides information on the state of the ionosphere. As a result algorithms were developed for predicting and extrapolating the maximum usable frequency (MUF) for traces not equipped with diagnostics by adapting the ionospheric IRI model ([3] as a brief overview) according to oblique sounding data on control traces [4]. The influence of solar and magnetic activity on the characteristics of short-wave signals along subauroral and mid-latitude traces has been studied, and the relationship between ionospheric effects due to a magnetic storm and the intensity of geomagnetic disturbance has been established [5].

Figure 1 shows the temporal behaviour of the signal transmission frequency range Δf = MOF - LOF (MOF is the maximum observable frequency, LOF—the lowest one) for reflection from the F region (F-mode, red) and from the sporadic E layer (E_s-mode, blue) on the Lavozero–Vasilsursk subauroral trace during a magnetic storm on September 8, 2017. During a strong storm F-mode propagation took place only for a short time from 08:30 to 11:00 UT at the recovery phase of the "night" storm before the beginning of the explosive phase of the "day" storm in a narrow frequency range of $\Delta f \approx (8.8 - -10.0) - -(8.5 - -9.0)$ MHz.

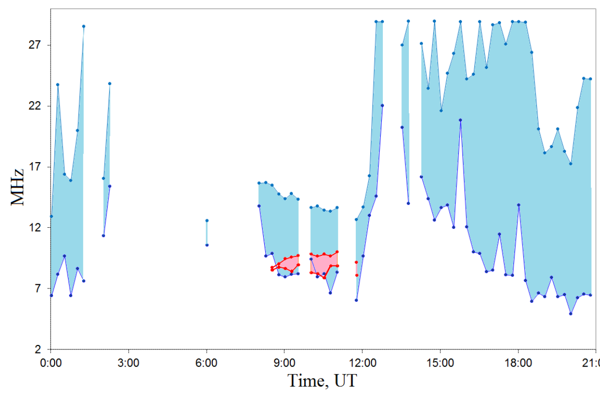

Figure 1. Transmission frequency range behaviour on the Lavozero–Vasilsursk trace during the September 8, 2017 magnetic storm. F-mode propagation with reflection from the F layer of the ionosphere is shown by red filling, E_s-mode propagation with reflection from the sporadic E layer—by blue one.

At the same time while a strong sporadic E_s layer with a high electron density is presented in the auroral ionosphere a possibility of E_s-mode propagation of HF signals with reflection from sporadic E layer existed at significantly larger time interval and frequency range Δf. The development of a sporadic E_s layer during a magnetic storm significantly expands the ability to control the frequency resource of radio links to provide reliable HF radio communications on high-latitude traces.

During a weak storm on September 15, 2017 a decrease in the frequency range Δf for the F-mode reflection and better propagation conditions for E_s-mode one (Figure 2) were also observed. But the frequency range Δf for E_s-mode propagation is smaller compared to similar data for the strong storm of September 8, 2017 (Figure 2).

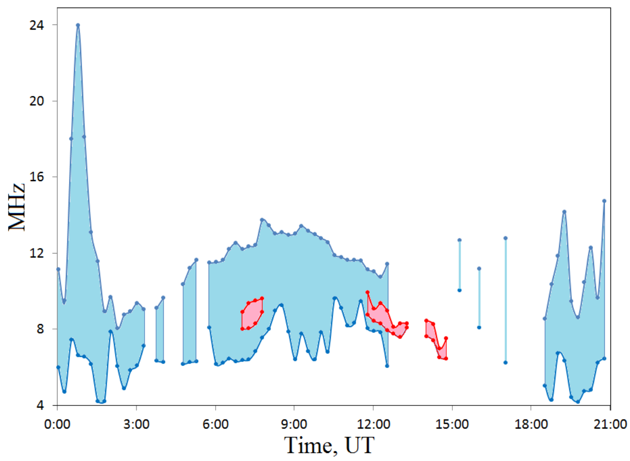

Figure 2. The same as in Figure 1 for the September 15, 2017 magnetic storm.

3 Travelling ionospheric disturbances study

The close location (about 120 km) of the transmitting (Vasilsursk) and receiving (Nizhny Novgorod) parts of the ionosonde allowed to study the parameters of travelling ionospheric disturbances (TIDs). Typical examples of oblique ionograms obtained on February 9, 2015 on the Vasilsursk–Nizhny Novgorod trace with 2 minutes intervals are shown on Figure 3. The observations were carried out under quiet magnetic conditions with index of 1–2. Sickle-shaped tracks on both magneto-ionic components moving with time toward smaller group delays are clearly seen.

Numerical simulations of decameter radio wave propagation in the presence of TIDs showed that in the daytime under quiet magnetic conditions disturbances of electron concentration with medium horizontal scales of 75–100 km, periods of about 15 minutes, and relative amplitudes of about 0.1 can be responsible for observed sickle-shaped tracks on oblique ionograms. Responsible for these tracks wave perturbations propagated at a speed of about 100 m/s at an angle of about $-45°$ to the horizon with the predominant orientation of the wave vector in the east-west direction [6].

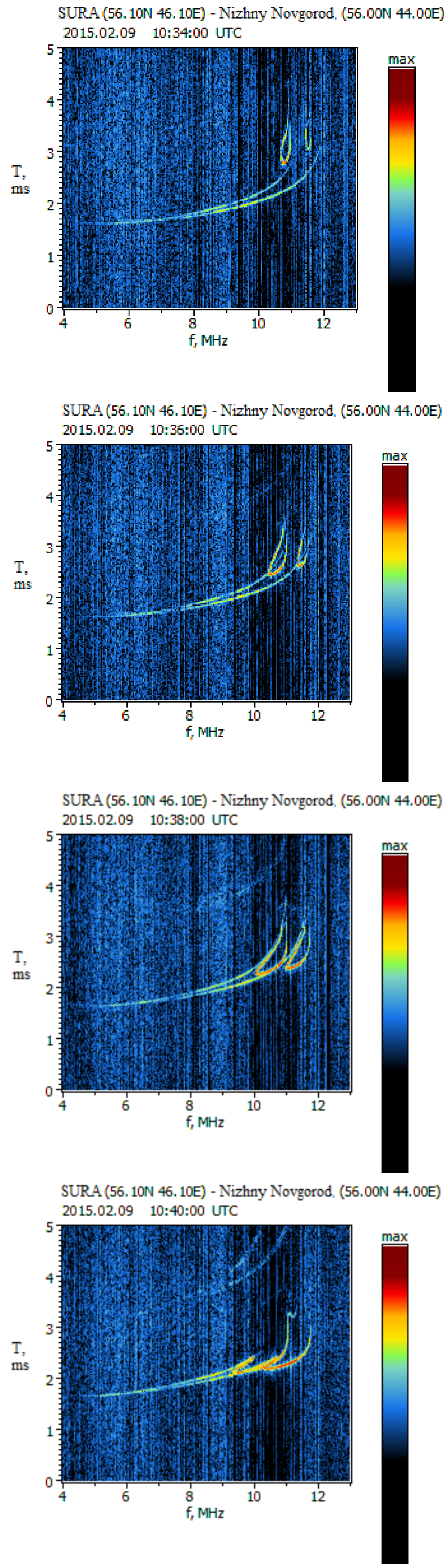

Figure 3. Successive oblique ionograms obtained on the Vasilsursk–Nizhny Novgorod trace on February 9, 2015 with 2 minutes intervals.

Further development of the network of closely spaced chirp ionosondes (Nizhny Novgorod, Vasilsursk, Yoshkar-Ola, Kazan) with mutual distances of 120–320 km could permitted to carry out a series of test experiments on sounding the ionosphere during the passage of TIDs with a temporal resolution of about 1 minute. Obtained results make it possible not only to estimate the parameters of the observed disturbances, but also to perform three-dimensional dynamic modeling.

4 Conclusions

Oblique chirp ionosondes observations on several known traces and adapting the ionospheric IRI model on obtained data algorithms provided the development of algorithms for predicting the maximum usable frequency for traces not equipped with diagnostics. Investigations of subauroral traces showed substantial increase of observable frequency range of sporadic E_s layers reflections under magnetic storm conditions while F region reflections are very limited in frequency or fully absent. Observations on the short traces using closely spaced chirp ionosondes with minute range temporal resolution can provide an information on parameters of small scale travelling ionospheric disturbances.

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