VERTICAL SOUNDING IONOGRAM IN THE POLAR CAP REGION

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Abstract. The investigation of the signatures of enhanced electron density localized regions (patches and arcs) in the F region of the high latitude ionosphere is based on the model developed in collaboration with University of Leicester (UK). The original model consists of models of the background ionosphere, mid-latitude trough, auroral oval, patches and sun-aligned arcs. Based on this model the vertical ionograms for different time and geophysical conditions were simulated. The typical shapes of the ionograms traces were classified by types: “calm” - typical for mid latitude, “fork” - with splitting at the end of the trace, “complex” - multiplied splitting, “U-shaped” - with arc shape trace, “spots” - with detached spots and “multiplied” – with a number of arc shape structures. The approach in this paper is to employ the scenario with one patch in order to interpret observed ionograms. Analysis of the simulated ionograms corresponding different parameters of the patch of enhanced electron density reveal that the ionogram structures changes while the patch moves away the receiver in the sequence “complex”, “fork”, “spots”, “U-shaped”, “calm”.

There are a number of radio science methods for monitoring high latitude ionosphere. Among them: satellite measurements of the total electron content (TEC), data of the coherent HF radar, data of the vertical and oblique ionosondes [Weber, et al., 1996; Alfonsia, et al., 2008; Carter et al., 2012]. The interpretation of these experimental data is complicated due to intricacy of the high-latitude ionosphere structure and occurring processes.

The complexity and variability of the high-latitude ionosphere structure is induced by the presence of the localized regions of enhanced electron density in the F region - patches and arcs. The monitoring of the high latitude ionosphere shows that the formation processes and evolution of the patches and arcs are rather stochastic than regular. Parameters of the patches of enhanced electron density (number, speed, trajectory and intensity) strongly depend on geophysical condition. They are typically of about 500 km in dawn to dusk direction but they range from 200 to 1000 km and exhibit electron-density enhancements of up a factor of 10 above background [McEwen, et al., 1996; McDougall, et al., 1996]. Typical period of the patch appearance is about half an hour. The patches are observed most frequently in winter, especially in period of maxima of the solar activity. They have also observed at sunspot minimum [McEwen, et al., 1996], but less pronounced. There is evidence that they can retain their form as they traverse the whole polar cap [McEwen, 1998].

Ionograms of the vertical sounding in high latitude are rather complex. During one day very different structures of the ionograms were observed. In this work ionosonde located in (THULE/QANAE) (77.5N; 69.2E) was chosen for ionograms analysis. The vertical soundings data were took on via the Internet (http://car.ulm.edu).

Figure 1. Map of the HF radar signal power distribution
Different experimental ionogram’s structures could be classified in a number of types: “calm” - ionogram typical for mid latitude (Fig. 2a), “fork” - ionogram with splitting at the end of the trace (Fig. 2b), “complex” - ionogram with multiple splitting (Fig. 2c), “U-shaped” - ionogram with arc shape trace (Fig. 2d), “spots” - ionogram with detached spot (Fig. 2e), “multiplied U” - ionogram with a number of arc shape structures (Fig. 2f).

Figure 2a. “Calm” ionogram.

Figure 2b. “Fork” ionogram.

Figure 2c. “Complex” ionogram.

Figure 2d. “U-shaped” ionogram.

Figure 2e. “Spots” ionogram.

Figure 2f. “Multiplied U” ionogram.
When the patch of the enhanced electron density does not affect on the ionogram structure is named as “calm” (Fig. 2a). Main trace was marked by solid line (arc-shaped structure without any splitting) corresponds to vertical O-mode (ordinary) echoes. X-mode trace (extraordinary) is indicated by dot line. The upper separated curves correspond to multiple reflections from the ionosphere. Herein and after only O-mode echoes traces are under consideration.

**Figure 3.** Model of the ionosphere

**Figure 4a.** “Fork” ionogram.

**Figure 4b.** Simulated ionograms.

**Figure 5a.** “Complex” ionogram.

**Figure 5b.** Simulated ionograms.
Structure presented on the Figure 2b is characterized by the splitting at the end of the main trace. Three different traces start from the same specific frequency. Another structure is illustrated on the Figure 2c, where splitting set out over a range of frequencies, forming “complex” structure of ionogram. Ionogram with “U-shaped” structure is presented on Figure 2d. Ionograms depicted on the Figures 2b, 2c, 2d are rather typical. These ionogram’s structures were observed almost every day.

Ionogram structures with “spots” shown on the Figure 2e take place much rare in observation. Such structure is “U-shaped” trace with detached spot above it. Ionogram shown on the Figure 2f could be called as “multiplied U”. “Multiplied U” ionograms were detected relatively seldom.

The original model of the ionosphere with irregularities (Fig. 3.), oriented to application for the wave propagation problem was developed in collaboration with University of Leicester (UK) [Zaalov et al., 2003, 2005], where the background ionosphere is modeled on basis of the vertical sounding data (e.g. http://spidr.ngdc.noaa.gov/spidr/index.html).

The model enables to reproduce the main types of the ionogram structures.

![Figure 6a. “U-shaped” ionogram.](image)

![Figure 6b. Simulated ionograms.](image)

![Figure 7a. “U-shaped” ionogram.](image)

![Figure 7b. Simulated ionograms.](image)

Figures 4a-7a represent ionosonde data. Simulated ionograms corresponding different type of the ionograms structure (“fork”, “complex”, “spots”, “U-shaped”) are shown on the Figures 4b-7b. The results of simulation are very reminiscent of the data observed in the measurement.
The approach in this paper is to employ the scenario with one patch in order to interpret observed ionograms (Fig. 8). The patch located in vicinity of the receiver makes the main contribution to the ionogram structure formation.

The dynamics of the ionogram structures was investigated as well. On Fig. 9 the evolution of the ionograms structure is shown, while the patch with specific critical frequency and size moves above receiver.

The ionogram structure “fork” corresponds to the case when the centre of the patch is located over receiver. While the patch moves away from the receiver ionogram structure transform from “fork” to “complex”. When the edge of the patch passes the receiver the ionogram take on shape “U” with “spots”. After that detached “spots” disappear and “U-shaped” structure comes into the picture. If the distance between edge of the patch and receiver exceed 300-400 km the impingement of the patch on the ionograms is getting negligible. The structure becomes “calm” for wide range of the patch size.

![Fig. 8. Model of the one patch of enhanced electron density.](image)

![Fig. 9. Vertical ionogram for different distance from the patch to the receiver.](image)
References:


