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The program complex for interpretation of ionospheric backscatter sounding data

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Abstract

We consider techniques and algorithms for program complex of automatic interpretation of ionosphere backscatter sounding data obtained on the basis of chirp ionosonde located in Institute of Solar-Terrestrial Physics SB RAS. Within this problem the following tasks are considered: a) carrying out preprocessing for removal of noise from the image and improvement of amplitude characteristics; b) compression of data with use of the cellular automaton; c) backscatter ionograms interpretation. The interpretation technique for ionograms is based on results of frequency dependences modeling for the minimum group way in the mode of the long-term forecast and results of experimental data processing. We also present results of operative diagnostics for HF radio channel on the base of backscatter sounding current data.

1 Introduction

One of effective digital aids for ionosphere diagnostics is chirp ionosonde [1, 2]. Multi-purpose chirp ionosonde, working in the modes of vertical (VS), oblique (OS) and backscatter (BS) sounding, can be basic element of monitoring system for ionosphere parameters and radio waves propagation parameters. The input data for the methods realized in a program complex are results of secondary data processing of ionosphere sounding (ionogram).

The BS technique allows obtaining information about sounding area, and about remote scattering areas located on thousands of kilometers from sounding area. The results of operative diagnostics for radio channel on the base of current BS data can be used for restoration of spatial distribution of electronic concentration in sector of ionosphere sounding by chirp ionosonde in BS mode. Generally the diagnostics of HF channel with use of results of BS has to include the following procedures:

- processing and interpretation of BS data and recovery of the distance-frequency characteristic (DFC);
- operative calculation of the maximum usable frequency (MUF) and DFC of the oblique sounding (OS) on the base of the current DFC of BS signals.

2 Techniques and algorithms of secondary processing

The ionogram processing includes the following tasks[3]:

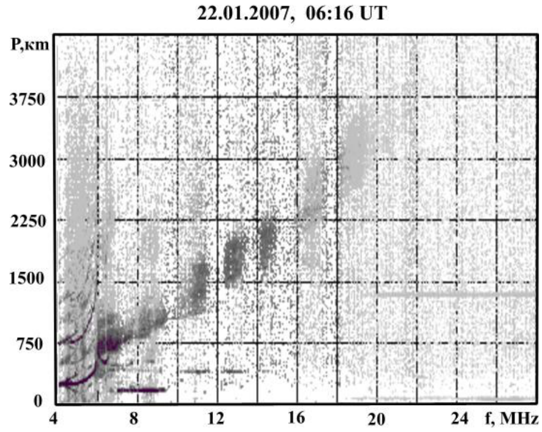
a) carrying out ionograms preprocessing for removal of noise from the image and improvement of amplitude characteristics;

b) compression of the data allowing to carry out reduction of their volume without essential loss of useful information.

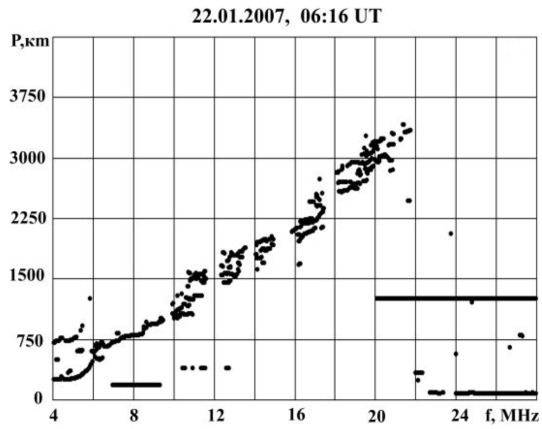
The ionogram preprocessing consists in cleaning of noise components for the purpose of allocation of a useful signal against hindrances, and also removal of single emissions which have intensity, comparable with a useful signal and can result to failures in the work of algorithms for ionospheric parameters determination. For noise reduction we use local methods of smoothing that allow creating estimates of the field of the non-noisy image by the analysis and processing of the fragments limited by the certain size. These techniques are characterized by computing efficiency and possibility of images processing in real time. For removal of the noise on the image and restoration of the signal counts at a stage of preprocessing it is possible to use the median filter which allows to smooth hindrances and to reduce degradation of track borders, and also to restore values in of tracks gaps. Upon transition between realizations on adjacent frequencies low correlation between noise hindrances leads to the fact that the noise becomes impulse and so the best technique for its deleting is the median filter.

The technique of data compression is applied for separation of points with significant amplitude that physically connected to certain values – the moments of the signal arrival on leading signal front or the maximum of the amplitude relief. For elimination of single artifacts, partial recovery of data and identification of primary track on ionogram the mechanism of the cellular automaton is effective.

Cellular automatons are discrete dynamic systems which behavior is completely defined by a local interconnection of elements in these systems. The dynamics law of such system is expressed by some set of rules by which each cell



(a) BS ionogram



(b) Results of secondary processing of BS ionogram

Figure 1. Backscatter sounding data. Usolye (52.88°N, 103.26°E) – Tory (51.70°N, 103.0°), 22.01.2007, 06:16 UT

changes the condition depending on conditions of neighboring cells, entering some local area. As a result we have points on crests of tracks and insignificant part of the noise. The realized algorithm has allowed to reach compression of initial information till 5-10 times depending on the noise level and diffusion[3].

On Fig. 1 we present BS ionogram (a) and results of secondary data processing (b). Transmitting point – Usolye (52.88°N, 103.26°E). Receiving point – Tory (51.70°N, 103.0°E). Radiation azimuth – 55°. Registration time – 22.01.2007, 06:16 UT.

3 Basic conceptions

In paper [4] the method of direct diagnostics of the radio channel by results of sounding ionosphere sounding by chirp signal developed in ISTP SB RAS is offered. The method is based on the adiabatic (weakly changing) ratios of frequency dependences of OS and BS signals group characteristics in various heliogeophysical conditions.

Under the modeling of signals characteristics for oblique and backscatter sounding and the analysis of experimental data we reveal the following ratios that weakly changing under ionosphere parameters variations[4]:

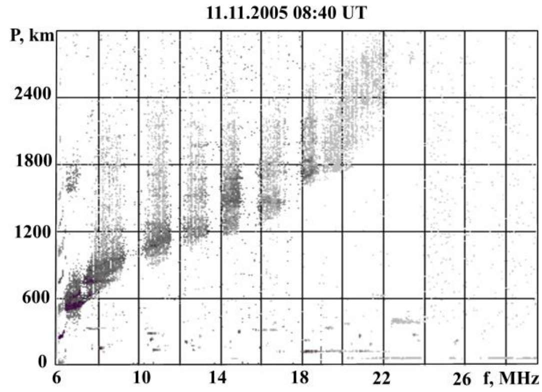
- the ratio of the group way P_m corresponding to the BS signal forward front (the point of interlocking of the lower and top beams on OS ionogram), to distance to the border of the lit zone D_m (to radio route length);
- the ratio of MUFs for modes of various multiplicities;
- the ratio MUFs for modes on various radio routes;
- DFC of one mode of BS signal on leading front on the relative grid of frequencies $\nu = f/f_m$, where f_m is MUF for the maximum propagation distance of BS signal;
- DFC of one mode of OS signal on the relative grid of frequencies $\beta = f/f_m$, where f_m – MUF mode for considered range.

Thus, the algorithm of restoration of BS DFC is based on adiabatic dependence of the minimum group way of the signal dispersed by an earth surface on the relative grid of frequencies $\nu = f/f_m$ under change of ionosphere parameters. For prognosis parameters of an ionosphere on a grid of frequencies calculation of DFC of BS signals for leading front is carried out. The prognosis DFC of BS signal is recalculated on the relative grid of frequencies ν. As initial frequency f_m MUF for the maximum propagation distance of a signal is selected. After secondary processing of the BS experimental we have a matrix of the experimental points corresponding to a two-dimensional array of a group way values P_i on a grid of frequencies f_i for points with a significant amplitude. The experimental points are also transferred to the relative grid of frequencies ν. The algorithm for identification of propagation modes on the BS ionogram in automatic mode consists in determination of a maximum of the histogram of distribution for number of the experimental points getting to the model mask constructed according to the long-term forecast under frequency f_m change on the relative grid of frequencies $\nu = f/f_m$.

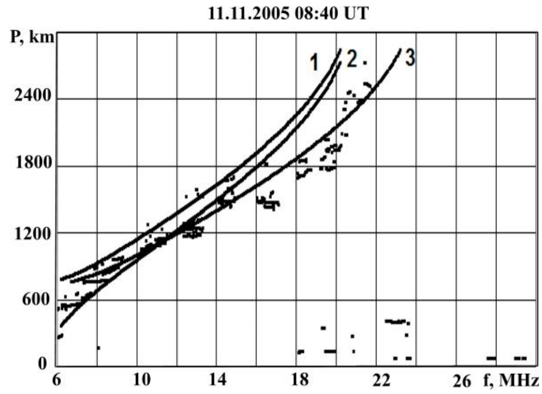
4 Results

Results of secondary processing and interpretation of BS ionogram are given in fig. 2b. Line 1 and line 2 indicated results of simulation P_m and D_m for the long-term forecast, line 3 – the interpreted BS DFC, black dots – points with significant amplitude of BS signal.

Calculation of MUFs for OS signal with the set radio route length on the base of current DChH for BS signals is based on an adiabatic ratio P_m/D_m. At the first stage for prognosis ionosphere parameters we calculate distance-frequency characteristics $P_m(f)$ and $D_m(f)$. Calculation of BS DFC for the forward front $P_m(f)$ and $D_m(f)$ is carried out within the waveguide approach. For given range D_0 we calculate



(a) BS ionogram 11.11.2005, 08:40 UT



(b) Results of secondary processing and interpretation for BS ionogram. 1 – P_m, 2 – D_m, 3 – BS DFC.

Figure 2. Backscatter sounding data. Usolye (52.88°N, 103.26°E) – Tory (51.70°N, 103.0°), 11.11.2005, 08:40 UT

ratio $\eta = P_m/D_0$. Further on real BS DFC by forward front the frequency for which the group way is equal to value $P = \eta D_0$ is determined. The frequency calculated in this way thus will be actual frequency f_m for the given range D_0.

After determination of DFC for the given range on BS current data , there is an opportunity to calculate real OS DFC of corresponding propagation mode by results of the long-term forecast on the relative grid of frequencies $\beta = f/f_m$. In Fig. 3 we present the results of recalculation for prognosis OS DFC for 1F2 mode on MUF for propagation mode calculated on the current DFC of BS signal for ionogram from Fig. 2. The offered interpretation method for BS ionograms can be applied in lack of strong perturbations of artificial and natural origin.

5 Conclusion

One of the most important applications of the method of backscatter sounding is the possibility of operative diagnostics a specified radio channel and calculation of MUF of propagation modes. It allows us to adjust the range of operating frequencies on a given radio route. Program complex for interpretation of data of backscatter ionospere sounding

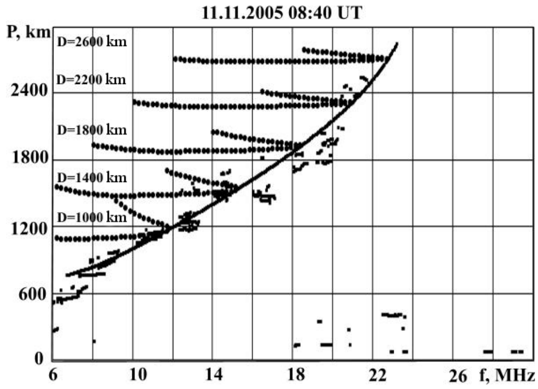


Figure 3. Results of secondary processing and interpretation of BS ionogram and OS DFC for range grid: 11.11.2005, 08:40 UT. BS DFC – solid line, OS DFC – dotted line.

allows us to provide an operative diagnostics of radio channel automatically.

6 Acknowledgements

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