The processing and interpretation of ionosphere sounding data using the continuous Chirp-signal

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Abstract

In this paper, we have considered a software package of automatic interpretation of radiophysical information acquired by an ionosonde of vertical and oblique sounding (VS and OS). Ionogram interpretation methods rest on results of modeling of frequency dependences of propagation characteristics in the regime of long-term prediction and on results of experimental data processing. These methods have been employed in this package to realize algorithms of direct diagnostics of decameter radio channel from VS and OS data which are used for automatic link establishment of communication radio channel.

1. Introduction

Ionospheric communication lines are a component part of radio technical information transfer systems which use radiowaves of decameter range. Modern information transfer systems are supposed to process in big variety of noise situations quite often in condition of a priori information insufficiency. Thus the construction of adaptive systems with maximal effectiveness of signal detection in noise situation presents big interest. Since the operating mode of these systems consist in processing of large data sets, real time mode is possible only in automatic data interpretation regime under various ionosphere sounding modes with a help of a program complex. The input data for our program complex are the results of secondary processing for ionosphere sounding (ionograms).

2. The techniques and algorithms of secondary processing

Here we shall select the main features of secondary processing. On the basis of spectral analysis we form ionogram. On ionogram we may select four main object types: useful signal, background noise, concentrated hindrances and isolated surges. The main problem of automatic ionogram processing is the selection of tracks on ionogram which satisfy some criteria with following determination of points with significant amplitude. By considering the ionogram as a complex image we may use the techniques of image processing theory.

The secondary ionogram processing is reduced to solving of two independent problems:

a) undertaking of ionogram pre-processing for removing the noise from image and improving amplitude characteristics;

b) data compression which allows to conduct sufficient data volume reduction without essential loss of useful information.

The ionogram pre-processing is concluded in clearness from noise components [1], i.e., it is necessary to select useful signal on noise and stationary hindrances background as well as to delete isolated surges which has an intensity comparable with useful signal and cam inflict malfunctions in algorithms for ionosphere parameters determination. The analysis of filters which can be used for ionogram processing has shown that for removing the noise from image and signal restoring on pre-processing stage one can use local filters built on the use of ordinal additive statistics which connected with processed fragment characteristics.

The data compression technique [2] is used for selection of points with significant amplitude which physically corresponds to signal receipts moments determining by signal front or amplitude relief maximum. For sitting out the single artifacts, the partial data reconstruction and revealing ionogram primary track one can use effective cellular automaton technique. Cellular automatons are the discrete dynamical systems which completely defined by local mutual connection of theirs elements. The whole data space is divided on elementary cells which

afterwards evolutes under discrete time. The dynamics laws of such system is expressed by some set of rules on which every cell changes its parameters depending on parameters of neighbour cells from certain local area

Our algorithm allows to reach the input date compression up to 5-10 times depending on noise level and data diffusion. [2].

3. Vertical sounding ionogram interpretation technique

The ionogram interpretation technique is based on using of height-frequency characteristic (HFC) modeling results in long-run forecast mode and experimental ionograms processing results. By using ionosphere models (for example, IRI as a standard ionosphere model [3] or Semiempirical Model of the Ionosphere [4]) one can calculate height-frequency characteristic for vertical propagation. Under modeling of this dependence we can obtain the value of integral on the base of general formulas. This problem pertains to direct problems class and its solving does not form big difficulty [5]

The obtained height-frequency characteristic is superimposed on experimental ionogram and is used for model mask building. Then by scanning of model mask along the ionogram one can construct the histogram of coincidences for model and real tracks. After that we change the slope of model tracks and repeat the scanning process.

After the termination of the process we select the histogram with maximal number of points with significant amplitude falling into model mask. On Fig.1 we present the results of automatic interpretation for vertical sounding ionogram: input ionogram (the 11/17/2005 Usol'ye - Tory (Irkutsk) path) with secondary processing results (a) and interpretation results (b).

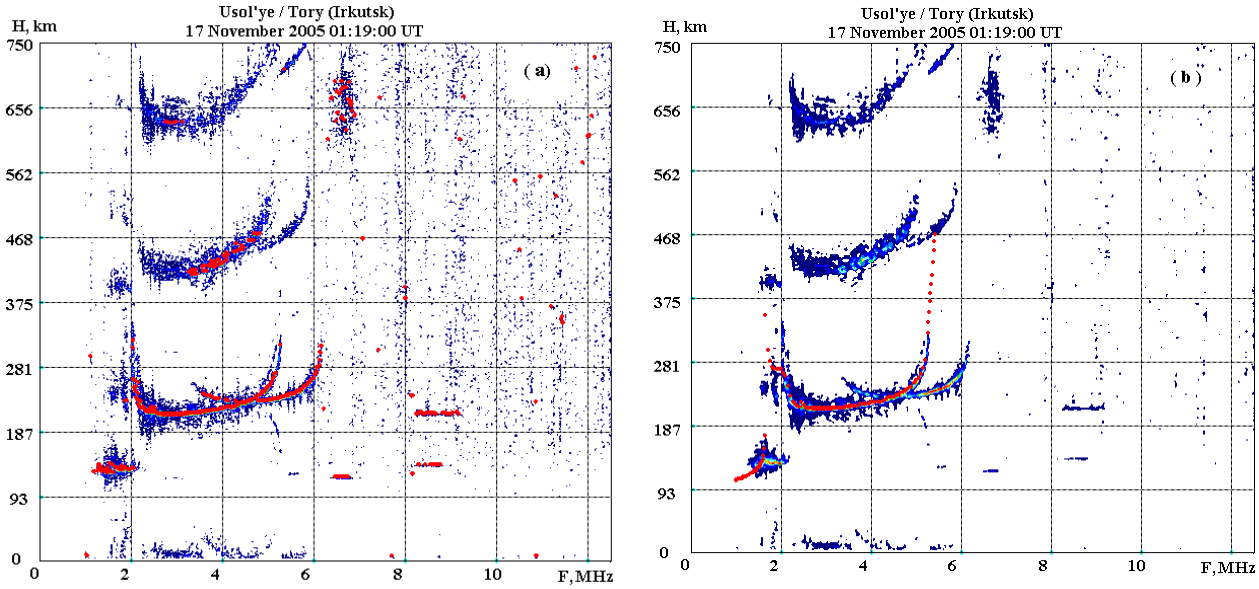

Fig. 1. Vertical sounding ionogram (a) and the interpretation results (b), November 17, 2005, 14:15 UT

4. Oblique sounding ionogram interpretation technique

The technique is based on using of modeling results for distance-frequency characteristic (DFC) on given path in long-run forecast regime, adiabatic relations and experimental ionogram data processing matrix of points with significant amplitude $A(f_i, P_j)$.

For oblique sounding ionogram interpretation problem one can formulate the following background suggestions [6]. Under the ionosphere parameters variations within the accuracy of long-run forecast are saved the following values :

- the ratio of group path P_m in joining point of lower and upper rays for some mode on path length;

- the ratio of maximal usable frequency (MUF) for modes of different multiplicity which propagates in one of waveguide channels (with lower wall as Earth surface but upper wall asoй E, F1 or F2 layer);

- distance-frequency characteristic for one mode with multiplicity l, on relative frequency grid $\beta = f / f_{m,l}$,where $f_{m,l}$ - mode of maximal usable frequency for given range.

The algorithm of oblique sounding ionogram interpretation in automatic mode is built as follows. The calculation of oblique sounding distance-frequency characteristic for given path in the regime of long-term prediction are cried out. Coming thereof, one can construct the model mask for minimal multiplicity mode of F layer, which includes two bands of width ΔP km (on vertical) and extent on frequency from μf_m^p to f_m^p, where f_m^p – forecast maximal usable frequency of supporting mode for upper ray and with extent from νf_m^p to f_m^p for upper ray.

The algorithm of supporting trace on ionogram is concluded in count of point number for signal receipts moments under moving of model mask along experimental points on relative frequency grid. The mask moves on points of the matrix $\grave{A}(f_i, P_j)$ by joining the "nose" with point A_{ij}. Under moving the mask we count the number of points $\grave{A}(f_i, P_j)$ which falls into mask within rectangle [Δf x ΔP], where Δf and ΔP are selected due to ionosounder resolution on range and frequency. The maximal values of experimental points count are saved.

In the case of f_m^r and P_m^r determination the remained experimental points which correspond to mode of first multiplicity are identified by lengthening of mask bands to lower frequencies range along model distance-frequency characteristic scaled by multiplier f_m^r / f_m^p and searching for elements P_{ij} falling in these bands.

After than we carry out linear interpolation of tracks in order to turn on uniform frequency grid. The identification of modes with greater multiplicity is conducted by above-mentioned procedure.

Figure 2 shows the results of automatic interpretation of an oblique sounding ionogram for the 11/17/2005 Magadan-Tory (Irkutsk) path.

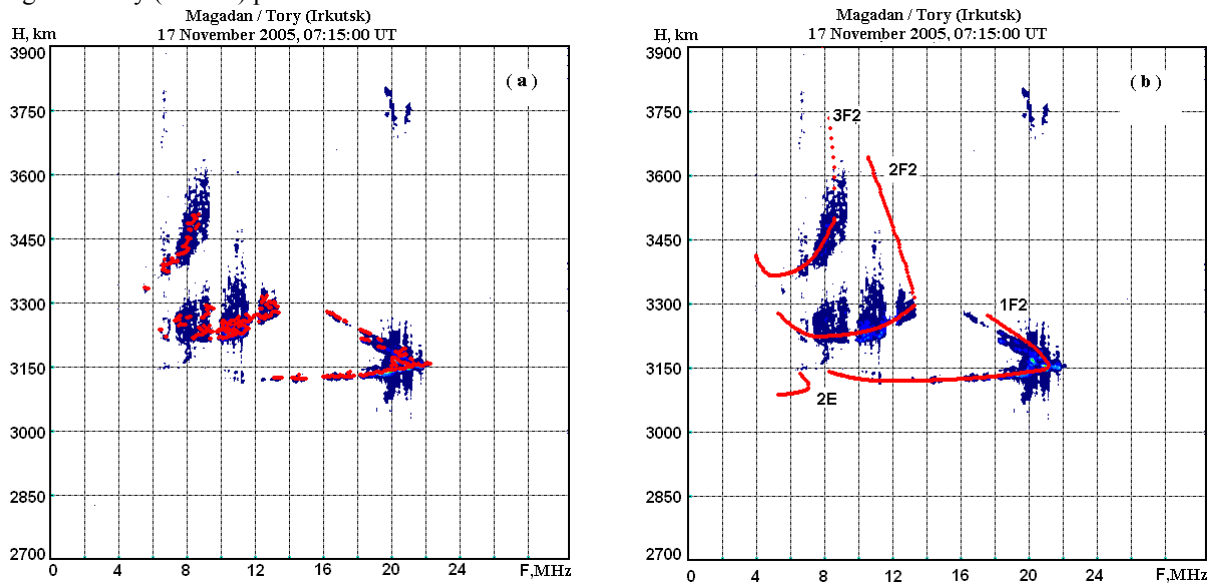

Figure 2. Oblique sounding ionogram (a) and the interpretation results (b), November 17, 2005, 07:15 UT

The test showed that the OS ionogram interpretation technique provides quite a good accuracy on average. Figure 3 presents relative errors in interpretation of maximum usable frequency for the 3/25/2010 Magadan-Irkutsk path.

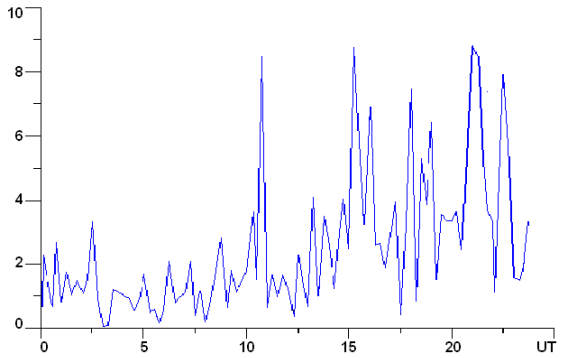

Figure 3. Relative error in determining the maximum usable frequency between manual and automatic processing

3. Conclusion

Considering above techniques and algoritms of ionogram secondary processing and signal interpretation for vertical and oblique ionosphere sounding are realized as a program complex which allows to select track and conduct their identification in automatic regime.

For vertical sounding we conduct the calculation of ionospheric parameters – critical frequencies and minimal reflection heights for each ionosphere layer. In the event of correct identification of all height-frequency characteristic layers on the base of track one can calculate the characteristics of oblique sounding: distance-frequency characteristic, maximal usable frequencies for propagation modes and signal level in input receiver. For oblique sounding case our techniques allow to conduct operative determination of modes composition, maximal usable frequencies for each mode, signal distance-frequency characteristic on the base of significant points of amplitude relief and to carry out the identification of propagation modes. These methods have been employed in this package to realize algorithms of direct diagnostics of decameter radio channel from vertical sounding vertical sounding and oblique sounding data which are used for automatic link establishment of communication radio channel.

4. Acknowledgments

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5. References

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