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AUTOMATIC PROCESSING OF SIGNALS IN THE SYSTEM OF OBLIQUE-INCIDENCE AND BACKSCATTER SOUNDINGS

Victor P. Grozov, Boris G. Dolgoarshinnykh and Vasili E. Nosov
Institute of Solar-Terrestrial Physics, P.O.Box 4026, Irkutsk, 664033 Russia

INTRODUCTION

The most powerful tool for obtaining global information about propagation conditions of HF radio waves is the method of backscatter sounding (BS). The most promising approach in the problem of determining propagation characteristics from real BS data is the one based on a direct diagnostics of propagation conditions when the sounding signal is used to determine the radio channel characteristics, by omitting a correction of ionospheric parameters. Such an approach may be exemplified by different methods of determining the maximum usable frequency (MUF) for a given range. However, by knowing only the MUF, it is impossible to choose correctly an optimal operating frequency. In order to make a correct decision, it is necessary, as a minimum, to be able to diagnose the distance-frequency characteristic (DFC). To diagnose the DFC, it is necessary to separate, on OIS and BS ionograms, their structural elements, or traces, of echoes from separate ionospheric layers.

For an automatic segmenting of ionograms (separation of traces), it is customarily to use the methods of processing binary (black-and-white) images and of analyzing amplitude patterns. In particular, the algorithm of "spreading paints" [2] which separates structural elements of the ionogram on the basis of the property of connectivity of traces. Problems are discussed, which are associated with separation of ionograms into well and weakly structured ones, with the detection and elimination of noise effects. For well-structured (typical) ionograms, traces are separated, and "tracks" are constructed, i.e. point-specified lines, consisting of a subset of special ("cape") contour points [3]. Weakly structured ionograms are analyzed as amplitude patterns - plots of table-specified functions of two variables. Specifically, an hierarchical segmenting of the pattern is carried out to separate "ridges" and "valleys" [4]. Proper allowance is made for the importance of obtaining the radio channel characteristics in real time by applying procedures of fast segmenting.

THE METHODOLOGY

Techniques of automatic processing of ionograms are divided into two fundamentally different classes: methods that use numerical values of reflected signal amplitude, and methods that use only the fact of the presence of the amplitude in excess of a given threshold. In the former case, OIS and BS ionograms can be regarded as the amplitude pattern. In the latter case, ionograms are represented as binary (flat) images. Visual inspection and model calculations of ionograms, on the one hand, confirm the presence of structures of a certain shape and, on the other, are striking, owing to the diversity of features of the shape of these structures and to an extreme variability of their relative position. For an automatic recognition of the structural elements of the ionogram (traces), it is necessary to provide a technique for their constructive determination, a procedure for detecting fragments of the ionogram with certain properties.

For separating traces on typical ionograms, use is made of a rather simple algorithm for separating and counting connected objects using the property of connectivity of traces. The ionogram is represented by a binary matrix Z. Meshes that have at least one common vertex, are considered neighbouring meshes. For the image meshes, the ratio of connectivity is introduced: two image meshes are connected if there exists a chain from neighbouring meshes connecting them, no one of which belonging to the background. Connectivity specifies the ratio of equivalence on a set of non-background meshes. Classes that are generated by such a ratio of equivalence, do form the connected objects. The chief goal is to extract all connected objects, and this means to construct a separation of the set of non-background meshes of the image into equivalence classes. The process of separating connected objects may be visualized as the spreading process of paints: at first, all image meshes are of different colors; subsequently, each paint flows to all neighbouring meshes with greater numbers; as a result, all meshes of the same connected object become of the same color.

THE REALIZATION

Usually, the problem of analyzing the amplitude pattern (OIS or BS ionograms) is substituted with a simpler problem of analyzing the horizontal section of the amplitude pattern using a given threshold. The section results in a binary image, on which dark areas correspond to amplitudes of the reflected signal in excess of the threshold value. But such an approach leads to the need to resolve a number of problems. Thus, the most important question is that of choosing the threshold. In the case of an underestimated threshold, a false combination ("sticking-together") of traces occurs, and in the case of an overestimated threshold, the trace breaks down into a sequence of "islands", or is lost altogether. It is quite probable that inaccuracies of both kinds can be inherent in different parts of the same ionogram. In order to improve the ionogram structure as a whole, procedures for thinning-rejecting the boundary points were developed. Applying the procedure to a negative image, on the contrary, leads to the elimination of isolation of closely lying structural features and is used for reconstructing traces represented by a chain of "islands". Procedures for erasing thin vertical lines and for recognizing and dissecting "stuck-together" traces were also developed. Results of operation of these procedures make it possible, in most cases, to satisfactorily separate on the ionogram the individual traces and, after that, to start their individual processing which implies constructing so-called "cape" points. Cape points may be given the following procedural definition: these are points of the trace, in the small vicinity of which it is possible to construct the right-hand upper or the right-hand lower raster quadrant, devoid of points of this trace. The line that connects the chain of cape points, as was demonstrated by practice of the processing of OIS and BS ionograms, approximates reasonably well the traces of echoes. Our developed algorithm [2] consists of two parts: the first part - separation proper of connected objects, and the second part - counting the number of separated objects, recoding, as well as calculating the areas and some other morphometric characteristics of connected objects. Separation of connected objects is carried out with the help of a sequence of straight lines (from top to bottom and from left to right) and inverse (from bottom to top and element by element from right to left) scannings of the image. This algorithm was realized and used for processing OIS and BS ionograms obtained on an BS system with a continuous FMCW-signal [1]. The figures show the initial OIS - (upper, F = 7 - 30 MHz, DO= 3000 km, 5.02.1989, 4:36 UT) and BS (lower, FO = 7 MHz, Dmax = 8000 km, 26.09.1989, 14:47 UT) ionograms and the results of their processing.

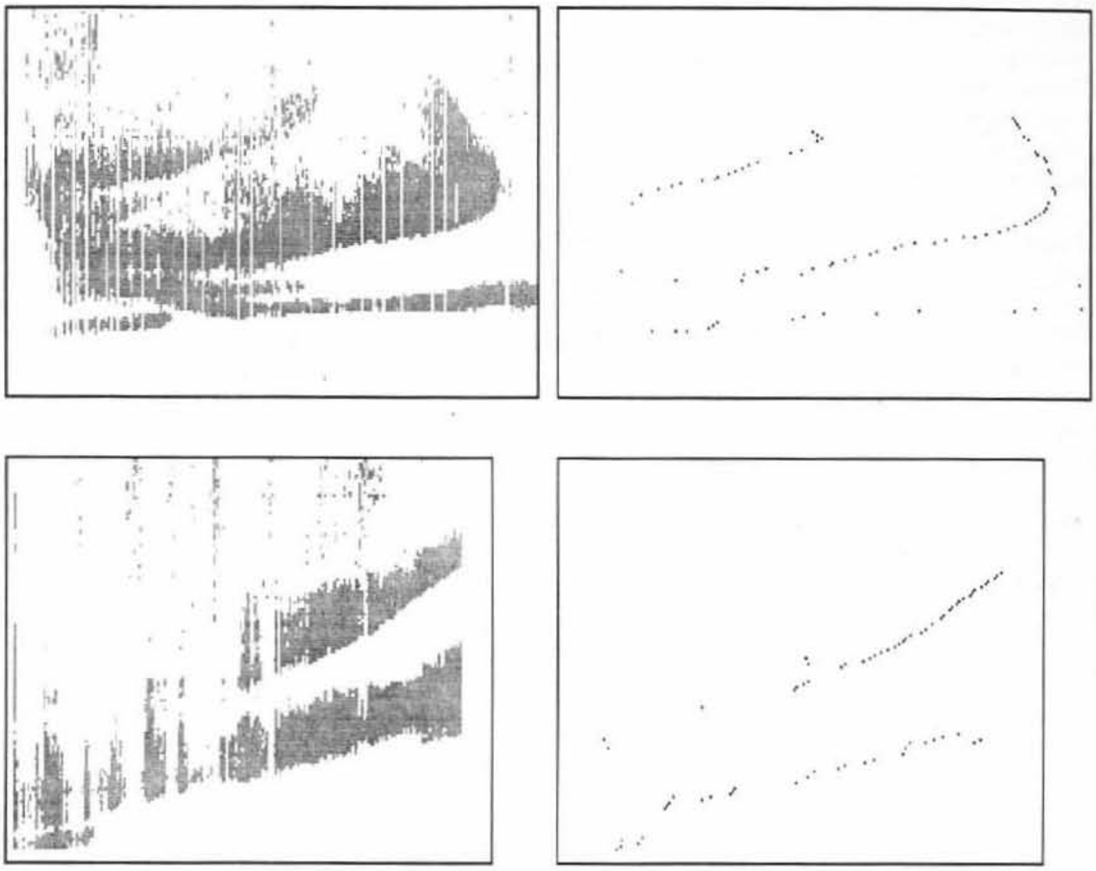

Fig.1. The initial OIS (upper) and BS (lower) ionograms and the results of their processing.

It should be noted that the solution of a primal problem of separating traces and constructing the set of cape points requires a small fraction of the time needed to analyze ionograms. The main consumption of computer time is associated with the detection and elimination of ionogram defects cause by the substitution of the amplitude pattern with its horizontal section. Thus, detecting "stuck-together" traces and dissecting them requires, at least,. a double application of the segmenting algorithm to each trace. In order to remove inaccuracies of different kinds and to reduce the time taken by the ionogram analysis, it is necessary to pass from the processing of the horizontal section of the amplitude pattern directly to the processing of the amplitude pattern. Although the addition of the third dimension generates a much richer set of possible geometrical shapes, but the final goal - to separate the main modes (traces) - remains. Therefore, there also remains the methodology when analyzing amplitude patterns: separate the main structural components of the pattern. When analyzing amplitude patterns, the procedure of segmenting is usually divided into two stages: filtering and segmenting proper [4]. Filtering is used as a process of evaluating the image at each point from the set of neighbours. For example, a sigma-filter can be used in the evaluation. The filter is rather simple, features a high computing efficiency, is adapted to the character of the scene and can be applied if the noise dispersion is not constant in the image field [5]. Filtering is followed by segmenting, i.e., breaking up of the amplitude pattern into connected, uniform (in a sense) regions of maximum area. All subsequent constructions are based on breaking up the pattern into isoregions, i.e., regions with the same value of amplitude (for any amplitude pattern, breaking up into isoregions always exists and is unique). Segmenting the pattern into isoregions is easily done through a modification of the algorithm of "spreading" paints considered above, in which the conditions for spreading of paints is supplemented with the requirement for the equality of the amplitudes in the neighbouring meshes of the raster. "Roofs", i.e., isoregions rising above all boundary isoregions, are separated from the isoregions. A transitive ratio of reachability between the meshes of the pattern is introduced: one mesh is reachable from another if there exists a chain of neighbouring meshes connecting them, along which the values of amplitudes decrease monotonically. The ratio of reachability makes it possible to separate, using the method of "spreading paints", one-extremum structures of the pattern and the background. The hierarchical character of the pattern of OIS and BS ionograms does not permit full information about its structure to be obtained by a single application of the algorithm. It becomes necessary to construct a finite iteration process of segmenting when the first iterations make it possible to separate secondary, usually accidental, details of the pattern, while main structural components are separated in subsequent iterations. The result of ionogram analysis is a set of points (tracks), by interpreting which it is possible to obtain information about the radio channel characteristics.

CONCLUSION

Automatic processing of signals for a system oblique-incidence and back-scatter soundings were outlined. A further investigations are required in order to find what could be done to improve the method processing of image.

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