AIRBORNE WEATHER RADAR AS AN INSTRUMENT FOR AUTOMATIC MAPPING

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ABSTRACT

Classification of navigational radar landmarks and the principles of their displaying at automatic radar mapping are proposed. Selection algorithms of each type of navigational landmarks are developed. The priority of navigational landmark classes is established, and the scheme of the combining different channels is designed. The automate recognition of landmarks and radar mapping is implemented in new airborne weather radar.

I. INTRODUCTION

The mode of the surveillance of earth and aqueous surfaces for the purpose of forming radar map with the separating the characteristic navigational landmarks is one of the basic duties of multifunction weather radars. Complication of the relief, availability of a great many of various reflective objects on the terrain, which are not load-carrying to the useful information in most cases, clutter up the radar map, complicating the separation of the useful information.

In this paper the classification of radar navigational landmarks and the principles of their displaying at the automatic forming of a radar map of the earth surface are proposed. The classification includes five classes: background, aqueous, area, and two types of point landmarks. The algorithms of selection of each type of landmarks are developed. These algorithms use the reflected signal power as an informative feature of the object. The appropriate radar signal processing is carried out and implemented in weather radar. However more sophisticated parameters of radar signal can be used as well. Specifically, it is supposed to use polarization parameters for improving the identification of landmarks.

We will show how to synthesize the radar map of terrain by the complexation of the selected landmarks. The complexation is carried out in two stages. During the first stage the integration over each range cell should be done. During the second stage it should be done over the element of the range scale when several range cells can be combined. The developed methods and devices have rather simple engineering implementation. They provide improving the quality and self-descriptiveness of radar map. What is also important, the process of imaging of the surface map can be reduced significantly due to the implementation of proposed way of automatic classification and mapping.

II. THE CLASSES OF LANDMARKS

The analysis of navigational landmarks and necessary navigational information have allowed us to develop and classify navigational landmarks and principles of presentation them at automatic radar mapping. The classification consists of the following types of landmarks: aqueous (water), area, dot and background of an underlying surface.

Background of an underlying surface is determined by a reflected radar signal in all coverage area exceeding sensitivity of the receiver of radar.

Water landmarks are determined by absence of an echo signal on a background of a signal, reflected from an underlying surface. The absence of a signal can be also specified by the characteristics of the radar. In these cases because of absence of the full map of water landmarks their identification is conducted by the shape of the coastline displayed on the indicator of radar.
Suppose that a radar signal is reflected from a water landmark or its part (for example, part of the river), lying within the limits of the resolution element. Suppose also that the sizes of this landmark are less than the sizes of the resolution element. Under these conditions the following different cases of the receiving of a total signal reflected from a segment of a resolution element of a surface are possible:

- total signal does not exceed a sensitivity of the receiver, hence the water landmark can be determined on the absence of an output signal of the receiver;
- total signal from the given segment of a resolution element of underlying surface is less than the total signals from the next and previous resolution segments; this decreasing of an echo serves as a characteristic of detection of the water landmark;
- total signal from the given segment of a resolution element of underlying surface practically does not differ from the summary signals, reflected from the

next and previous resolution segments; in this case water landmark on the given segment of a resolution surface can not be detected.

The area landmarks are the designated on the geographical maps parts of earth relief, which reflect well radiowaves and whose horizontal sizes exceed the radar resolution element. The radar signal reflected from them is characterized by sharp increasing of its value in the places where the area landmarks are located. They are the complicated distributed targets located on the background of an underlying surface. The radar signal reflected from them is characterized by sharp increasing of its value in the places where the area landmarks are located. The sizes of the area landmarks are unknown beforehand. Therefore gradient of change of a reflected radar signal from an underlying surface can be used as a characteristic of the appearance or disappearance of an area landmark. The experimental data shows that the area landmarks can give an increasing of the radar signal of 5 dB and more. In some cases the area landmarks can be shown as a set of the close located point landmarks. In this case the detection of them can be done only on a display screen of the radar.

Point landmarks are the objects, mainly from the unnatural facilities, whose sizes do not exceed the size of resolution element of airborne radar (weather radar). They are designated on geographical maps, have precise binding to coordinates and can be entered into the onboard navigational computer for the correction of airplane position. A radar signal has sufficient radio-visibility in comparison with a background and with the receiver noise. The duration and spectrum of radar signal, reflected from point targets, corresponds to the duration and spectrum of a sounding signal. Usually such signal has sufficient radio-visibility in comparison with a background and with the receiver noise. A part of water landmarks described above can also be considered as point landmarks, and the similar criteria can be used to detect (select) them.

III. SELECTION OF LANDMARKS

The selection of the background of an underlying surface is the simplest of the listed above problems. Therefore for these purposes automatic binary threshold detectors are useful. Signal processing at the detection of the background consists of the comparison of the signal with a given threshold level.

For selection the water landmarks it is possible to use a channel of background marking out of an underlying surface. If the signal does not exceed an established threshold, it is necessary to consider, that it bearings on signals reflected from a water surface. The identification of water landmarks can be made by the operator on a radar map of terrain displayed on the indicator, by the typical configuration of the not lighted segments of the display screen or by the character of the coastline displayed as a background of an underlying surface.

When the water landmark is less than the resolution element of an area defined in parameters of a radar resolution, it can be referred to point landmark, giving the mirroring of an irradiated signal. The typical feature of an echo in this case is that its value will be less then the values of echo from the adjacent resolution elements. This feature is put as the basis definition of such water landmarks as point targets, having the "negative" radio-visibility.

The area landmarks concern to the distributed targets, but reflected from them the signal has certain visibility relatively to the signal, reflected from the underlying surface.

The process of automation of selection of area landmarks might be improved by recovering the signal, reflected from the background of the underlying surface, from a full radar signal by spectrum analysis of a signal, reflected from an underlying surface and particular considered targets.

Using a set of matched low frequency filters, it is possible to filter and to select a signal, reflected from a background of an underlying surface, and also to select the signals, reflected from the area and point targets.

The undetermined beforehand sizes that can change in very broad limits, starting from the sizes appropriate to the resolution of the radar are typical for area landmarks. It results that the duration of an echo signal reflected from them can not be calculated beforehand and used for definition of the passband of LF filters. The mentioned disadvantages of the filter-type device result in necessity to use additionally other differences of area landmarks to provide the radio-visibility of them. Those are:

· gradient of the radar reflectivity on boundaries of the area landmarks, which are determined by the increasing of the specific radar cross section (RCS) of the landmarks in comparison with the specific RCS of a background of an underlying surface;

· large value of RSC in relation to a background.

The indicated differences were put in the basis of the development of the graded-index method of selection of area landmarks. The essence of the method is that the beginning of an area landmark is considered as selected, if the positive gradient of an echo signal exceeds an established threshold. The landmark is present so long as the negative gradient of an echo signal will not exceed an established threshold for the negative gradient. The gradient is determined by processing the radar signals in sliding "window".

Thus, the gradient finds out, if its expansion on distance exceeds the resolution of radar, and its value exceeds an established threshold. If there are two countings of distance on a resolution element at digital signal processing, the gradient will be present there, where the values of three consecutive countings on distance will differ from two previous ones on the value of the threshold.

Selection of point landmarks on the background of underlying surface is reduced in using the adaptive detectors on a noise background. The threshold of detection changes depending on a local interfering situation. To receive the necessary information about the local interferences, it is necessary to analyze a part of space around the tested resolution element. In adaptive systems with the stabilization of the level of false alarms the decision about the location of a target is made by using the "sliding window" method. The data available in the monitoring "window" are entered in algorithm for calculation of the decision making threshold. These procedures are almost identical in all systems with the stabilization of the false alarm level. They differ only by processing of a signal in "window" and by using different coefficients to counting the threshold of detection.

The analysis of the existing adaptive systems with a false alarm stabilization has shown that the technique of Z and T determination at the calculation of threshold S and length of "window" are important for the efficiency of the system. We developed methods of detection of point landmarks in narrow "window" (N=5) by a relative estimating the nearest K “neighbors” in the "window" is developed. The sense of this method is, that the point landmark finds out, if the echo signal duration corresponds to the range resolution of radar, and its magnitude relative to the values of neighboring signals exceeds an established threshold.

The typical feature of the designed methods of signal processing for the selection of point landmarks is the small length of "window". This feature allows eliminating an effect of masking of the multiple targets. Apart of that these methods are characterized by the persistence of a threshold of the detection and "rigidity" of the criterion of detection in relative to the target.

IV. FORMATION OF THE INTEGRATED SIGNAL

The output information of different channels is joined into a unified data link onto display devices. The radar map is synthesized by the integration of the selected navigational landmarks.

The integrating of the information coming from all channels of navigational landmark selection implements in two phases. At the first phase it is necessary to unite the information from channels of selection in each cell of the distance. At the second phase the information of several range cells should be integrated into a single scale cell. That is necessary in digital systems of processing and information transmission to mapping the required number of range cells for an established scale of the radar. Here the scale means a distance of detection and mapping of a radar map of terrain. For this purpose the algorithm of the unification is developed, which is based on the logic of the output data application to the tasks of weather and navigational radars. The higher priority in algorithm of unification of the information is given to the point landmarks. The appropriate output signal is formed irrespective of presence of landmarks of other types in the range cell or in the scale cell. The next priority is given to point landmarks with "negative" radio-visibility. Then the area landmarks go, and the last is background of a underlying surface.

V. CONCLUSION

In this paper the classification of radar landmarks is presented based on researches of the authors. The described classes of landmarks can be mapped using of special coding and denotations and have precise binding to a geographical map.

The developed and patented algorithms of the selection of navigational landmarks and synthesizing the radar map of a terrain have simple technical implementation, which is especially important for onboard radars. They can be a basis of automatic identification of navigation landmarks with forming of synthesized radar map of terrain. Realization of work results allows improving the quality and selfdescriptiveness of radar mapping, reducing the process of the solution of navigational tasks.

Algorithms of identification of navigation landmarks and automatic radar mapping of terrain considered in this paper is implemented in prototypes of multifunctional weather radar "Buran A-140", which is installed on airplanes Antonov-140 [1-2].

It is supposed to use polarization portraits for the recognition of landmarks, maintaining the idea of classification and constructing the synthesized radar map of terrain in order to improve the quality of the identification.

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