Quality indicators of devices for trajectory processing of radar information and methods of their testing

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Abstract. The indicators of the quality of devices for trajectory processing of radar information and methods of their testing are considered. Practical recommendations are proposed that simplify the assessment of quality indicators of trajectory processing devices.

Introduction
One of the most important stages of designing a system for trajectory processing of radar information is the choice of quality indicators, their predictive assessment, as well as the determination of methods for their testing [1, 2]. It boils down to combining in time the results of the primary processing of the received signals in order to detect tracks, recognize their classes, and refine the coordinates and motion parameters.

As can be seen from the innovation cycle of the radar [1], one of the most important stages in the design of the trajectory processing system is the choice of quality indicators, their predictive assessment, as well as the determination of methods for their testing.

Fig. 1. Radar innovation cycle [1]
Despite a significant number of publications devoted to various aspects of trajectory processing, they practically do not pay attention to the quality indicators of trajectory processing and methods of their testing.

In this report, taking into account new achievements and trends in the field of constructing tracking processing systems, quality indicators will be considered and methods for their testing will be proposed. The paper covers the studies of domestic and foreign scientists [1, 3, 4, 6, 7, 8], summary data from various international organizations (EuroControl, ICAO, EACA and other) [5]; as well as our own experience in the development and testing of tracking systems.

It should be noted that the assessment of a number of quality indicators is difficult and requires complex preparatory calculations and the provision of test conditions.

This report will present a number of solutions to greatly simplify data collection and analysis of quality indicators. Examples are given for the tests based on the results of mathematical modeling, but they can be generalized for semi-natural and full-scale test methods.

1. Quality indicators for trajectory processing

It is expedient to divide the trajectory processing indices into three directions [1, 2, 9]: the quality indices of the scan-to-scan selection of moving targets against the background of discrete interfering reflections (DIR), the quality indices for a single-target situation and the quality indices for a multi-target situation.

The indicators of the quality of scan-to-scan selection include [9, 10]: the coefficient of suppression of DIR and the average number of false tracks formed by DIR.

The quality indicators of devices for a single-target situation include [1, 2, 5]: the probability of correct trajectory detection; average time of trajectory detection; probability of trajectory disruption from tracking; probability of correct trajectory reset from tracking; average time of trajectory reset from tracking; total errors in measuring the location, coordinates and parameters of the observed objects.

The quality indicators for a multitarget situation include [1, 2, 5]: the average number of false tracks, the average duration of the false trajectory, the probability of trajectory confusion, the wiring coefficient, the coefficient of false tracks.

Evaluation of quality indicators of trajectory processing devices is carried out by means of mathematical (computer) modeling, semi-natural and full-scale experiments. When carrying out mathematical modeling, as a rule, a simulator of the formation of an input action on the tested tracking processing device is used. To expand the testing capabilities, it is proposed to include a device for generating trajectory processing stress tests in the simulator of the formation of an input action. The following stress tests are recommended:

- throughput check - a stream with the maximum number of evenly distributed tracks over the entire viewing area;
- verification of tracking filters with probabilistic data fusion - maximum concentration of tracks in specific azimuth sectors;
- checking the tracking filters for the permissible value of the overload of the tracked air object – the flow of maneuvering objects within the specified overload interval.

For an effective assessment of the quality indicators of the trajectory processing system, it is proposed to include a device for monitoring the quality indicators of primary and secondary (trajectory) processing of radar information, which should provide:

- analysis of information supplied to the input of the tested device for trajectory processing of radar information (output of the primary processing device);
- analysis of quality indicators of scan-to-scan selection against the background of DIR.
- analysis of quality indicators of the tested device for trajectory processing of radar information for a single-target and multi-target situation.

When analyzing the primary processing of radar information, it is necessary to evaluate the probability of detection of the received signal, the probability of a false alarm in the radar coverage.
area, and errors in one-time estimation of the polar coordinates of the observed objects. For this, it is proposed to use the device for monitoring the interference environment, proposed in [11].

2. Features of testing devices for scan-to-scan selection
Scan-to-scan selection is inextricably linked with the operation of the trajectory processing system. Its main task is to combat discrete interfering reflections. These disturbances are remnants of compensation of concentrated local objects, distributed objects and atmospheric discontinuities (see Fig. 2). They are purposeful motion models close to low-speed objects (for example, helicopters, UAVs and light aircraft), their number can reach several tens or even hundreds, and in some cases they can paralyze the trajectory processing system.

Most often, preliminary scan-to-scan selection is used, based on clutter maps [7, 10-12]. Its task is reduced to the preliminary setting of each primary plot of a feature – «useful object» or «discrete interfering reflections (clutter)» (see Fig. 3). All plots are passed to the path, but no new paths should be created for discrete clutter plot. The decision is made from the condition of hitting the plot in the cell of the clutter map if the interference detection criterion is met.

![Fig. 2. An example of the operation of the scan-to-scan system according to the experimental data of the miniature radar layout](image)

![Fig. 3. Generalized structure of the trajectory processing system with registration and monitoring devices](image)
The main quality indicator is the suppression coefficient, which characterizes the ratio of the amount of noise at the input to the amount at the output.

To simplify tests of scan-to-scan selection, it is proposed to use a flow of discrete interfering reflections. It differs from the classic stream of false plots in that it takes into account the prehistory of spatial movement; the speed of movement occurs under the influence of the wind, taking into account the selected model. An example of an interference stream 50 is shown in Fig. 4, a-b (input and output).

![Image of a diagram showing suppression coefficient and number of false tracks.](image)

**Fig. 4.** Scan-to-scan section input (a) and output (b), and the result of the registration system: suppression coefficient (c) and number of false tracks (d)

To test scan-to-scan devices by the method of mathematical modeling, it is advisable to use the DIR flow. This flow should take into account the distinctive features of the DIR: distribution of tracks...
by heights and speeds of movement (altitude and speed characteristics); type and parameters of the setting action; characteristics of the disturbing effect.

The results of the scan-to-scan selection are transferred to the registration device. Figure 4, b shows the results of the scan-to-scan selection and trajectory processing system. Blanked plots (plotted in blue) and false tracks are visible. Figure 4, c-d shows the work of the registration device, it fixes the suppression coefficient on the current view and the number of false tracks. The tests are carried out without the participation of useful objects.

It is recommended to evaluate the efficiency of the scan-to-scan selection depending on the density of the DIR flow (the number of DIR plots formed per second). Similarly, the number of tracks formed by uncompensated DIR is counted and averaged over the entire observation time (total number of scans). Then you can enter the results in a table and collect statistics for DIR.

3. Stress tests for trajectory devices. Monitoring device
When analyzing the quality indicators of the tested device for trajectory processing of radar information for a single-target and multi-target situation, it is proposed to use a monitoring device for trajectory information. At the current moment of time this device must count the number of one-time evaluations at the input; the number of detected, confirmed, followed and dropped tracks; the total number of tracks; number of tracks without gaps. The use of such a device makes it relatively easy to evaluate quality indicators in real time without additional laborious calculations.

For testing, it is proposed to use the classical Poisson flow of false plots with a known intensity (it is enough to simply recalculate it later into the conditional probability of a false alarm). An example of such a flow is shown in Figure 5.

![Fig. 5. An example of a Poisson flow of false plots (a) for testing trajectory processing quality indicators and the results of the monitoring system (b and c)](image)

The task of trajectory processing here is to ensure the minimum number of false tracks with a minimum average duration. In this case, the monitoring device records both false tracked tracks, and detected and confirmed ones. This allows evaluating the quality of the detection and reset algorithms. Figure 5, b-c shows the results of the monitoring device for several scans. By analogy with interspecific selection, the results can be tabulated for different values of the intensity of false plots.

It is proposed to test the trajectory processing system for the maximum number of tracks using a stress test (see Fig. 6). Its peculiarity lies in the formation of tracks of the same type, evenly distributed over space, moving with the same height, speed and direction of flight.
The trajectory processing results are shown in Figure 6, b. Objects outside the detection area are added again. In addition to checking for the maximum possible number of tracked tracks, the time spent on detection can be estimated.

**Conclusions**

The report discusses the quality indicators of devices for trajectory processing of radar information and methods of their testing. Indicators of the quality of scan-to-scan selection of moving targets against the background of discrete interfering reflections, quality indicators for a single-target situation and quality indicators for a multi-target situation are given. Measures are proposed that simplify the assessment of these quality indicators: use of simulator with a device for generating stress tests and
integrated trajectory filters; use of a device for monitoring interference conditions; use of a trajectory information monitoring device.

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