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Agenda Item 7: Report on surveillance ground system and avionics performance monitoring and improvement in compliance

SUGGESTIONS OF PERFORMANCE PARAMETERS OF RADAR SYSTEM AND RELEVANT TEST METHODS FOR APAC REGION

(Presented by China)

SUMMARY

This paper presents a minimal set of performance parameters that can effectively evaluate radar system. For each parameter in the set, a detailed description and the specific test method are given.

1. INTRODUCTION

1.1 According to the ACTION ITEM 6-4 of SURICG/6, a group was suggested to study performance specifications and benchmarking of radar for APAC Region. China has actively carried out relevant works.

1.2 During MODE S DAPs WG/5, China presented a brief overview of the radar performance parameters included in the Guidance Material on Surveillance Technology Comparison (GMST) version 1 published in 2007 and Doc 8071 Vol 3, and proposed a minimal set of radar performance parameters. With the paper presented, New Zealand proposed to consider referring to EUROCONTROL Specification for ATM Surveillance System Performance (Volume 1) Edition 1.1, issued September 2015.

1.3 With continued research on the above three documents, China updates the minimal set of performance parameters proposed during MODE S DAPs WG/5 and the corresponding test methods are studied. The paper provides a detailed description of both the parameters and the corresponding test methods.

2. DISCUSSION

2.1 The two minimal sets of radar performance parameters before and after the update are shown in table 1 below:

No	Parameters Before Update	Parameters After Update	Note
1	Probability of Detection (PD)	Probability of Detection (PD)	Combined
2	Probability of Target Missing		
3	Probability of False Target	Probability of False Target	-
4	Horizontal Error (RMS)	Accuracy	-
5	Processing Delay	Processing Delay	-
6	Probability of False Mode A/Mode C	Valid Mode A/Mode C Detection Rate	Combined
7	Special Code Error		
8	PSR/SSR Combination Rate	PSR/SSR Combination Rate	-
9	Vertical Rate Error	-	Omitted
10	Speed Vector Error	-	Omitted
11	Aircraft Identification Error	-	Omitted

Table 1 Radar Performance Parameter Sets Comparison

2.2 It is obvious that the parameters are further simplified. The reasons for the simplification are as below:

- The analysis of missing data is considered as part of the probability of detection analysis. Thus the *Probability of Target Missing* is combined with the *Probability of Detection*;

- Aircraft Identification is an application of Mode S while the Mode S technique provides sufficient protection to ensure that no more than one undetected error occurs in 10^7 messages with 112-bits. In other words, there will be few undetected errors in Aircraft Identification. Thus the *Aircraft Identification Error* is omitted;

- Vertical Rate and Speed Vector are more application-level concepts than parameters. They are based on the accuracy of the track detection. Thus the *Vertical Rate Error* and *Speed Vector Error* are omitted; and

- When a data item is valid, it means that the data item is provided to the user and can be used by the Air Traffic Controller to perform the application. From this point of view, valid data should be correct data. Besides, special code detection is considered as a prat of Mode A detection. So the Special Code Error and Probability of False Mode A/Mode C are combined into one parameter: Valid Mode A/Mode C Detection Rate.

2.3 All the data used for analysis in this paper are recorded data in ASTERIX format.

2.4 For each parameter, the detailed description and test method are respectively given in the Appendix.

3. ACTION BY THE MEETING

3.1 It is suggested that the participants consider the parameters mentioned in this paper as basic functions when developing relevant software, and try to use the test methods.

3.2 It is also suggested to update the definition of relevant parameters and test methods in the GMST.

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APPENDIX

RADAR PERFORMANCE PARAMETERS AND RELEVENT TEST METHODS

1. PROBABILITY OF DETECTION (PD)

1.1 Parameter Description

The probability of detection (PD) is the probability that at each scan, for a given wanted target within the PD measurement volume, a radar target report with position data will be produced. The PD measurement volume defines the volume of airspace within which the radar system should be expected to detect targets.

For a radar system (both PSR and SSR), this parameter is defined by the following formula:

$$PD = \frac{number\ of\ times\ a\ target\ was\ detected}{expected\ number\ of\ target\ reports}$$

1.2 Test Method

From the definition, it can be seen that PD is a parameter associated with the measurement volume. To simplify the test, the measurement volume here is equal to the radar's actual coverage, which is determined by the data recorded.

Every target is tracked with a tracking number assigned by the radar. The number of times a target was detected can be obtained by counting the associated track number.

The expected number of target reports are the reports that should be obtained between the first report and the last report from the same aircraft before it leaves the volume to be analyzed. It can be obtained by calculating the number of the north reports received by the system during the period from the appearance of the target to its disappearance. The expected number of target reports is equal to the number of North Marker Messages received by the system plus one.

With the detected number and expected number of a target and the formula above, its PD can be calculated. Then the overall PD of the system can be obtained by making an average.

Note 1 — It should be noted that multiple target reports (splits, reflections, etc.) and non-combination cases must be handled correctly in the PD calculations. The basic principle to handle such situations is that only one target report per scan per wanted target will be expected from a radar.

2. VALID MODE A/MODE C DETECTION RATE

2.1 Parameter Description

The valid Mode A/Mode C detection rate is the ratio of the received number of SSR target reports with a valid Mode A/Mode C code to the received number of SSR target reports in the trajectories used in the detection analysis.

2.2 Test Method

All monoradar target reports in ASTERIX format have a “V bit” to indicate whether Mode A/Mode C code is valid. For example, in ASTERIX Category 048, and bit 16 in data item 048/070 indicates whether Mode A code is valid, bit 16 in data item 048/090 indicates whether Mode C code is valid. By counting the number of the reports whose “V bit” is properly set, it is quite easy to calculate the valid rate.

Note 1 — It has to be noted that the precise criteria, for deciding whether a data item is valid or not, are assumed to be defined in the radar system. That is to say, the “V bit” is the result of these criteria. The accuracy of this test method is deeply based on the accuracy of these criteria. In fact, it is impossible to make sure that these criteria are completely accurate, so the European Surveillance Standard has a requirement that as a maximum the percentage of incorrect but validated Mode A/Mode C codes shall be lower than 0.1%.

3. FALSE TARGET RATE

3.1 Parameter Description:

The term “false target” is defined as any target report (plot, blip, track position) presented on the user’s radar display that does not represent the position of a wanted target (aircraft). The false targets are divided into different categories:

False PSR target reports are generated from thermal noise and by reflections from objects other than aircraft. Under anomalous propagation conditions (ducting effects) clutter plots (mainly ground clutter) from beyond the horizon or line of sight may be detected as second, or even multiple, time around clutter.

False SSR target reports are generated from fruit (synchronous and asynchronous), second-time around replies, shipborne transponders, reflected interrogations or replies, and by interrogator side-lobe replies.

Another category of false targets, applicable to both PSR and SSR, are split plots. The split plot can be identified in the SSR case as each report will often have the same identity and height information.

The false target rate is the ratio of false plots to the total number of plots detected.

3.2 Test Method

The analysis of false plots must attempt to identify the cause of the false plots and quantify the number of occurrences of each category in relation to the total number of plots present. The false targets can be divided into two generic groups:

Group 1 — False targets related to aircraft — splits, reflections, side-lobe responses;
Group 2 — False targets not related to (targets) aircraft — clutter, “angels”, thermal noise.

Analysis of group 1 false targets is usually made with respect to the target associated with each false target. In the case of a small number of false targets, it can be done by visual analysis. Group 2 provides inter alia the false alarm rate, which is due to noise (either atmospheric, receiver or video processing) which can be assessed by turning the transmitter into stand-by and recording any targets which appear on the technical monitor.

But a computer-based method is preferred since it could provide repeatable quantitative results whereas a visual analysis is subjective. A recommended procedure is as follows:

a) group the target reports into different sets based on the ATCRBS id, scan by scan;

b) correlate the report from the current scan to the report from the previous scans (if any) up to the firmness limit;

d) compute the range and azimuth velocities for validation;

e) create a scoring procedure when multiple reports existing for one ATCRBS id to determine the real target.

Note 1 — For a radar system, it is often necessary to compromise between good detection and a low false target rate acceptable by the ATC controller.

4. ACCURACY

4.1 Parameter Description

As aircraft are normally moving when a radar position measurement is taken, the plot position variables (usually azimuth and range) will have a certain accuracy with respect to a stated position reference. The errors of these variables can, in most cases, be separated into a systematic as well as a random part.

a) Systematic errors are bias errors for each radar in position and time with respect to an absolute reference system caused by, e.g. a bad north alignment of the radar.

b) Random errors are the deviations in position which exist between the measured target report position and the trajectory at the time of the target report, after correcting the respective systematic errors. Random errors are caused by such phenomena as occasional beam distortion, small timing errors, quantization noise, etc.

4.2 Test Method

For radar accuracy performance assessment, it is more feasible to use trajectory reconstruction. The accuracy analyses would be divided into the following stages:

a) estimation of the systematic errors using site monitors (A common practice with SSR and co-mounted PSR/SSR systems is to first align the SSR using the remote field monitor as a reference and then, in the case of co-mounted systems, use the SSR plot data as a reference for aligning the primary system);

b) reconstruction of the true aircraft trajectory from the recorded radar target data using curve fitting techniques;

c) analysis of the random errors in position, range and azimuth for each category of plot data after correction of systematic errors. The errors are expressed in terms of the slant range standard deviation and azimuth error standard deviation.

5. PROCESSING DELAY

5.1 Parameter Description

Processing Delay is the relative time difference from the time of detection to the end of plot processing in the radar sensor. A corresponding error is mainly systematic.

Note 1 — The plot processing time can be a parameter that depends on processing algorithms, target bunching, etc.

5.2 Test Method

One key to calculating the Processing Delay is to determine the time of detection and the end time of the plot processing.

A plot report should be time stamped at the radar site. This stamped time should be the time of detection and it should be included in the ASTRIX Message as the Data Item “Time of Day”. The end time of the plot processing can be considered to be identical with the start time of the transmission, which can be obtained via *wireshark*.

Another key to calculating the Processing Delay is to provide a common time source as a reference for the two times above. It can be realized by GPS derived UTC.

Note 1 — Different radar manufacturers define “Time of Day” differently, some manufacturers may define Time of Day as the start time of the transmission rather than the time of target detection. In this case, it is recommended to evaluate the “end-to-end delay time”,which is the relative time difference from the target detection time to the time of plot presentation on the ATC display.

6. PSR/SSR COMBINATION RATE

6.1 Parameter Description

The combination rate is expressed as the following formula for targets within the common maximum range for the PSR and SSR systems:

$$combination\ rate = \frac{total\ number\ of\ combined\ targets}{total\ number\ of\ combined\ and\ SSR\ targets}$$

The combination rate will be more accurate if steps are taken to ensure that false targets (SSR only or combined) are not included in the calculation. This can be accomplished by applying a chaining function.

The calculation is based on the principle that all aircraft targets within the shared coverage volume and within the common maximum ranges of a collocated PSR/SSR system will be detected as a combined target. Therefore, the calculation is only valid if all aircraft are equipped with SSR transponders and it may not be valid for aircraft populations which include military aircraft or for coverage which includes VFR airspace, etc.

6.2 Test Method

The data used for the calculation must be within the common range of both primary and SSR elements. Normally it is limited to the PSR coverage.

All target reports in ASTERIX format have a data item "Target Report Descriptor", in which several bits (category depends) are used to indicate if the report is a combined target or an SSR-only target. After the classification, the combination rate can be calculated easily.