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ADS-B data gating technique and its probabilistic models

E.A. Rubtsov[1], S.A. Kudryakov[1], I.M. Dalinger[1], A.S. Kalintsev[2]
[1] *Russian University of Transport (MIIT), Moscow, Russia*
[2] *FSUE "State Air Traffic Management Corporation of the Russian Federation", Arkhangelsk Air Traffic Management Center, Mezen, Russia*

Abstract: The article developed a gating technique that allows us to validate ADS-B data without the necessity to verify using the secondary surveillance radar or multilateration. Probabilistic models of the ADS-B data gating technique, as well as the algorithm for applying these models were proposed. Benchmark cases that occur when aircraft (A/C) positioning by ADS-B systems, determined by threshold values of navigation and pilot's errors, were analyzed. The first benchmark case assumes not exceeding of navigation and pilot's errors the bounds of the tolerance limits, which allows us to draw up a conclusion concerning the ADS-B data validation. The second one assumes exceeding of a pilot's error the bounds of the tolerance limits under an allowable navigational error. Herewith, the air traffic controller (ATC) obtains a message about the proper ADS-B operation and the necessity to issue instructions to the pilot to correct a flight. The third benchmark case assumes exceeding of a navigation error the bounds of the tolerance limits under an allowable or not allowable pilot's error. In this case, the ATC obtains a message about not valid ADS-B data and the incapability to use these systems. The simulation of the given benchmark cases was performed. In addition, the Rayleigh and Rice distributions were applied to implement the ADS-B data gating technique. The simulation results allow us to assess the required amount of accumulated ADS-B data for the evaluation. Thus, it was found that during the estimate based on the Rayleigh distribution, it is sufficient to accumulate 15–20 measurements, which, when transmitting 2 messages per second and under the condition of the normal ADS-B equipment operation, will take 8–10 s. During the estimate, using the Rice distribution, an accumulation of 25–30 measurements is sufficient, which will take 13–20 s. The developed method will allow the use of ADS-B systems at regional aerodromes with the low intensity of air traffic as the primary or sole surveillance means.

Key words: flight safety, ADS-B, gate, Rayleigh distribution, Rice distribution, distribution parameter estimate, error of navigational measurements, pilot's errors.

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Метод стробирования данных АЗН-В и его вероятностные модели

Е.А. Рубцов[1], С.А. Кудряков[1], Я.М. Далингер[1], А.С. Калинцев[2]
[1] *Российский университет транспорта (МИИТ), г. Москва, Россия*
[2] *ФГУП «Госкорпорация по организации воздушного движения», Архангельский центр ОВД, г. Мезень, Россия*

Аннотация: В статье разработан метод стробирования, который позволяет оценить достоверность данных АЗН-В без необходимости проверки с помощью вторичного радиолокатора или многопозиционной системы наблюдения. Предложены вероятностные модели метода стробирования данных АЗН-В, а также алгоритм применения данных моделей. Проанализированы типовые ситуации, возникающие при определении местоположения воздушного судна с помощью систем АЗН-В, определяемые пороговыми значениями погрешностей навигации и пилотирования. Первая типовая ситуация предполагает невыход погрешностей пилотирования и навигации за пределы допуска, что позволяет сделать вывод о подтверждении достоверности данных АЗН-В. Вторая типовая ситуация предполагает выход погрешности пилотирования за пределы допуска при допустимой погрешности навигации, при этом диспетчер получает сообщение о корректной работе АЗН-В и о необходимости выдачи команды пилоту на корректировку полета. Третья типовая ситуация предполагает выход погрешности навигации за пределы допуска при допустимой или недопустимой погрешности пилотирования; в этом случае диспетчер получает сообщение о том, что достоверность данных АЗН-В не подтверждается и применять эти системы нельзя. Выполнено моделирование этих типовых ситуаций, при этом для реализации метода стробирования данных АЗН-В применялись распределения Рэлея и Райса. Результаты моделирования позволяют оценить требуемое количество накопленных данных АЗН-В для проведения достоверной оценки. Так, было установлено, что при выполнении оценки с применением распределения Рэлея достаточно накопления 15–20 измерений, что при передаче двух сообщений в секунду и при условии штатной работы оборудования АЗН-В потребует 8–10 с. При выполнении оценки с применением распределения Райса достаточно накопления 25–30 измерений, что потребует 13–20 с. Разработанный метод позволит применять системы АЗН-В на региональных аэродромах с низкой интенсивностью полетов как основное или единственное средство наблюдения.

Ключевые слова: безопасность полетов, АЗН-В, строб, распределение Рэлея, распределение Райса, оценка параметров распределения, погрешность навигационных измерений, погрешности пилотирования.

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Introduction

An automatic dependent broadcasting-type surveillance (ADS-B) is referred by the International Civil Aviation Organization to the cutting-edge surveillance technologies which is reflected in the provisions of the Global air navigation plan[1].

The reduced cost to implement ground stations, compared to costs to deploy secondary surveillance radars (SSR) and multilaterations (ML), is attributed to the ADS-B benefits. The operation cost is also considerably below. If high-precision navigation sensors are installed on board aircraft (as a rule, receivers of the Global Navigation Satellite Systems – GLONASS), ADS-B provides surveillance accuracy not worse than radar aids [1–3].

However, the Aeronautical Surveillance Manual[2] points to the relevance for the data validation derived from ADS-B with the aid of SSR and ML. It is associated with the possibility of an increase in the navigation error (when using self-contained inertial systems and range/azimuth positioning systems of navigation). Thus, the relevance for the data validation levels out the economic ADS-B technology attractiveness.

The task of the ADS-B data validation without applying additional surveillance facilities can be accomplished by the techniques of the algorithmic data validation. The paper [4] dealt with the techniques of the algorithmic ADS-B data validation to ensure ground maneuvers at an aerodrome. The techniques, presented in the article [4], are based on the accumulation of aircraft coordinates measurements with the subsequent statistical analysis of derived data. The given paper proposes to modify the methods, described in [4], and employ the gating technique, which has already found practical use in radar surveillance [5, 6], when processing ADS-B data.

When processing ADS-B data, the gating technique will make it possible to evaluate the data validity about the aircraft position and use reasonably priced ADS-B ground stations as the sole or primary surveillance means, which is pertinent for regional airports with the low intensity of air traffic.

In conformity with the analysis of ADS-B data [7], most of aircraft operate normally in the direction of a rectilinear trajectory without tending toward violating boundaries of airways. Notably, the proportion of such aircraft amounts to 76% in general traffic.

A maneuver in horizontal or vertical planes is inherent in 9% of aircraft. It is worth noting that a maneuver can be carried out with the deviation from the route (Flight Planed Route – FPR) due to flight crew errors concerned with the incorrect interpretation of reliable navigation data. The probability of such an event can reach 10^{-3} [8].

1 The Global Air Navigation Plan. ICAO GANP Portal. Available at: https://www4.icao.int/ganpportal (accessed: 17.03.2023).

2 Doc. 9924 AN/474: Aeronautical Surveillance Manual. 3rd ed. ICAO 2020, 432 p.

For approximately 6% of aircraft, the tendency toward violating boundaries of airways or separation regulations is displayed, or the violation of airway boundaries is revealed. It can result from significant errors of navigation systems. The situation can be affected by pilot's errors which will cause a greater deviation from a nominal aircraft path [7].

Subsequently, while determining the position of an aircraft using ADS-B, the described possible situations during the aircraft flight operation can be displayed in the form of the following benchmark cases:

1. A flight operation according to the FPR, in this event, pilot's and navigation errors are within the tolerance limits.
2. A flight deviates from the FPR (due to significant pilot's errors) under allowable navigation errors.
3. Not tolerated significant pilot's and navigation errors.

The first scenario can be considered routine, at the same time, navigation error values of the board navigation complex are minor, and a flight crew operates a flight in full compliance with the FPR with insignificant pilot's errors. The patterns of conducting maneuvers as well as the air traffic management (ATM) requirements in the vicinity of the airport are regulated and contained in the Aeronautical Information Publications (AIP).

Scenarios 2 and 3 can be considered non-routine, while in scenario 2, ADS-B data meets the requirements in terms of accuracy, and it is valid. In scenario 3, allowable values are exceeded, and data is not valid. In practice, it is necessary to identify all the listed variants and provide an ATC with information concerning the ADS-B data validity.

When solving the ADS-B data validation problem, the paper [9] illustrates the features of employing the gating technique to process ADS-B data. In radar surveillance, this technique is employed to reveal false coordinates, when developing a motion trajectory [5]. Applicably to the assigned problem, let us take a gate as an area of space around the extrapolation point of the aircraft path with the center at the point of extrapolated aircraft coordinates within which the estimate of aircraft coordinates will be considered reliable.

For aircraft with the maximum take-off mass exceeding 5700 kg, or with a maximum cruising true airspeed capability greater than 250 knots, the European Commission Implementing Regulation (EU) No 1207/2011[3] and its first amendment 1028/2014[4] lays down the mandatory carriage and operation of the ADS-B mode S (EHS) and mode 1090 ES Enhanced Surveillance installations. Mode S (EHS) enhanced surveillance represents a set of advanced features of mode S and comprises reports about a chosen intention in the vertical plane (BDS 4.0), a report about a track and a turn (BDS 4.0), as well as a report about a track and a turn (BDS 5.0). The listed types of reports contain information about values of velocity, track variations, heading, indicated airspeed (IAS) and a chosen intention in the vertical plane.

In the Russian Federation, mode S (EHS) and ADS-B mode 1090 ES enhanced surveillance applications are installed in different aircraft (DA-42, L-410, An-148, etc.) and helicopter (Mi-8, etc.) models.

The use of mode S transponder allows for current and planned aircraft coordinates (intentions) to be derived from the ADS-B ground station. However, a nautical data error remains unknown. In order to solve this problem, the use of the gating technique [9] is proposed, for which, it is necessary to accumulate the sufficient number of measured values of aircraft coordinates to determine a center of gate by the extrapolation method. Afterwards, in conformity with the obtained sampling of accumulated measurements, the interval parameter estimate for the distribution of aircraft positioning error is made, and the probability of entering aircraft an area of gate is computed. A key point is to ensure the conformity of the distribution parameter estimate for the sampling of accumulated values with the entire

[3] Regulation 1207/2011. Requirements for the performance and the interoperability of surveillance for the SES. Official Journal of the European Union, pp. 35–52

[4] Regulation 1028/2014. Requirements for the performance and the interoperability of surveillance for the SES. Official Journal of the European Union, pp. 7–8.

assembly parameters. The interval estimate is made with the assigned level of reliability. Sizes of gate are assigned based upon the requirements for allowable errors of surveillance systems. The probability of aircraft entering an area of gate can be found based on the Rayleigh and Rice distributions.

Methods of research

According to the Aviation Regulations of the Interstate Aviation Committee "Certification Requirements for Aerodrome and Airway Facilities" (AR-170, volume 2), allowable values of the mean square error (MSE) of an airport surveillance radar amount to 150 m at a maximum range of 100 km.

The requirements for MSE accuracy of the aerodrome radar facility, stated in the Certification requirements (Basis), amount to 120 m for the primary channel and 70 m for the secondary one (under the probability of coordinate and supplemental information integration not less than 0.95).

The specifications of surveillance systems "Eurocontrol"[5] provide the recommended MSE value to determine aircraft coordinates horizontally equal to 300 m with the minimum separation of 3 nautical miles.

As far as we can see, the requirements of national and international standards for tracking an aircraft in the aerodrome zone slightly differ and vary from 70 to 300 m. In order to assign sizes of a gate area and solve a problem of the ADS-B data validation, it is feasible to choose some averaged value. It is supposed to assume a radius of a gate area equal to the allowable MSE value of 150 m (which complies with the Interstate Aviation Committee Requirements published in AR-170, volume 2).

The condition of the ADS-B data validity is met if the parameter estimate in conjunction with the confidence intervals, with the assigned reliability, does not exceed assigned gate sizes. Thus, when confidence interval values of the random variable estimate do not exceed the value for a radius of a gate area, assumed data is considered valid. If the interval estimate exceeds a radius of a gate area, the condition of data validity is not met.

Since the time for the ADS-B data validation is an important factor, it is feasible to identify such a level of reliability which will ensure the data validation within the acceptable time. In conformity with [9], for the level of reliability 0.95, data about aircraft entering or not entering an area of gate will be valid.

Errors of aircraft deviation from the assigned trajectory (FPR) can be described in the normal distribution law [3]. For the Cartesian coordinates, the distribution density of the bivariate normal law with parameters m_x, m_y, σ_x, σ_y is defined as [10, 11]:

$$f(x,y)=\frac{1}{2\pi\sigma_x\sigma_y\sqrt{1-\rho^2}}e^{\frac{1}{2(1-\rho^2)}\left[\frac{(x-m_x)^2}{\sigma_x^2}-2\rho\frac{(x-m_x)(y-m_y)}{\sigma_x\sigma_y}+\frac{(y-m_y)^2}{\sigma_y^2}\right]}, \quad (1)$$

where m_x, m_y – the mathematical expectation of a random variable along the Ox - and Oy -axis accordingly,

σ_x, σ_y – MSE of a random variable along the Ox - and Oy -axis accordingly,

ρ – coefficient of correlation.

A solution to define the probability of aircraft position in the gate can be formulated as a computation problem of the probability of a random variable entering a circle of radius R (defined with the requirements for errors of surveillance systems) with the center at the point of extrapolation, which coordinates belong to a maneuver pattern.

Depending on values of random variable parameters inherent in various benchmark cases, errors of aircraft positioning can be characterized by different distribution laws.

Let us consider a problem solution for benchmark cases to determine the aircraft position using ADS-B. In the simplest case, let us assume that errors of determining the aircraft position along the Ox - and Oy -axis of the Cartesian coordinates are equal.

[5] Euro control Specification for ATM Surveillance System Performance (Volume 1). (2021). 92 p.

The first benchmark case is indicative of an insignificant pilot's error, for the problem formalization, let us assume it as zero. Thus, the mathematical expectation (ME) of aircraft positioning error equals zero, MSE along the Ox - and Oy -axis equal each other: $m = 0$, $\sigma_x = \sigma_y = \sigma$. In this case, an ADS-B error depends merely on a board navigation complex error. Such a situation is inherent in the aircraft rectilinear motion case.

When meeting the condition $\sigma_x = \sigma_y = \sigma$, the random variable distribution is referred to as the circular normal distribution [10–12].

Thereafter, a random variable $r = \sqrt{X^2 + Y^2}$, where X, Y – independent Gaussian distributed random variables, under the condition of the circular normal distribution of a random variable and the lack of a fixed error, follows the Rayleigh law. Thereupon, the probability of aircraft exiting an area of gate for R radius can be found as the miss probability [13–15]:

$$F(r) = P(R < r) = \begin{cases} 1 - e^{-\frac{r^2}{2b^2}}, & r \geq 0, \\ 0, & r < 0 \end{cases} \quad (2)$$

$$f(r) = \frac{r}{b^2} e^{-\frac{r^2}{2b^2}}, \quad r > 0, \quad (3)$$

where b – a scale parameter.

The second benchmark case is indicative of a flight technical error and a navigation error. A similar scenario can occur when an aircraft deviates from the trajectory of motion. In this context, the ADS-B system can operate properly under the condition of non-exceedance of a navigation error the bounds of the tolerance limits. If errors of the board navigation complex exceed the bounds of the tolerance limits, we have the third benchmark case under which it is impossible to apply ASD-B.

In this case, a problem of the fixed and navigation errors evaluation arises. A fixed error, that is ME is not equal to zero, is the distinctive feature of the situation under consideration from the previous one. For the simplest case under consideration, MSE are equal to each other: $m \neq 0$, $\sigma_x = \sigma_y$. Thereafter, a random variable $r = \sqrt{X^2 + Y^2}$, where X, Y – independent Gaussian distributed random variables, has the Rice distribution with the density of distribution [13, 16]:

$$f(x \mid s, \sigma) = \frac{x}{\sigma^2} \exp\left(\frac{-(x^2 + s^2)}{2\sigma^2} \right) I_0\left(\frac{xs}{\sigma^2} \right), \quad (4)$$

where I_0 – the modified zero-order Bessel function of the first kind;

s – bias equal to $s = \sqrt{\mu_1^2 + \mu_2^2}$, where μ_1^2, μ_2^2 – Ox and Oy ME;

σ – the scale parameter.

The distribution function is presented as:

$$F(\alpha) = \int_0^{\alpha} \frac{x}{\sigma^2} \exp\left(\frac{-(x^2 + s^2)}{2\sigma^2} \right) I_0\left(\frac{xs}{\sigma^2} \right). \quad (5)$$

The probability of entering aircraft an area of gate (P_{in}) can be found as the probability of non-exceedance of a random variable r of the assigned radius of gate and can be computed using (5). In this case, the probability of deviation from the trajectory can be found as

$$P_{out} = 1 - P_{in}, \quad (6)$$

where P_{out} – the probability of aircraft deviation from the assigned trajectory,

P_{in} – the aircraft position probability in an area of gate.

A two-phase algorithm of applying probabilistic models of the ADS-B data gating technique is proposed for the practical implementation. The estimate of the Rayleigh distribution parameters is calculated in the first phase of the analysis. If the upper confidence interval of the b parameter estimate does not exceed an allowable value, a conclusion about the ADS-B data validation is drawn up (the first benchmark case). In case of exceedance of the b parameter estimate, the estimate of the Rice distribution parameters is calculated. If during the analysis, a significant pilot's error is revealed with the allowable navigation error, the ATC obtains a message about the proper ASD-B operation and the necessity to issue instructions to the aircraft flight crew (the second benchmark case). If during the analysis, significant pilot's and navigation errors, exceeding allowable values, are revealed, the ATC obtains a message that ADS-B data validation is not ensured, and other ATC methods are required (the third benchmark case). The Rayleigh distribution *b* parameter as well as the Rice distribution *s* and σ parameters are estimable parameters in these simplest cases.

It is essential to note that the A/C airspeed and the frequency of position reporting impose limitations for the surveillance number. Taking into consideration the limited surveillance number, the parameter estimate is calculated based on the sampling of the entire assembly. The interval parameter estimate is calculated with the assigned level of reliability.

The benchmark cases were considered while assuming the equality of errors of determining the position along the *Ox*- and *Oy* -axis of the Cartesian coordinates. The stated simplification allowed for the Rice and Rayleigh distributions to be used as an example.

In practice, error values along the *Ox* - and *Oy* -axis will be distinguished from each other. Therefore, for the data validation, we should use more complicated distributions: the Hoyt distribution [17, 18] and the Beckmann distribution [19–22].

Research results

For simulating benchmark cases, MATLAB and Wolfram software packages were applied. The simulation modelling of the aircraft positioning error was conducted. The error of aircraft positioning was assigned as a random variable distributed in accordance with the Rayleigh and Rice laws. Based on the sampling from the entire assembly, the Interval estimate of distribution parameters with the level of accuracy 0.95 was obtained. The parameter estimate was calculated by means of the maximum likelihood method.

As a result of the simulation, the dependencies of distribution parameter estimate on the number of measurements N, i.e., data derived from the ADS-B ground station, were obtained. Figure 1 illustrates the results of the *b* parameter estimate of the Rayleigh distribution (corresponds to the error of aircraft positioning). Figure 1 and the subsequent ones, using a dotted line, illustrate simulated parameter values of distribution (input data). The red line illustrates the input data parameter estimate, the light blue and blue lines illustrate the upper and lower 95% confidence intervals as applicable.

In Figure 1, *b* parameter values of the Rayleigh distribution amount to 50 and 100, which conforms with MSE values 50 and 100 m. In Figure 2, input *b* value parameters of the Rayleigh distribution amount to 50 and 100, which conforms with MSE values 50 and 100 m. In the Figures, the following designations are assumed: PCI b Up and PCI b Low – the upper and lower 95% confidence interval of the *b* parameter estimate of the Rayleigh distribution; Param b – the assigned source of the *b* parameter value; Est param b – the *b* parameter estimate; Rline – the gate area boundary (the condition of the ADS-B data validity).

Figure 3 illustrates the results of the Rayleigh distribution parameter estimate when the input distribution parameters: s = 100, σ = 50, which conforms with ME 100 m, MSE 50 m. Figure 4 illustrates the results of the Rice distribution parameter estimate based on the sampling from the entire assembly for a random value distributed in accordance with the Rice law when input distribution parameters: s = 200, σ = 100, which conforms with ME 200 m, MSE 100 m. Figure 5 illustrates the results of the Rice distribution parameter estimate when input distribution parameters: s = 300, σ = 150, which conforms with ME 300 m, MSE 150 m. The input data parameter estimate by accumulated values commences after 5 measurements. The Figures have the following designations: PCI Sigma Up and PCI Sigma Low – upper and lower 95% confidence interval of the parameter estimate σ; PCI S Up and PCI S Low – upper and lower 95% confi-

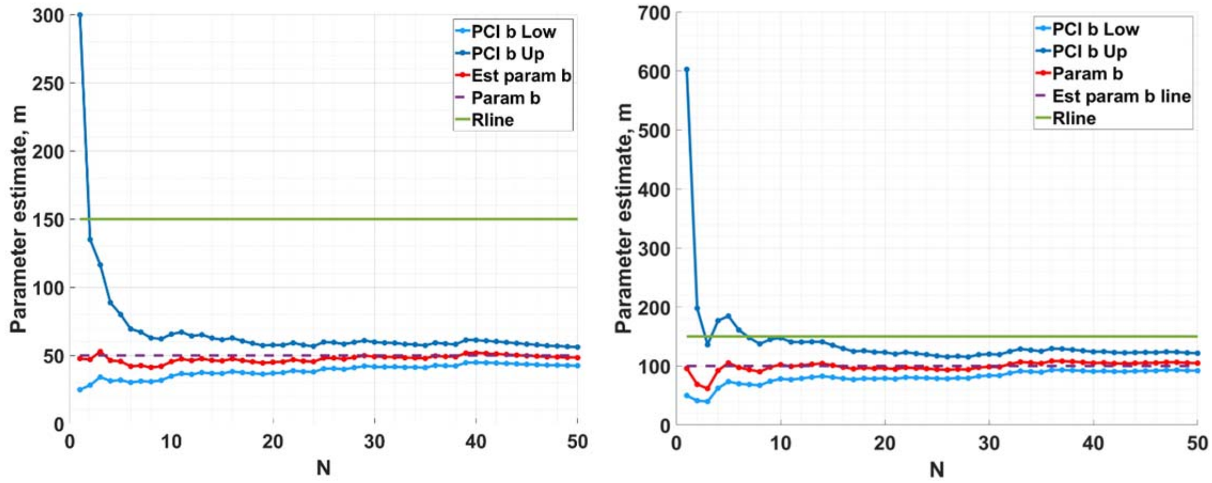

Fig. 1. Graphs for the estimate of the Rayleigh distribution parameters for the input values: b = 50 and b = 100

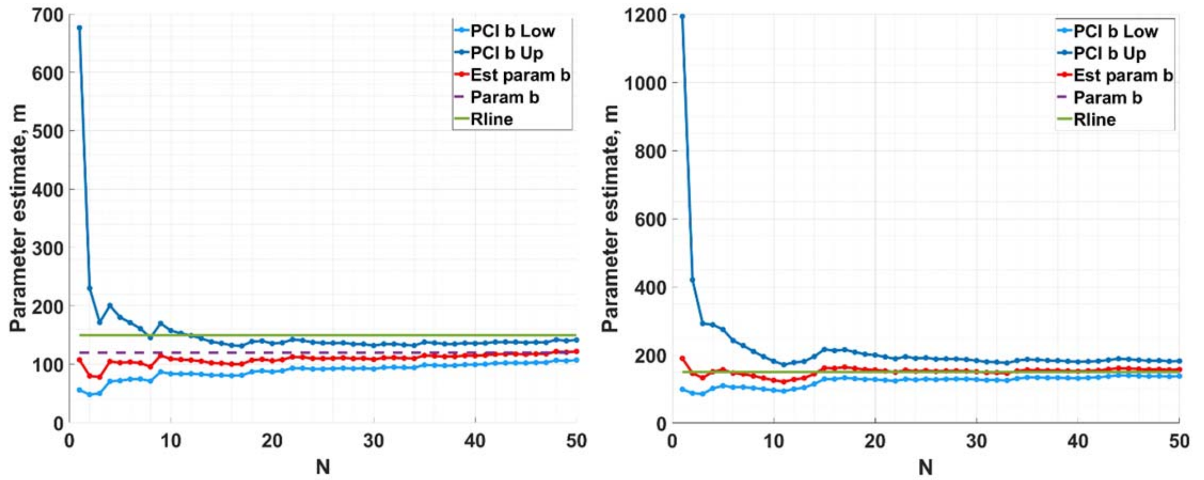

Fig. 2. Graphs for the estimate of the Rayleigh distribution parameters for the input values: b = 120 and b = 150

dence interval of the parameter estimate s; Est param Sigma and Est param S – the parameter estimate σ and s; SigmaLine and Sline – assigned values of parameters σ and s; Rline – the gate area boundary (condition of ADS-B data validity).

The results of simulation established that for meeting validity conditions, the estimate of random variable parameters distributed in conformity with the Rayleigh law can be obtained during 15–20 measurements, which, provided that two messages per second are transmitted by ADS-B installations, takes 8–10 s. In order to meet the validity conditions, the estimate of random variable parameters distributed in accordance with the Rice distribution law – 25–30 measurements, which, provided that two messages per second are transmitted by ADS-B installations, takes 13–15 s.

The obtained results allow us to draw up a conclusion about the capability to utilize ADS-B ground stations at regional airports with the low intensity of air traffic as the primary surveillance means. For example, at aerodromes Ust-Kuiga, Chokurdakh, Cherskiy and other G and D-class aerodromes, it is feasible to replace exhausted life-span radars (generally DRL-7 SM) for ADS-B stations, upgrading software (ADS-B data

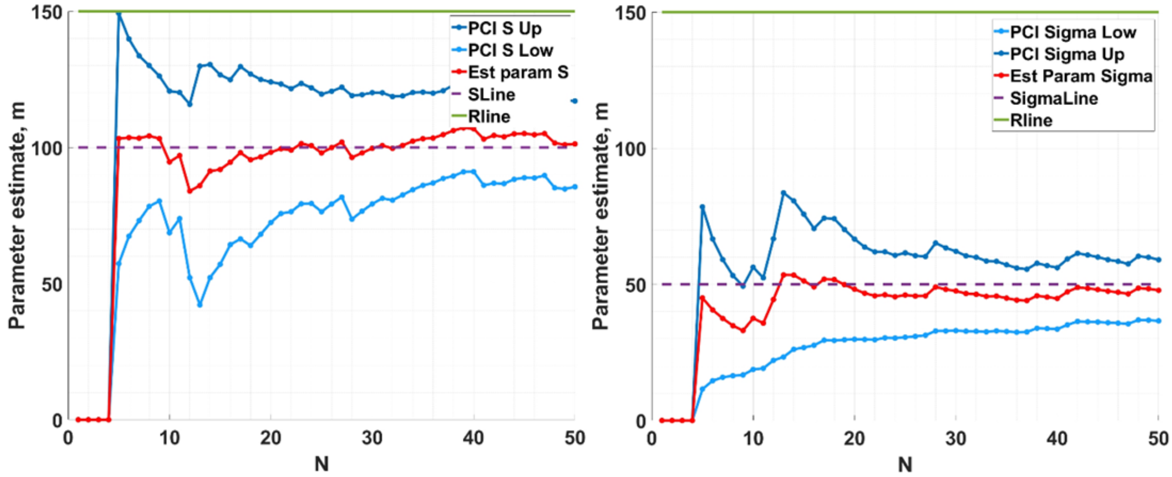

Fig. 3. Graphs for the estimate of the Rice distribution parameters for the input values $s = 100$, $\sigma = 50$

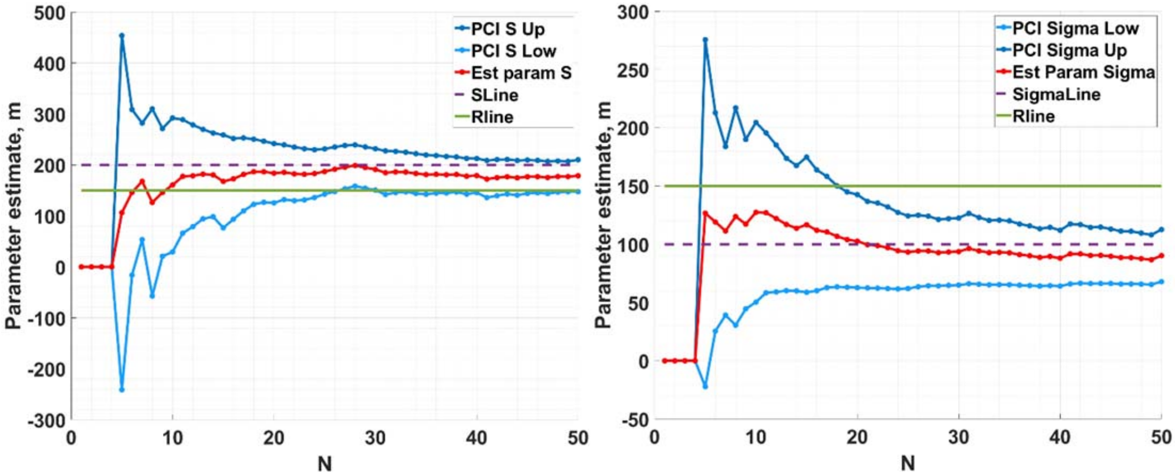

Fig. 4. Graphs for the estimate of the Rice distribution parameters for the input values $s = 200$, $\sigma = 100$

processor), to ensure ADS-B data validation. Compared to implementing up-to-date surveillance radars (for example, AORL-1 AS), it will yield savings of approximately 120–150 million rubles for each aerodrome.

Discussion of the obtained results

The position determination error is computed relatively a point of extrapolation of aircraft coordinates, i.e., relatively the center of the gate area. For the given benchmark cases, under the assumption concerning the equality of errors along the axes of the Cartesian coordinates, it is feasible to apply the Rayleigh and Rice distributions. However, in practice, there are more plausible situations going beyond the scope of the considered. Errors along the *Ox*- and *Oy* -axis can be distinguished, notably substantially. Thus, in case of an insignificant pilot's error, a substantial navigational error can occur, i.e., ME equals zero, navigation MSE do not equal each other: $m = 0$, $\sigma_x \neq \sigma_y$. In that event, the error of aircraft positioning has the Hoyt distribution (Nakagami-Q) [17, 23, 24]:

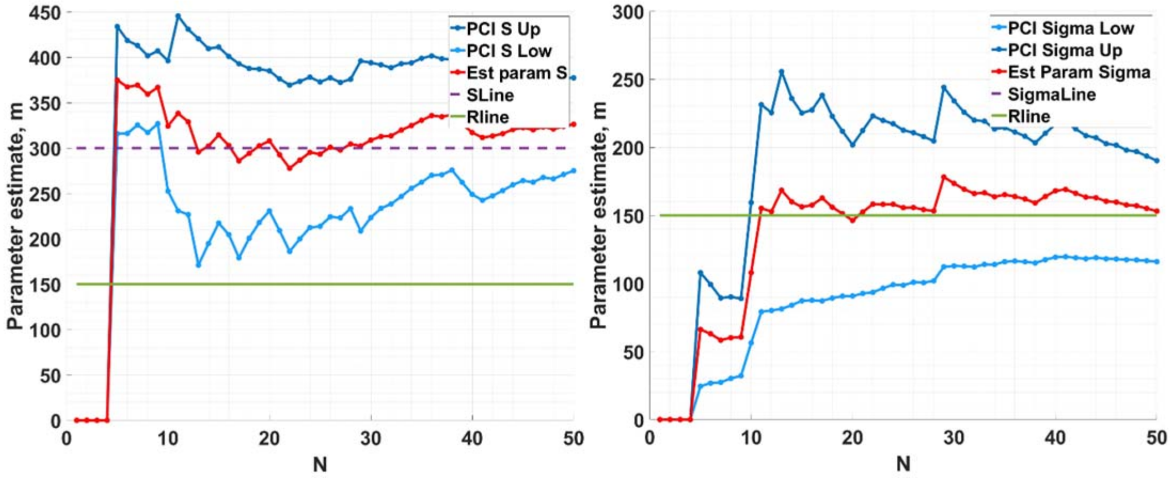

Fig. 5. Graphs for the estimate of the Rice distribution parameters for the input values $s = 300$, $\sigma = 150$

$$w\{r\} = \frac{r}{\sigma_x \sigma_y} \exp\left[-\frac{r^2}{4}\left(\frac{1}{\sigma_x^2}+\frac{1}{\sigma_y^2}\right)\right] I_0\left[\frac{r^2}{4}\left(\frac{1}{\sigma_x^2}-\frac{1}{\sigma_y^2}\right)\right]. \qquad (7)$$

Another scenario is possible in-flight when there is a significant deviation from the FPR (ME does not equal zero) and the navigation MSE inequality $\sigma_x \neq \sigma_y$. In this case, an error of aircraft positioning has the Beckmann distribution [20].

The distribution laws of Rayleigh, Rice and Hoyt are the specific cases of the Beckmann distribution. Thus, the probability of the aircraft position in an area of gate can be computed using the Beckmann distribution as the given distribution comprises all the plausible benchmark cases for the distribution of aircraft positioning error. The development of models for the parameter estimate of the Hoyt and Beckmann distributions for the ADS-B data validation by the gating technique is the subject for further research.

Conclusion

The paper considers the algorithmic technique of the ADS-B data validation based on gating. Errors of determining coordinates were found relatively the point of extrapolation which is the center of gate. Three simplest benchmark cases, which might occur when determining the aircraft position by ADS-B, were considered. The algorithm of the derived data validation was proposed. The estimate based on the Rayleigh distribution is obtained in the first phase. If the parameter b does not exceed the bounds of the tolerance limits, a conclusion concerning ADS-B data validity (the first benchmark case) is drawn up. If an error exceeds the bounds of the tolerance limits, the estimate is obtained via the use of the Rice distribution. If not tolerated significant pilot's errors with allowable navigation errors (the second benchmark case) are detected, a conclusion concerning ADS-B data validity is drawn up, the ATC obtains a message about the aircraft deviation from the FPR. If not tolerated significant pilot's and navigation errors are detected, the ATC obtains the ADS-B data-not-valid message and the necessity to use other ATC procedures. The results of simulation established that during the estimate based on the Rayleigh distribution, it is sufficient to accumulate 15–20 measurements, which, under the transmission of 2 messages per second and provided that ADS-B equipment operates normally, will take 8–10 s. During the estimate based on the Rice distribution, the accumulation of 25–30 measurements is sufficient, which will take 13–20 s.

The practical research importance is that it is possible to employ the gating technique for ADS-B data validation without the necessity to validate with the aid of SSR or ML. It will enable regional airports with the low intensity of air traffic to replace exhausted life-span radars for ADS-B ground stations (with upgraded software), which will yield considerable savings.

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Information about the authors

Evgeny A. Rubtsov, Candidate of Technical Sciences, Specialist of the Scientific and Educational Center of Air Transport, Russian University of Transport (MIIT), rubtsov.rut.miit@gmail.com.

Sergey A. Kudryakov, Doctor of Technical Sciences, Senior Researcher, Director of the Scientific and Educational Center of Air Transport, Russian University of Transport (MIIT), psi_center@mail.ru.

Iakov M. Dalinger, Candidate of Technical Sciences, Associate Professor, Vice-Rector of the Russian University of Transport (MIIT), iakovdalinger@gmail.com.

Andrey S. Kalintsev, Radio Navigation, Radio Location and Communication Engineer, Arkhangelsk Air Traffic Management Center, North-West Air Navigation Branch, FSUE “State Air Traffic Management Corporation of the Russian Federation”, kas4job@gmail.com.

Сведения об авторах

Рубцов Евгений Андреевич, кандидат технических наук, специалист научно-образовательного центра воздушного транспорта Российского университета транспорта (МИИТ), rubtsov.rut.miit@gmail.com.

Кудряков Сергей Алексеевич, доктор технических наук, старший научный сотрудник, директор научно-образовательного центра воздушного транспорта Российского университета транспорта (МИИТ), psi_center@mail.ru.

Далингер Яков Михайлович, кандидат технических наук, доцент, проректор Российского университета транспорта (МИИТ), iakovdalinger@gmail.com.

Калинцев Андрей Сергеевич, инженер по радионавигации, радиолокации и связи, Архангельский центр ОВД филиала «Аэронавигация Северо-Запада» ФГУП «Государственная корпорация по организации воздушного движения в Российской Федерации», kas4job@gmail.com.

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