Onboard device for UAS remote identification

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Abstract. The unsupervised use of UAS creates threats to the security of general aviation and ground objects, including objects of critical information infrastructure. Equipping UAS with a remote identification device can be the solution to this problem. It should increase the sense of responsibility among UAS pilots and allow the public, aviators and law enforcement to identify and track UAS and their operators during flight. The goal of the article is the technical requirements specifications of a device for UAS remote identification. The existing technologies of UAS remote identification have been reviewed during this research, and the criteria of their choice have been defined. The result of the work takes into account the territorial features of Russia and the concept of the RUTM system. The authors propose the network model for UAS remote identification using the ADS-B direct broadcast technology to form the aircraft pilots' situational awareness of the air situation near the vessel. ADS-B 1090 ES, cellular and satellite communications have been chosen as data transmission channels for the onboard UAS remote identification device. Based on this, the technical requirements have been developed for the onboard device for UAS remote identification.

1. Introduction

Remote identification is the ability of unmanned aircraft systems (UAS) in flight to provide identification information that can be received by other parties [1]. It is an essential requirement for the full integration of drones into the airspace.

The UAS control process is completely different from the control of an airplane. The fact that the pilot is not located inside the UAS and operates the UAS remotely can lead to a reduced sense of responsibility. Meanwhile, the threat of their irresponsible use is not illusive anymore, and there are precedents of that. The enactment of the UAS remote identification regulation will allow identifying and tracking UAS and their operators during flight by the public, aviators and law enforcement agencies.

The remote identification regulation provides for the identification of UAS in flight and reporting the coordinates of the location of UAS and their ground control stations (GCS). It will reduce the risk of UAS interference with other aircraft or posing a threat to people and property on the ground. The risk of collision between small UAS and general aviation is one of the biggest problems for small UAS flying out of the line of sight today. Although the remote identifier technical requirement does not explicitly include a safety application, it contains some critical information for shared airspace separation [2].

Another major problem is ensuring the security of the objects of critical information infrastructure [3]. The function of UAS identification will allow the security service to timely determine the legality of the UAS being in the vicinity of the protected object and take appropriate measures to ensure the safety of it if it should be necessary.
Equipping UAS with special devices that carry out UAS remote identification can be a solution to these problems.

The purpose of this work is to select the optimal technology for UAS remote identification and to formulate requirements for the device that performs UAS remote identification. The scientific community is actively analyzing data transmission channels at the present moment but the development of a full-fledged device for transmitting identification data has not been considered [4-8].

The publication [4] discusses the use of satellite communications (SATCOM), cellular networks using the D2D option in 3GPP, and direct air-to-air communications using Wi-Fi. The authors argue that the additional capabilities of the three methods imply the use of all three means of communication as a standby for each other.

The architecture and services of UAS traffic management are described, and existing data transmission technologies (Bluetooth, ZigBee, APRS, ADS-B, Wi-Fi, LoRa) are analyzed in [5]. The authors propose their Wi-Fi-based messaging scheme after discovering from the analysis that the existing LoRa and WiFi modules can support the initial deployment of UTM for low-altitude UAS flights.

The scientific team [6] considers ADS-B and LTE networks for monitoring small UAS. The conceptual system solution "Vigilant" based on ADS-B and LTE technologies, which assumes the use of a new ADS-B frequency for air-to-air communications and a new format of the identification message for small UAS, was proposed as the result of the study.

The work [7] explores the matters related to the requirements applying for traffic control and operators of UAS, the requirements for the capacity and architecture of the communication network, and the possibility of reusing the existing mobile communication system. Possibilities of using technologies of cellular communication (Cellular Networks), Ad-Hoc Networks, Wi-Fi (IEEE 802.11p) are considered. According to the authors, Wi-Fi, cellular communication and their combination are efficient channels for data exchange with the UAS board at very low altitudes.

The authors of [8] present the system for monitoring flights of small UAS, which provides continuous monitoring for aircraft dual redundancy. The authors propose to use the new DSI-B message format for reporting the aircraft status, similar to ADS-B and including data on the purpose of the flight being performed to inform administrative officials about the intentions of the flying UAS.

2. UAS remote identification technologies

The analysis of the standards, specifications and concepts [9-12] proposed for introduction in the USA and Europe shows that there is no clear understanding of the implementation of the UAS identification process. Summarizing the information on the considered UAS identification methods, two groups of remote identification technologies can be distinguished:

- direct broadcast technologies, based on the transmission of radio signals directly from the UAS to ground receivers near the UAS;
- networked technologies, based on the connection of the UAS with the air traffic services (ATS) system of the UAS via the Internet.

Communication can be organized directly or through a repeater, for example, a ground control station of a UAS when the network identification is remote. Actually, the UAS communicates with some device that provides information about remote identification to the Internet. Therefore, there are several scenarios to transmit data during remote identification over a network:

- the UAS can have a persistent Internet connection, in which case it can transfer the identifying information directly to the UAS ATS system via the Internet without interruption;
- the UAS may have an intermittent Internet connection, in which case the UAS ATS system obtains identifying information whenever an Internet connection appears;
- the UAS may not have its own Internet connection but instead have some other form of communication, typically a GCS that can transmit identifying information to the Internet.

The ARC committee [13] identified 8 remote identification technologies:

- direct broadcast remote identification:
• ADS-B;
• low power direct RF (Bluetooth, Wi-Fi, RFID, etc.);
• unlicensed integrated C2;
• physical indicator;
• visual light encoding;
• networked remote identification:
  • cellular;
  • satellite;
  • SW-based flight notification.

It is important to note that none of the technologies discussed above has been originally designed for UAS. ADS-B and cellular communication are the most optimal and promising of the existing technologies [13].

The destination of the ADS-B system is to monitor the aircraft when receiving information about its location and other additional information, which is transmitted from it via the data transmission line in broadcast mode. A piloted aeroplane can receive information about UAS location when it is fitted with an ADS-B data receiver. It is the main advantage of the system. The disadvantage of the ADS-B resides in the power loss of the signal in the receiving point because signals from different transmitters have interference when air traffic density is high. For this reason, the range of ADS-B in areas with heavy air traffic is 50-70 km.

The study by MITER [14] shows that the ADS-B radiofrequency transmission Out with the power equal to 1 Watt paralyzes any monitoring system which operates at a frequency of 978 MHz or 1090 MHz when many UAS (one UAS per 2 km²) conduct flights at low altitudes (up to 150 m). Thus, large-scale equipping of small UAS with ADS-B Out equipment is impractical since, in its current form, the system cannot simultaneously monitor a large number of UAS. Devices based on mobile communication (4G/5G) can be prospectively considered for the UAS flights monitoring within the city.

The readiness level of 4G or 5G is relatively high but not as high as the ADS-B has. It is necessary to note that there is a flying altitude limit because the directional pattern of antennas does not cover the upper hemisphere due to technical specifics. That is why 4G / 5G networks are positioned for low city flights. Future optimization of LTE and 5G for UAS use cases will take time. Experts point out that 4G / 5G can also be used for UAS positioning.

Nowadays, onboard satellite trackers grow in popularity for UAS flights monitoring. These trackers are intended to locate UAS and other navigation parameters using GPS and GLONASS. Data is transmitted from the onboard satellite tracker to a telematic server via short messages of the Iridium satellite system. This ensures the performance of the tracker on almost the entire territory of the globe.

3. Criteria for choosing a technology for UAS remote identification

The technology for UAS remote identification has not been defined in Russia yet. Remote identification will be based on the available technical capabilities in terms of aircraft identification according to the concept of the Russian RUTM system. The ADS-B 1090 ES or other devices providing the appropriate observation characteristics are proposed to be used at the initial stage. In the course of the further implementation of the project, other technical means of obtaining information about the UAS (mobile data transmission networks and other means similar to ADS-B) are planned to be tested as far as possible. It is pointed out that the subsequent phases of the creation of the RUTM system will comply with the current standards regarding remote identification.

As the developers of the concept note [15], RUTM service areas are technologically equipped territories of the airspace of the Russian Federation where there is a need to carry out regular flights of UAS and piloted aircraft or only UAS with the purpose of business. The used technologies make it easy to scale service areas. It is supposed that such zones will be outspread and united into the air navigation service space. In some cases, they will be joined with a tunnel to produce flights over large distances.
The following criteria for the choice of UAS remote identification technology have been formulated, taking into account the tasks of organizing monitoring of UAS flight and ensuring the safety of manned aircraft:

- service area range;
- service area scalability;
- notification about aircraft location in real-time;
- maturity level;
- support of increased UAS density in airspace;
- high-capacity;
- possibility of interaction with piloted air transport;
- security;
- total cost.

4. Results

4.1. The purpose of the function of the UAS remote identification device

The research has defined a minimum set of functions that are necessary to operate the onboard device for UAS identification. The set has been determined with consideration to the following tasks of transmitted information: aircraft identification, flight monitoring, forming the pilots’ situation awareness about air activity near the aircraft.

The functions of the onboard device for UAS identification include:

- remote radio frequency identification of the aircraft by a unique identification number;
- exchange of coordinate-time information with the surrounding aircraft in the "board-to-board" direction;
- preventing flights in a prohibited flying area;
- detection and prevention of conflict situations;
- "black box" function.

4.2. Choosing technology of UAS remote identification to implementation

The choice of UAS remote identification technology for use in RUTM service areas is carried out following the formulated criteria. Evaluation of technologies is shown in Table 1.

| Criteria                             | UAS remote identification technologies |
|--------------------------------------|----------------------------------------|
|                                      | ADS-B, unlicensed integrated C2, cellular and satellite communications have the highest compliance with the criteria for choosing UAS remote identification technology. |
Due to the research, it was resolved to choose the ADS-B broadcast technology to implement the network model of remote identification. This technology is the most optimal to form pilots’ situation awareness about air activity near the aircraft. It is supposed that all ADS-B ground receiving stations will be connected to the UAS ATS system.

The Russian Federation has vast areas and ground infrastructure based on remote identification technologies reviewed in this work. Given these features, it is reasonable to use the following communication channels, depending on the zone of flight execution:

- cellular;
- satellite;
- ADS-B 1090 ES.

Their combined use as part of one device will satisfy all the criteria for choosing a technology for UAS remote identification.

### 4.3. Requirements for the set of transmitted data

The network model of remote UAS identification implies that all information is received, processed and stored in one place. The relevant parties receive the necessary information about the UAS of interest from there. The provided information is divisible into static and dynamic. Static information (registration data) is stored in the database of the system; dynamic information is received from the UAS.

Dynamic information should contain a set of data which is minimum and sufficient to identify a UAS and control a safe performance of a flight. Thus, the following information should be transmitted from a UAS:

- UAS ID;
- UAS coordinates with time reference;
- speed;
- speed vector;
- residual reserve of autonomy;
- indication of emergency state.

UAS coordinates contain:

- UAS latitude and longitude indication;
- indication of the barometric altitude of a UAS above sea level;
- timestamp in UTC format.

The indication of an emergency condition is the notification message about a malfunction of an element of the onboard system or detection of conflicts.

### 4.4. Technical requirements for UAS remote identification device

As the frequency of UAS operations increases, additional requirements will be imposed on the remote identifier (such as higher throughput, higher vertical coverage, higher density support, etc.). The onboard device, combining several technologies of remote identification, can solve this problem.

The onboard device for UAS remote identification should be universal and suitable for all types of commercial UAS. Therefore, it should have minimum mass and dimensional parameters. There is a need to make provision for connectivity to the onboard feed system of a UAS to reduce the device weight. It should be noted that the output voltage of an onboard system can be varied between 5 and 36 V for different UAS.

The influence of weather conditions should be taken into account when developing the design. The external location of the device assumes that the temperature regime of UAS operation should also apply to it. It is supposed that UAS flights will take place at temperatures of $-40$ to $+60$ °C.

Implementation of the function for transmitting the coordinate-time information requires the presence of the geolocation module. The device must be equipped with its own geolocation module to ensure the same accuracy for all monitored UAS. This module should provide the maximum permissible accuracy of determining spatial coordinates. At the moment, the use of the GNSS augmentation system...
(System for Differential Corrections and Monitoring) allows increasing the accuracy of determining spatial coordinates up to 2 m in azimuth [16] and 3 m in height when working in the combined GLONASS/ GPS mode [17].

The device must support signal receipt from no less than 24 navigational satellites to ensure geolocation of an aircraft with a probability not lower than 0.95 [18]. In this regard, the geolocation module must include a receiver with no less than 24 universal channels that allow processing signals from GLONASS and GPS satellite navigation systems. The speed of navigation parameters determination must be not lower than 10 Hz for extra accuracy detection of the baseline vector in real-time.

Performing such functions as prevention of flights in exclusion zones, detection and prevention of conflict situations and "black-box" functions implies using a nonvolatile storage module. This module stores flight data and information about the restriction of the use of sky space. Also, it has a range of standard interfaces for co-functioning with the autopilot controller of UAS. The UAS autopilot controller reads the coordinates of the closed airspace zones and the data on the current air situation received via the ADS-B channel. The read data is compared with the planned route. The UAS autopilot controller transmits the alarm signal to the onboard device of UAS identification. The device relays this signal to the UAS ATS system in case of a conflict situation. USB, UART, SPI, I2C and CAN have been chosen as the interfaces for interaction between the UAS autopilot controller and the onboard UAS identification device. This choice has been conditioned by the following: the USB interface is present in all UAS, and among the additionally supported interfaces, the most common ones are UART, SPI, I2C and CAN.

Flash and MicroSD drives are planned to be used in the quality of a nonvolatile storage module. The Flash memory card supports a system for protecting the content from alteration or deletion, and it is used as a "black box". Flight data logs of one flight occupy an average of 16 MB, so at least 512 MB of memory is required to log during a working week. MicroSD drive is used to store the coordinates of flight restricted areas. The volume of stored data with flight restrictions zones will grow with the increase in the granularity of the rules for the use of airspace. On average, the amount of data for one region will take up to 2 GB of memory.

The function of detection and prevention of conflict situations should detect potential conflicts with the prediction depth of at least 0.034 h [19] and the surveillance distance of 5.6 km [20] for timely notification of the pilot. Based on this, the detection range of a potential conflict is calculated. The calculation is carried out according to Formula 1 [20].

\[ r^2 + r \cdot \dot{r} \cdot TAU - SMOD^2 = 0 \]  

where \( r \) is the detection range,
\( \dot{r} \) is the closing speed,
TAU is the time to collision,
SMOD is the surveillance distance.

The detection range depends on the closing speed; in its turn, the closing speed depends on the type of aircraft. Table 2 has been compiled to provide an obviousness of the dependencies.

| Plane category     | Fixed-Wing UAS | Rotor-Wing UAS |
|--------------------|---------------|---------------|
|                    |   km h\(^{-1}\) |    km         |   km h\(^{-1}\) |    km         |
| General aviation   |   370         |   14.7        |   350         |   14.1        |
| Commercial plane   |   770         |   27.3        |   750         |   26.7        |

Thus, the minimum value of the identification and surveillance range will correspond to the maximum calculated value of the detection range, which will be 28 km (rounded up from 27.3). This
value meets ICAO requirements. According to the requirements, the trajectory tracking range should be not less than 26 km for an airborne collision avoidance system [20].

All UAS flight data is transmitted to the UAS ATS server. The onboard device must transmit data at a rate of at least 100 kbps to update information on the dispatcher monitor with a frequency of at least one time per second.

The technical requirements for the onboard UAS remote identification device under development are shown in Table 3.

**Table 3. Technical requirements for the UAS remote identification device.**

| Characteristic parameter                      | Value                              |
|-----------------------------------------------|------------------------------------|
| Received GNSS signals                         | GLONASS L1, GPS L1, SBAS           |
| Number of GNSS signal channels, not less than | 24                                 |
| Rate of determining navigation parameters, at least | 10 Hz                             |
| Accuracy of determining coordinates/course/speed, at least | 2.5 m (in azimuth) and 3 m (in height) / 1 gr / 1 km h⁻¹ |
| Identification and surveillance range         | not less than 28 km                |
| Supported surveillance and identification technologies | ADS-B 1090ES, 4G/ 5G, satellite     |
| Data receipt/transmission rate                | not less than 100 kbps             |
| Nonvolatile storage                           | Flash (not less than 512 MB), MicroSD (at least 4 GB) |
| Interfaces                                    | USB, CAN, I2C, SPI, UART           |
| Supply voltage                                | 5-36 V of direct current           |
| Operating temperature range                   | from - 40 to + 60 °C              |
| Mass, max                                     | 0.5 kg                             |
| Design                                        | monobloc                           |
| Dust and water resistance                     | IP67                               |

5. Conclusion

The technologies of remote UAS identification and the conception of the RUTM system were analyzed in this work. Selection criteria for technologies of remote UAS identification were formed from the analysis. According to these criteria, it is recommended to use the network model of UAS remote identification using the ADS-B 1090 ES broadcast technology. ADS-B 1090 ES, cellular and satellite communications were selected as data transmission channels for the onboard UAS remote identification device. The technical requirements for the onboard UAS remote identification device are presented.

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**References**

[1] UAS Remote Identification. Site of Federal Aviation Administration, available at: https://www.faa.gov/uas/getting_started/remote_id/

[2] Kubo D, Oseo A and Yasui I 2020 AIAA AVIATION 2020 FORUM (Reston: AIAA) p 2867

[3] Federal Law of the Russian Federation No. 187-FZ "On the Security of the Critical Information Infrastructure of the Russian Federation": [Feder. law: adopted by the State. Duma on July 12, 2017] (SPb.: Stown-country) p 15

[4] Murrell E, Walker Z, King E and Namuduri K 2020 Int. Workshop on Communication Technologies for Vehicles (Cham: Springer) pp 194-202
[5] Vinogradov E, Minucci F and Pollin S 2020 *IEEE Vehicular Technology Magazine* (New York City: IEEE) pp 88-95
[6] Orrell G L, Chen A and Reynolds C J 2017 *IEEE/AIAA 36th Digital Avionics Systems Conf.* (New York City: IEEE) pp 1-10
[7] Schalk L M 2017 2017 *Integrated Communications, Navigation and Surveillance Conf.* (New York City: IEEE) pp 6B2-1-6B2-11
[8] Yeniceri R, Hasanazade M, Koyuncu E and Inalhan G 2017 2017 *Integrated Communications, Navigation and Surveillance Conf.* (New York City: IEEE) pp 2E1-1-2E1-13
[9] Realizing Remote ID 2019 (Syracuse: Hidden Level) p 16
[10] ASTM F3411-19. Standard Specification for Remote ID and Tracking (West Conshohocken: ASTM International) 2019. p 67
[11] Federal Aviation Administration. Notice of Proposed Rule Making on Remote Identification of Unmanned Aircraft Systems. Federal Register 2019 p 72438-524.
[12] U-space Concept of Operations. Concept of operations for European UTM systems (Brussels: SESAR) 2019 p 92
[13] ARC U. A. S. Identification and Tracking (UAS ID). ARC Recommendations Final Report (Washington: Aviation Rulemaking Committee) 2017 p 213
[14] Gutierrez M, Jones S, Orrell G and Strain R 2017 *AIAA Information Systems-AIAA Infotech@ Aerospace* (Reston: AIAA) p 1154
[15] Era RUTM. Site of National technology initiative, available at: https://nti2035.ru/media/publication/era-rutm
[16] Systems of functional additions to global navigation satellite systems. Site of Information and analysis center, available at: https://www.glonassiac.ru/guide/gnss/function_dop.php
[17] Skrypnik O N 2017 *Crede Experto: transport, society, education, language* (Irkutsk: Crede Experto) pp 1-14
[18] GOST 8.207-76. Direct measurements with multiple observations. Methods for processing observation results [Text]. Enter. from 01.01.177. - M.: Publishing house of standards, 1986. p 8
[19] Orefice M, Di Vito V, Corraro F, Fasano G and Accardo D 2014 2014 *IEEE Metrology for Aerospace (MetroAeroSpace)* (New York City: IEEE) pp 277-82
[20] International Civil Aviation Organization. Secretary General 2012 *Airborne Collision Avoidance System (ACAS) Manual* (Montreal: International Civil Aviation Organization) p 203